

Oxford Brookes University

Does culture evolve? Testing evolutionary theories of culture through a case study of El Khiam points from three sites in the Pre Pottery Neolithic A of the Southern Levant

Director of Studies:

Dr S. Underdown

Second Supervisor:

Dr S. J. Smith

Candidate:

Jon Gorrie

Does culture evolve? Testing evolutionary theories of culture through a case study of El Kham points from three sites in the Pre Pottery Neolithic A of the Southern Levant

Abstract

This thesis addresses the question of whether human culture evolves. Evolutionary approaches to understanding culture are introduced, synthesised and challenges considered to provide context and focus to the thesis. Cultural evolution theories have been used to explain much of human complexity, but they remain contested and empirical studies are needed to provide support or challenge to the theories. Archaeological approaches to testing theories are reviewed to help develop a research methodology to address this through a case study.

The case study is presented, examining El Kham points, small stone arrowheads or perforators from three contrasting sites of the early Neolithic in the Levant. Two complementary analytical techniques, variation and phylogenetic analysis, are applied to examine the patterns of attributes of El Kham points. Variation analysis, specifically the coefficient of variation, is used to show patterns of reducing constraint in metrical attributes of points across the three sites. Phylogenetic analysis is applied to attributes related to the shape of the points, and how they were made. This shows the remarkable preservation of distinctive patterns of manufacture within each site over long periods of time to show a pattern of similarity within and differences between the three sites. The results of the analysis are interpreted using cultural evolution theories, particularly social learning and transmission processes, and developed to explore social structure and community identity in the Neolithic.

The results of the case study enable a further test of the predictions of cultural evolution theories. Combined with detailed studies of the emergence of early Neolithic communities, the theories provide a good model in this instance, allowing, with limitations, a productive interpretation of the evidence. Within the idea of culture and evolution as models of complexity the conclusion is reached that culture can reasonably be said to evolve.

‘Each of us is responsible for everything and to every human being.’

Simone de Beauvoir rephrasing Dostoyevsky

Acknowledgements

I would like to thank Dr Simon Underdown and Dr Sam Smith for their support, guidance and inspiration throughout the conception and completion of this research and particularly to Dr Smith for providing the starting point for this research and transmitting to me his enthusiasm for small El Khiam points from the Neolithic in the Levant.

Contents

Abstract

Acknowledgements

Chapter 1. Thesis introduction.....	7
1.1 Introduction	7
1.2 Aims of this research.....	9
Chapter 2. Evolutionary approaches to culture in context.....	10
2.1 Introduction	10
2.2 Critiques of theories of cultural evolution.....	12
Chapter 3. Cultural evolution theories	17
3.1 Introduction	17
3.2 Social learning and transmission.....	18
3.3 Cognitive evolution	20
3.4 Cultural niche construction and gene culture co-creation	22
3.5 Cumulative culture.....	23
3.6 Social group identity and norms	24
3.7 Alternative models of cognition.....	25
3.8 How evolutionary?.....	26
3.9 Summary	27
Chapter 4. Towards a methodology - archaeological approaches to testing cultural evolution theories.....	28
4.1 Introduction	28
4.2 Archaeological approaches drawing on evolutionary theories	28
4.3 Variation in artefacts.....	30
4.4 Statistical analysis of variation.....	33
4.5 Phylogenetic analysis	36
4.6 Summary	39
Chapter 5. Case study introduction - the potential of an evolutionary approach to material culture from the early Neolithic of the Southern Levant	41
5.1 Introduction	41
5.2 The Epipalaeolithic to Neolithic in the Southern Levant	41
5.3 Stone tools, assemblages and the El Khiam point	43
5.4 Archaeology, context and comparison of the three sites.....	45

5.5 Three El Khiam assemblages: sources and sampling	49
5.6 Point attributes – the approach in Smith (2005; 2007)	50
5.7 Research questions	52
Chapter 6. Case study - research methodology	54
6.1 Introduction	54
6.2 Data formation and validation	55
6.3 Descriptive analysis.....	58
6.4 Variation analysis	59
6.5 Phylogenetic analysis	60
6.6 Summary	65
Chapter 7. Case study - variation and phylogenetic analysis of El Khiam points	66
7.1 Introduction	66
7.2 Descriptive analysis.....	66
7.3 Variation analysis	70
7.4 Phylogenetic analysis	74
7.5 Summary of key results.....	83
Chapter 8. Case study interpretation - the implications of the results of analysis for social structure and community identity in the Neolithic	85
8.1 Introduction	85
8.2 The origin and spread of El Khiam points	85
8.3 Attribute changes and mode of transmission between sites	87
8.4 Social learning within sites.....	89
8.5 Social structure and identity in the Neolithic	92
8.6 Conclusion.....	95
Chapter 9. Does culture evolve? The implications of this research for theories of cultural evolution	96
9.1 Introduction	96
9.2 How useful are theories of cultural evolution in this case?.....	96
9.3 Limitations.....	97
9.4 Does culture evolve?.....	99
9.5 The nature of human culture	100
9.6 Summary	101
Chapter 10. Thesis conclusion	102
Appendices.....	103
References	121

List of Appendices

- Appendix 1: Distribution of El Khiam and Harif points
- Appendix 2: Comparison of morphological and retouch attributes for WF16a and b samples
- Appendix 3: Multivariate analysis of point metrics test statistics
- Appendix 4: Normality tests and boxplots of El Khiam point metrics
- Appendix 5: Harifian and other comparator point CVs
- Appendix 6: One of five trees using 'archetype' outgroup for WF16 and Dhra' pair
- Appendix 7: Phylogenetic trees using the neutral outgroup
- Appendix 8: The process and steps for creating matrices of taxa and character for analysis
- Appendix 9: Results of discriminant analysis using only length, width and thickness
- Appendix 10: Majority rule consensus tree for Dhra' and Netiv Hagdud pair
- Appendix 11: Phylogenetic trees produced with the two metrical characters removed
- Appendix 12: Matrices used in experimental phylogenetic analysis
- Appendix 13: Phylogenetic trees showing character synapomorphies
- Appendix 14: Salibiya point analysis

List of Tables

- Table 2.1: Critiques of theories of cultural evolution and implications for the focus of this research
- Table 4.1: Potential factors in the variation in artefacts drawing from evolutionary theories
- Table 4.2: Examples of the use of the coefficient of variation and neutral theory
- Table 5.1: Historical sequence for periods and cultures in the Levant – Epipalaeolithic to Neolithic
- Table 5.2: Archaeological context and comparison of the sites of WF16, Dhra' and Netiv Hagdud
- Table 5.3: Analysis and comparison of point numbers and types from Wf16, Dhra' and Netiv Hagdud
- Table 5.4: The basis and source of El Khiam point samples used in the case study
- Table 6.1: Mean, standard deviation and coefficient of variation across metrics for complete points from the WF16a and b samples
- Table 6.2: How samples and sub-samples are related to the total of El Khiam points classified and used throughout the analysis
- Table 6.3: Examples of character systems from phylogenetic studies of points
- Table 6.4: Characters and character states developed for the phylogenetic analysis
- Table 6.5: Outgroups used for phylogenetic analysis
- Table 7.1: Comparison of the mean, standard deviation and coefficient of variation across metrics for WF16a and Dhra' samples
- Table 7.2: Comparison of the mean, standard deviation and coefficient of variation from the three assemblages
- Table 7.3: Analysis of character states for morphological and retouch attributes by site

Table 8.1: Correlates for the reducing levels of constraint from WF16, through Dhra' to Netiv Hagdud

List of Figures

Figure 1.1: Examples of 'typical' El Kham points

Figure 3.1: The interaction of elements of cultural evolution theories

Figure 4.1: A model of content and context biases

Figure 5.1. Map showing WF16, Dhra', Netiv Hagdud and other sites of the PPNA in the Southern Levant

Figure 5.2: Harif points from the Negev and El Kham points from across the wider Levant

Figure 5.3: Illustration of different retouch attributes for point tip and notch

Figure 6.1. How thesis research questions are addressed by different elements of analysis

Figure 6.2: Grouped scatter of length by width for WF16a and b samples

Figure 7.1: Grouped scatter of width by length of complete points from the three assemblages

Figure 7.2: Grouped scatter of thickness by length of complete points from the three assemblages

Figure 7.3: Discriminant analysis of five metric attributes from the three assemblages

Figure 7.4: Comparison of the coefficient of variation for length, width and L/W of Harifian points with those from WF16, Dhra' and Netiv Hagdud

Figure 7.5: Frequency differences consensus trees showing the results of phylogenetic analysis of points from pairs of sites

Figure 7.6: Frequency differences consensus tree showing the results of phylogenetic analysis of points from all three sites

Figure 7.7: Consensus tree showing the character state for character 5, notch type

Figure 7.8: Synapomorphies shown on experimental phylogenetic trees

Figure 8.1: Model of cultural transmission which shows modes relevant to transmission between and within sites

Chapter 1. Thesis introduction

1.1 Introduction

The aim of this research is to address the question of whether and how human culture evolves. Not just in the sense that it develops over time, but in a genuinely evolutionary sense, drawing on and extending Darwinian theory. Evolutionary approaches to the origins and development of human culture claim to be able to explain much of human complexity; the way people learn, how knowledge is built over generations, the behaviour of humans in social groups, issues of identity, social norms and much more (Henrich, 2016; Richerson and Boyd, 2005). If these approaches have validity, they can provide insight to historical accounts of change and potentially help improve planning for development and change in contemporary societies. The idea that evolutionary thinking can be applied to human cultural complexity is not uncontested however (Ingold, 1990; Lewens, 2012; Rapport, 2014); and within evolutionary approaches there is considerable debate about the merits of different theories (Fuentes, 2006; Laland and Brown, 2011). There is recognition from those in the field of the need for better evidence, and particularly empirical evidence, to support or challenge theories (e.g. Boyd and Richerson, 2010; Gray et al., 2007; Mace, 2014; Shennan, 2011; Stout et al., 2019).

The concept of culture, and evolutionary processes, are both complex and debated topics. To some extent theories of cultural evolution sidestep the issues around what culture means by adopting pragmatic research based definitions, for example, that it is information that affects behaviour acquired through various forms of social transmission (Chudek and Henrich, 2011). Theories apply Darwinian concepts of variation, competition and inheritance but also propose a variety of evolutionary mechanisms that while drawn from population genetics, operate in a variety of ways unrelated to gene theory (Laland and Brown, 2011; Mesoudi et al., 2004). Conceptions of culture and the evolutionary approaches proposed by theories of cultural evolution are the starting point for this thesis and are considered in greater depth in Chapters 2 and 3.

This research addresses the question of whether culture evolves through empirical testing of the archaeological record. Cultural evolution theories have been used to interpret patterns in the archaeological record and so provide a further test of the predictions of the theories (Garvey 2018). Something similar is intended in this research. However, this is not straightforward because cultural evolution theories invoke everyday individual decision and social transmission processes which have to be inferred from partial archaeological evidence operating to a very different time frame (Shennan,

2011). Archaeological theories and approaches have been developed to tackle these challenges, which are critically examined in Chapter 4.

A case study to test cultural evolution theories using archaeological approaches is introduced in Chapter 5, drawn from the transition from the Epipalaeolithic to the Neolithic in the Southern Levant, which is generally seen as occurring about 12,000 years ago (Kuijt and Goring Morris, 2002). This is a region and period where there is extensive research and rich archaeological evidence of social complexity and debate about its nature and origins (e.g. Coward, 2010; Finlayson et al., 2011; Sterelny, 2014). The focus of the case study is analysis of small stone El Khiam points (Figure 1.1), which functioned as arrowheads or perforators (Smith, 2005). These are sampled from three sites in the earliest phase of the Neolithic in the Southern Levant, which is conventionally called the Pre Pottery Neolithic A (PPNA). Although there has been extensive analysis of the period, and some of this draws on evolutionary approaches (e.g. Coward, 2010; Kuijt and Prentiss, 2009; Sterelny and Watkins, 2015), there has been limited application of variation and phylogenetic analysis to the issues and artefacts of the period.

Figure 1.1: Examples of ‘typical’ El Khiam points



Chapter 6 sets out the research methodology for this thesis, which involves applying two main approaches in tandem - analysis of variation of artefact measures around central tendency and phylogenetic analysis of the relatedness of artefact attributes. The results of analysis are presented in Chapter 7, while Chapter 8 covers the interpretation of the results and their implications for social

structure and community identity in the early Neolithic. Chapter 9 evaluates the implications of the research for theories of cultural evolution more broadly, and whether and how culture evolves. The analysis of El Khiam points presented in this research shows how point attributes are preserved within, and change between sites, and how these patterns in attributes are shaped by social transmission processes. This sheds light on both the value and limitations of cultural evolution theories.

1.2 Aims of this research

The aim of this research is to explore the question of whether culture evolves and how this can be tested. Specifically the aims are:

1. To evaluate theories of cultural evolution and synthesise them for testing in the archaeological record;
2. To assess and apply appropriate tools for testing theories, and specifically, undertake variation and phylogenetic analysis of El Khiam points from three sites in the PPNA of the Southern Levant;
3. To evaluate the implications of the pattern and distribution of El Khiam point attributes in respect of:
 - The origin and spread of the El Khiam point;
 - Attribute changes and the mode of transmission between sites;
 - Social learning environments within sites; and more broadly;
 - Social structure and community identity in the early Neolithic;
4. To evaluate the implications of the research for theories of cultural evolution.

Chapter 2. Evolutionary approaches to culture in context

2.1 Introduction

This Chapter considers ideas about culture and cultural evolution to provide the context for this research and provide a series of critiques and challenges to be addressed. The idea and definition of culture is highly contested and difficult to pin down (Eriksen, 2004; Lewens, 2012; Ortner, 2005; Rapport, 2014; Whiten et al., 2011). Culture can be seen as those things that separate us from nature, those things that are learned such as knowledge, beliefs, art and customs, and which are seen to make us human (Eriksen, 2004). But culture is also used to distinguish one human group from another, something that divides rather than unites, with each group having their own distinct culture shared by its members (Eriksen, 2004; Ortner 2005). The idea of culture as a stable and homogeneous system of beliefs, practices and institutions that has an objective reality outside of individuals' minds has been a strong and pervasive concept in anthropology (Rapport, 2014). It is an idea that underpins much functionalist, structural-functionalist and structuralist thinking (Rapport, 2014). However human groups can never, under scrutiny, be successfully encapsulated in a cultural description. Variation always exists within groups, and may be greater than the supposed differences with others; and diffusion between groups is also constant (Eriksen, 2004). The characteristics and attributes of groups are ever shifting and changing, having of course emerged and developed over time in the first place.

The use of the term culture in oversimplified political or social contexts has led to its association with aggressive nationalism, and it has sometimes ended up being used as a short cut to explain away the characteristics and behaviours of human groups (Eriksen, 2004). It has also been tarnished by its association with colonialism and its legacy, as anthropological ideas about culture were inevitably part of a Western dominated and constructed dialogue (Rapport, 2014). Nevertheless, although some consider it more of a hindrance than a help and should be abandoned, culture remains an important concept for anthropologists (Eriksen, 2004; Rapport, 2014). It can be used to develop political critique as much as discourses of domination, and seems pointless to ignore (Ortner, 2005). The idea of culture is perhaps best seen as another model, a simplification used to communicate and express the fiendishly complex and contingent creations of everyday life. Which version of the model best represents the world and is most useful in supporting research is a key issue in looking at evolutionary approaches to culture.

Explanations for the origins of human culture are a longstanding anthropological as well as historical question. Early anthropologists of the nineteenth century developed evolutionist theories of cultural

development, suggesting that all human societies went through progressive stages of development, with the diversity of societies accounted for by them being at different stages (Barnard, 2000). A Darwinian account emerged in the 1970s, called sociobiology, synthesised in a book of that name by Edward Wilson (1975), which argued that many aspects of behaviour and culture had a biological basis and were rooted in humankind's animal nature. This was extensively criticised as highly speculative genetic determinism that provided ammunition for racist theories (Barnard, 2000; Perry and Mace, 2010). The debate and controversy that raged about sociobiology in the 1970s and 80s is arguably an important reason why negative views about evolutionary approaches to understanding culture are still widely held, by social anthropologists at least (Carroll et al., 2017; Perry and Mace, 2010). Since then, several fields of research have emerged that develop evolutionary approaches to human behaviour. These include behavioural ecology, which focuses on the fitness consequences of behaviour, and evolutionary psychology, which focusses on the psychological mechanisms that underpin behaviour developed in the environments humans faced during the Pleistocene (Laland and Brown, 2011; Lewens, 2012; Perry and Mace, 2010).

However here the focus is on a further group of approaches about the evolution of human culture more broadly, which still cover a large, complex and highly interrelated field. Sometimes referred to simply as the field of cultural evolution (Laland and Brown, 2011; Lewens, 2012; Perry and Mace, 2010), prominent theories and ideas include social learning and cultural intelligence (Reader et al., 2011; van Schaik and Burkart, 2011); cultural niche construction (Boyd et al., 2011; Laland et al., 2007); gene culture co-creation (Laland 2017; Richerson and Boyd, 2005); and group norms and psychology (Chudek and Henrich, 2011; Henrich and Boyd, 1998). Cultural evolution theories draw on cognitive evolution but emphasise the interplay between cognition and social learning, and how these work out in populations (Henrich and McCreath, 2003).

In the field of cultural evolution, culture has been defined in a number of ways that facilitate the development of hypotheses and research into its origins and causes. For example culture has been defined as information and knowledge acquired or learned from others and that affects their behaviour (Chudek and Henrich, 2011; Creanza et al., 2017; Laland et al., 2010). More broadly it can be seen as covering traditions in a group, social learning processes and the artefacts created through these (Whiten, 2011). Cumulative culture, a concept frequently used in the field, is seen as the way that knowledge and technologies are modified and accumulated over generations, leading to greater complexity (Stout et al., 2019; Tomasello et al., 2005). For the purposes of this research, which focusses on social transmission related to El Khiam points, culture is defined as cultural information transmitted through behaviour and artefacts, drawing on Richerson and Boyd (2008).

2.2 Critiques of theories of cultural evolution

Critiques of cultural evolution theories continue to develop and come from a number of different angles (Laland and Brown, 2011; Mesoudi et al., 2004). These critiques and responses to them are worth some analysis because this provides context, helps position this research and identifies issues that merit further consideration. As well as the overarching research question on whether culture evolves, an initial analysis identifies some more technical and some more epistemological challenges (Table 2.1).

Table 2.1: Critiques of theories of cultural evolution and implications for the focus of this research.

Issue or question	Critique and debate	Comment and implications for this research
Are theories really evolutionary?	Culture can be said to evolve in a general sense but the overarching research question is about whether cultural evolution theories involve an extension of biological evolution, and the application Darwinian mechanisms, or whether the mechanisms proposed are essentially just analogous (Lewens, 2012). Cultural evolution theories draw on population genetics and extends them to cultural processes based on the idea that cultural evolution involves the selective retention of favourable traits, as well non selective processes such as drift, which lead to changes in the frequency of such traits in the population (Creanza et al., 2017; Laland and Brown, 2011). Within a population based approach cultural evolution theories generally propose that culture evolves based on Darwinian characteristics of variation, competition and inheritance (Laland and Brown, 2011).	The mechanisms that provide an evolutionary underpinning to theories and criticisms of these are considered in more detail in Chapter 3. The implications of the research for theories of cultural evolution are considered in Chapter 9.
Lack of explanatory power	There are criticisms that cultural evolution theories do not always usefully explain change and complexity, but just set out a model that gets to the same answers as other more historical or anthropological approaches. A fitness model describing the spread of traits does not necessarily explain how they arose or why they are fitter (Ingold, 1990; Lewens, 2012). There are some areas where the theories seem more productive and insightful than others, for example, in respect of how different forms of social learning and transmission affect trait distributions (Lewens, 2012).	The explanatory power of the theories is considered in the next Chapter, tested in the case study (Chapter 7), and summarised in Chapter 9.
Limitations of the research style and approach	Cultural evolutionary theories are frequently based on mathematical models (Chudek and Henrich, 2011; Richerson and Boyd, 2005). The reliance on mathematical modelling means that these approaches are open to the criticism of oversimplification or error in the model (Lewens, 2012). This modelling based approach was the preserve of a relatively small number of researchers (Laland and Brown, 2011), which suggests a limited diversity of style and approach in a number of senses. More recently there has been a broadening out of the field and approaches with a bigger range of researchers using a greater variety of methods including phylogenetics and more use of archaeological data (Laland and Brown, 2011).	This research seeks to embrace a range of approaches and is focussed on examining more empirical methods to test cultural evolution theories.

Issue or question	Critique and debate	Comment and implications for this research
Lack of precision with respect to period and place	There is some ambiguity in respect of the period and place in which these theories are rooted. Because theories are based on mathematical models (Chudek and Henrich, 2011; Richerson and Boyd, 2005), or on the similarities and differences between humans and other primates based on a presumed last common ancestor with chimpanzees (Tomasello, 2005; Whiten, 2011), they are by nature not precise about the origins or historic development of cumulative culture.	This research is focussed on examining archaeological evidence from a specific period and place, the Pre Pottery Neolithic A of the Southern Levant.
Proximate or ultimate explanation	Social scientists are often concerned with proximate explanations of behaviour, and elements of cultural evolution theories such as social learning mechanisms are also proximate explanations, while evolutionary approaches generally are more concerned with longer term, ultimate or functional explanations. These do not however have to be seen as mutually exclusive (Eriksen, 2004; Mesoudi et al., 2010).	This issue is considered in Chapter 9.
Limitations of the concept of culture	Cultural evolution theories can be argued to sidestep some of the challenges of post colonialism and post-modernist thought in that they are not so interested in the differences between cultures, or in exoticising them, and are rooted in a much earlier time of human cultural origins. Instead they are closer to the conception of culture as those things that separate us from nature, that take us beyond the behaviours and technology of other animals (Eriksen, 2004). As a result a criticism is that cultural evolution theories can imply that there are human universals, an assumed mental unity (Eriksen, 2004; Lewens, 2012). These are to some extent more criticisms of evolutionary psychology, and cultural evolutionary theories are often, in fact, focussed on explaining cultural diversity (Laland and Brown, 2011). However, the idea of cumulative culture can imply an idea of linear progress that needs clear definition and is open to challenge (Vaesen and Houkes, 2017).	Limitations to the concept will be borne in mind in undertaking and reflecting on the results of the research, and particularly in Chapter 9.
Critiques from other evolutionary approaches to human culture	There is broad agreement across a range of disciplines that human culture might usefully be examined using evolutionary approaches (Fuentes, 2016; Laland and Brown, 2011; Mesoudi et al., 2006; Shennan, 2011; Speber, 1996; 2019). However, within broadly evolutionary approaches there are extensive debates about the merits of different theories. Prominent issues include:	Critiques from other evolutionary approaches are considered in the Chapter 3 and returned to in Chapter 9.

Issue or question	Critique and debate	Comment and implications for this research
	• An argument from evolutionary psychologists that our evolved cognitive abilities have given humans strong biases so that in effect genes dictate what cultural information will be acquired (Lewens, 2012; Laland and Brown, 2011). • A challenge that cultural traits are not discrete packages, and traits are not replicated in human minds but are reconstructed (Henrich et al., 2008; Speber, 1996). • A criticism that evolution is more complex than presented, made particularly by evolutionary developmental approaches, such as development systems theory (Andersson et al., 2014; Griffiths and Gray, 1994).	
Epistemological objections	The application of evolutionary thinking to human cultural complexity is regarded as misguided by a range of thinkers particularly in the social sciences (Lewens, 2012; Mesoudi et al., 2010; Perry and Mace, 2010). There is the sense that these theories miss the lived meaning of cultural experience and the agency of individuals – they de-emphasise the human as an organism with an ability to grow and develop consciousness (Ingold, 1990; Rapport, 2014). The important roles of social systems and power relations seem to disappear in the analysis (Fracchia and Lewontin, 1999; Ingold, 2007). These arguments tend to have a phenomenological edge.	These objections are considered and incorporated to a limited extent in the archaeological approaches to cultural evolution assessed in Chapter 4, and are returned to in Chapter 9.

In summary, technical challenges include whether theories are based in evolutionary theory or whether the mechanisms applied are merely analogous (Lewens, 2012); challenges from other evolutionary approaches to understanding human behaviour and culture (Laland and Brown, 2011); and questions as to how useful the theories are and what they help explain (Ingold, 1990). There are also limitations to the research style and approach adopted in cultural evolution, including a lack of precision with respect to the periods and places in which the theories are rooted, and the way culture is defined and applied (Lewens, 2012). Some of these issues, particularly how evolutionary are the theories and challenges from other evolutionary approaches, are considered in more detail in Chapter 3, summarising and integrating cultural evolution theories. Other critiques are more epistemologically based, particularly those with a phenomenological edge (Ingold, 1990; Rapport, 2014). These will be revisited in reflecting on the wider implications of the results of the research. Empirical testing of the validity and utility of the theories is an important way to address many of the critiques made. If the idea of culture is best seen as another model, then the archaeological record provides a way to test the models and give space to alternative approaches.

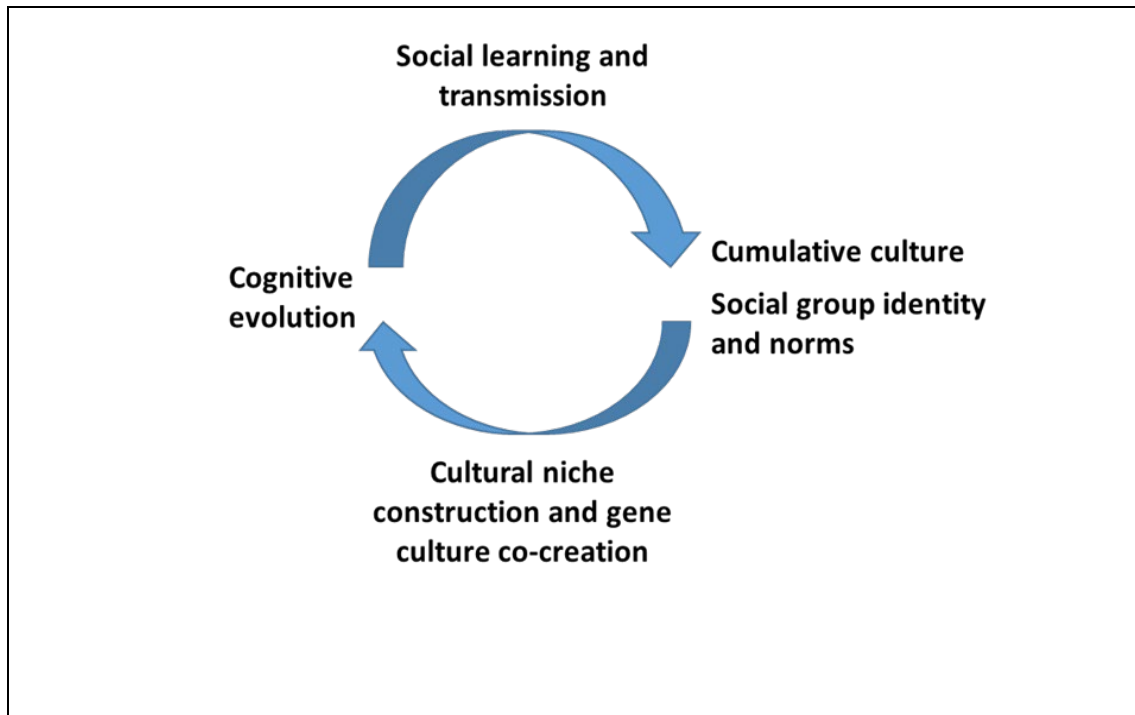
Chapter 3. Cultural evolution theories

3.1 Introduction

This Chapter provides a summary and synthesis of the theories of cultural evolution that are the subject of this research, with a focus on what is pertinent for testing in the archaeological record. Models of cultural evolution developed in the 1970s and 80s, notably summarised in Cavalli-Sforza and Feldman (1981) and Boyd and Richerson (1985), are often referenced as the starting point for theories of cultural evolution (Creanza et al., 2017; Laland and Brown, 2011; Mesoudi, 2011). Their models drew on population genetics to propose that patterns of transmission in culture operate in a similar way and could be studied using similar mathematical models. Over the last 40 years, these and other prominent researchers such as Kevin Laland and Joseph Henrich have, together with their collaborators and followers, collectively created a huge body of work which has been developed, debated and critiqued across a wide range of fields.

Cultural evolution theories focus on social learning and transmission processes within social groups (Laland, 2017). They are underpinned by ideas about cognitive evolution at the individual level, while at the same time proposing that group level processes in turn influence cognition (Richerson and Boyd, 2005). Key concepts used to explain this feedback loop are cultural niche construction and gene culture co-creation (Laland and Brown, 2011). The interaction of these processes provides an explanation for the origins of cumulative culture in hominins, as well as for social group identity and norms (Henrich, 2016). These interactions are shown in simplified form in Figure 3.1. This Chapter explores each of these elements in turn, followed by consideration of criticisms of the theories based on alternative views about the role of cognition, and how evolution is seen to be more complex than they assume. The analysis is not chronological, and like the theories themselves, draws on different and often imprecise periods of evolution. In brief, some aspects of the theories relate to primate evolution in general; some relate to hominin evolution since a last common ancestor with the chimpanzee, possibly 5-7m years ago (Boyd and Silk, 2015); and some relate to the emergence of social identity and norms is seen as occurring at least by the Pleistocene (Richerson and Boyd, 2005). This means that the complex of theories are in place and appropriate to test at the advent of the Neolithic.

Figure 3.1: The interaction of elements of cultural evolution theories, showing feedback loops that provide an explanation for the origins of cumulative culture and social group identity and norms.



3.2 Social learning and transmission

In cultural evolution theories social learning is the way information is transmitted and acquired by other people that affects their behaviour. It is defined in various ways, typically as forms of copying that range from simply being around others doing something (stimulus enhancement) through emulation and imitation to teaching (Laland, 2017; Lycett, 2016). In practice there are probably many mixes and iterations of modes of learning between individual and social mechanisms (Sterelny, 2006a). Experimental studies in humans and many different fish, birds and mammals suggest copying is widespread but can be very strategic (Laland, 2017; Whiten et al., 2011). For example, a series of studies of sticklebacks showed that ones with less defensive spines and scales observed others to see when feeding might be fruitful, particularly when past experience had not provided a clear guide (Laland, 2017). There is evidence of different cultural traditions in different groups of chimpanzees spread by social learning, and an experiment to examine how this worked showed that different techniques started in different groups of chimpanzees spread not only within but between groups with considerable reliability (Whiten et al., 2007; 2011). Copying pays because the observed have already filtered behaviour, providing adaptive behaviour to copy (Boyd et al., 2011).

The longevity of a cultural trait increases exponentially with more accurate copying, providing the starting point for accumulating cultural information (Laland, 2017). Studies have shown that copying,

combined flexibly with less frequent but strategic use of individual learning or innovation, sustains cumulative culture (Boyd et al., 2011; Laland, 2017; Miu et al., 2020; Muthukrishna and Henrich, 2016). Recombination and incremental improvements, as well as serendipity, (including beneficial copying errors) are the main sources of innovation. The few improvements from innovation compensate for the more common deterioration from repeated copying, and pay off for the population as a whole. Models suggest that copying is most useful when individual learning is costly, when there is uncertainty, and when copying successful and prestigious individuals. Conversely, when the environment is changing rapidly, individual learning might be favoured (Boyd et al., 2011; Henrich and McElreath, 2003; Laland, 2017; Muthukrishna and Henrich, 2016).

Social learning and transmission processes drive the way in which people acquire some cultural traits rather than others, changing the distribution of a trait in the population. There is effectively competition between traits given limitations to cognitive resources, and in the way traits affect behaviour (Richerson and Boyd, 2005). This provides an explanation for continuity and change in cultures - of traditions, in behaviours, in artefacts, in ways of seeing the world - through the operation of different social learning biases or forces (Mesoudi, 2011; Richerson and Boyd, 2005). In cultural evolution theory these forces are divided into content and context biases, both of which are population level processes (Henrich and McElreath, 2003). Cultural evolution theories recognise there are individual level as well as population level processes such as guided variation (Richerson and Boyd, 2005), where individuals intentionally shape change in accordance with their own cognitive biases (who might then be copied), but these tend to be of less interest in the population based modelling that underpins the theories (Mesoudi, 2017).

Content biases reflect the intrinsic attractiveness of an idea or aspect of an artefact and so are bound up in the debate about the nature of our evolved psychology (Henrich and McElreath, 2003; Richerson and Boyd, 2005). Context biases reflect the social environment of the decision maker through frequency dependent or model based biases. Frequency dependent biases are decision heuristics based on the frequency of a trait in the population such as conformity bias, where copying the commonest trait is seen as preferential, and potentially a shortcut to the most advantageous. Model based biases are where models in the population are chosen as the shortcut, for example copying successful or prestigious individuals, or those most similar to yourself (Henrich and McElreath, 2003; Mesoudi, 2011; Richerson and Boyd, 2005). Conformity and prestige biases have been subject to the most analysis and debate. Conformist transmission is argued to be the predominate mode of transmission, while the evidence for prestige bias operating has been more mixed (Henrich, 2001; Henrich and Boyd, 1998; Jiménez and Mesoudi, 2019; Kohler et al., 2004). Cultural or random drift is

also modelled like a frequency dependent bias as having an effect on the distribution of traits, but caused by statistical anomalies in small populations which might lead to the loss of a skill for example (Henrich 2004; Richerson and Boyd, 2005). The role of drift is developed further particularly in archaeological contexts (Section 4.4.2).

The different pathways, or social routes, of cultural transmission form a further set of processes that have been modelled, for example, vertical transmission as in parent to child, oblique, horizontal, one to many, or many-to-one (Cavalli-Sforza and Feldman 1981; Mesoudi, 2011). These processes also result in different patterns of variation, for example vertical and many-to-one are conservative transmission modes while oblique and horizontal result in more rapid change in traits. Oblique or horizontal learning, the ways we learn socially from others, not our parents, is therefore seen as important in the differential spread of traits and so in cultural evolution more widely (Muthukrishna and Henrich, 2016).

3.3 Cognitive evolution

Cultural evolution theories are underpinned by ideas about cognitive evolution. Cognitive evolution is a huge and complex field, so the focus here is on those elements that are most relevant to theories of cultural evolution. These include the propensity for copying and particularly imitation in humans; the cognitive basis for social interaction and communication; and theories of brain evolution that underpin sociality and general intelligence and so cultural behaviours.

Imitation as the basis of copying fidelity. Efficient imitation has been proposed as a characteristic of humans that underpins the fidelity of copying and part of a basic human psychology (Heyes, 2009). It is argued this was driven by the need for cognitive shortcuts or biases that facilitate the acquisition of useful behavioural knowledge when due to complexity, uncertainty or other cost it is difficult to quickly and accurately establish it on your own (Henrich and McElreath, 2003). Studies show children tend to copy the precise method of a task irrespective of the simplest means of achieving it, they imitate more than just emulate (Tomasello et al., 2005; Whiten et al., 2009). Similarly, studies conclude that shared intentionality, for example pointing to show interest and to inform each other is also an important human trait (Tomasello and Moll, 2010) and this understanding of other peoples' goals is crucial to effective imitation (Laland, 2017).

Theory of mind and symbolic thinking as a basis for social interaction. Shared intentionality, looking at something from both their own and another's perspective, is argued to facilitate the development of a third, bird's eye point of view (Tomasello and Moll, 2010). This is essential to having a theory of mind, the ability to attribute intention to others (Dunbar, 2003; Whiten and Erdal, 2012). This is

important in understanding other people with whom you can share emotions and experience, and cooperate on tasks and goals, but is also seen as important in the development of symbolic thinking and language (Tomasello et al., 2005; Whiten and Erdal, 2012). Symbolic thinking is a complex level of cognitively referencing things that underpins language (Deacon, 1997). The ability and desire to interact with others is crucial to cultural evolution theories.

The social brain hypothesis. The social brain hypothesis proposes that the reason for increasing brain size in primates relative to body size was the cognitive demands of managing and maintaining bonds in social groups (Dunbar, 1998; 2003). Social grooming in primates is essential for maintaining the coalitions that enable groups to function, and the time spent on grooming increases with group size. This was developed to suggest cognitive limits to group size in hominins, and that these limits indicate that humans are only able to sustain relationships with around 150 other people (Dunbar, 1998). The social brain hypothesis has also been used to suggest that the extension of fusion/fission, in which a group splits periodically into subgroups, facilitated social networks, aggregations and new group formation in the societies of the Upper Palaeolithic and the Epipalaeolithic (Grove and Dunbar, 2015).

The cultural brain hypothesis. The cultural brain hypothesis proposes that brain size and evolution in primates is linked to a more general intelligence, including behavioural flexibility, innovation, increased social tolerance, social learning, tool use, tactical deception, and extractive foraging (Muthukrishna and Henrich, 2016; Reader et al, 2011; van Schaik et al, 2012). Brains evolved for dealing with adaptive knowledge, such as resource finding and processing, with social learning an efficient use of costly brain tissue (van Schaik et al, 2012). The competing social and cultural brain hypotheses have been reconciled to some extent in the idea that selection for social intelligence was followed by a more restricted selection for cultural intelligence (Dunbar and Shultz, 2017; Laland, 2017; Navarrete et al, 2016). The cultural brain hypothesis is taken further to suggest how cumulative culture could have arisen in hominins, linked to brain size, group size and social learning (Muthukrishna et al., 2018).

Some conflicting theories about cognitive evolution are considered below (Section 3.7), but these hypotheses and studies of cognitive evolution suggest that human psychology is primed to focus on imitation and social interaction in groups and that these factors are arguably highly significant in primate and hominin cognitive development compared to environment alone, or individual learning processes. They provide a strong underpinning for the role and importance of social transmission and interaction that are crucial for theories of cultural evolution.

3.4 Cultural niche construction and gene culture co-creation

The key concepts used to explain the feedback loop between group level cumulative culture and individual cognitive evolution are cultural niche construction and gene culture co-creation. Niche construction is the idea that animals regulate and transform their environments, so that through organism-environment interaction, ecological inheritance plays a parallel role to genetic inheritance (Lewontin, 2000; Laland and O'Brien 2011; Laland et al., 1999). This has been developed to propose that cultural niche construction explains how humans maintain and develop knowledge and culture across generations (Boyd et al., 2011). Niche construction is formulated in a variety of ways beyond the ecological niche, including the social-cognitive niche (Whiten and Erdal, 2012), the cognitive-cultural niche (Sterelny and Watkins, 2015), as well as the cultural niche (Boyd et al., 2011), emphasising different aspects of development as well as a link to cognitive evolution. It can lead to stable culture-environment equilibria beyond what might otherwise be expected in both evolutionary advantageous and deleterious ways (Laland et al., 2007). Gene culture co-evolution, also known as Dual Inheritance Theory, is a particular case of niche construction, focussing on how genes and culture interact and influence the expression of each other as two streams of knowledge flowing down generations (Laland and Brown, 2011). Key elements of human psychology such as the capacity for language, social instincts and adherence to social norms evolved in a complex and convoluted feedback process in which hominins constructed aspects of their environments that created new selection pressures, and accelerated together in an autocatalytic way (Richerson and Boyd, 2005; Chudek and Henrich, 2011; Laland, 2017).

Cultural niche construction and gene culture co-evolution both operate to sustain and develop cultural complexity, or cumulative culture, through feedback loops with social learning and transmission. Niche construction is a broader concept, proposing the interrelated influences of genetic, developmental (e.g. learning) and cultural processes, so that it is not always about feedback loops with genetic evolution (Laland and O'Brien, 2011). Niche construction is particularly useful in an archaeological context, providing a broad evolutionary framework within which different theories and aspects of complexity can be examined with a focus on the active creation by humans of niches (social and cultural as well as ecological) that influence the inherited environment of future generations (Laland and O'Brien 2010). Gene culture co-evolution is relevant to this research particularly in the way it is argued to have promoted the adherence to social norms and cooperation in humans which is important in the development and maintenance of group boundaries and identity (Richerson and Boyd, 2005).

3.5 Cumulative culture

Cumulative culture is defined variously as the way that technologies and practices are modified and accumulated over generations (Stout et al., 2019); it is knowledge that could not be generated by a person in a single lifetime (Chudek and Henrich, 2011); and it involves the transmission of activities and practices across generations in a way that ratchets them up in complexity (Tomasello et al., 2005). It incorporates an extended or collective mind of the information held by group members and in the material culture of the group, which are preserved, enacted and transmitted through daily usage and interactions, and through customs, traditions and rituals (Muthukrishna and Henrich, 2016; Sterelny and Watkins, 2015); and an enhanced learning environment in which intergenerational knowledge is transmitted through apprentice like learning (Sterelny, 2011). Cumulative culture is argued to have evolved in hominins through a narrow set of circumstances, for example a threshold of transmission fidelity (Laland 2017) or a certain level of population density necessary for the maintenance and accumulation of traditions (Grove, 2016; Henrich 2004; Powell et al., 2010; Sterelny, 2011). It is argued to exist in other animals up to a point, but depending on the definition, the human version is seen as different or just more developed (Mesoudi and Thornton, 2018; Whiten, 2011).

As a system for the maintenance and transmission of culture down through generations cumulative culture has a clear resonance with the archaeological study of artefact lineages. It can be seen as the product, or the cause, of the feedback loops between social transmission, niche construction and cognitive evolution. So, for example, cumulative cultural knowledge provides more accurate and detailed information about the local environment than could be learned in a lifetime. This provides the specific knowledge that can be leveraged by general purpose learning (as proposed by the cultural brain hypothesis), that preserves the many small modifications previously made and exposes these to another round of modification. Cumulative culture therefore allows rapid cultural adaptation through learning mechanisms that are both more accurate and more general purpose and flexible than would otherwise be possible (Richerson and Boyd, 2008).

The complex interactions within these feedback loops mean that culture can be adaptive, maladaptive or just neutral. Culture can be adaptive in the way average fitness in a population can be improved with the right mix of copying combined flexibly with less frequent individual learning, as covered above (Section 3.2). But culture can also be maladaptive as well as adaptive, or so weakly one or the other it is effectively neutral. If people other than parents (i.e. where there is oblique or horizontal transmission) play an important role in cultural transmission, cultural traits can spread even though they reduce genetic fitness. Adaptive information is costly to obtain and people other than our parents are a vital source of such information, particularly through functional content biases (Richerson and

Boyd, 2005). The reason why such processes persist is that the psychology of imitation that provides rapid access to adaptive behaviour, also means people will tend to accept a behaviour is sensible and copy it, even when it might be maladaptive. This risk cannot be eliminated without losing the benefits of cumulative cultural evolution (Boyd and Richerson, 2009; Richerson and Boyd, 2005). This means that conformist bias together with social norms such as reputation management and group punishment can stabilise strange and costly behaviours even when there is no apparent benefit (Chudek and Henrich, 2011).

3.6 Social group identity and norms

The preservation of social group identity and norms is particularly relevant to testing archaeological approaches looking at artefact lineages linked to populations. Norms are generated and reinforced by cumulative culture feedback loops that amplify social learning of both information and social behaviour and strategies that support cooperation. In social groups, conformity and prestige biases mean people choose mates like themselves. Cooperation within groups becomes more important in success, creating pressure to behave more like others in the group, so generating social norms. (Chudek and Henrich, 2011). Gene culture co-evolution promoted existing cooperative norms such as reciprocity and established new ones fostering large scale cooperation in humans (Richerson and Boyd, 2005). These enable both the strong bonds of family and friendship; and community or tribal instincts that allow us to interact cooperatively with larger, symbolically marked sets of people (Henrich, 2016; Richerson and Boyd, 2005). Group identity is enabled and driven by social norms. To know to whom the norms apply we need to know who is in the group. Arbitrary markers allow humans to interact preferentially with those who share norms (Muthukrishna and Henrich, 2016). The combination of shared norms and the social transmission processes such as conformity bias that create and sustain distinctive distributions of traits maintain within group similarities and between group differences (Chudek and Henrich, 2011).

Theorising about group identity can give rise to concerns about essentialising groups of people or cultures (Eriksen, 2004; Ortner, 2005). Groups are not as similar as often assumed, and real differences are maintained, because community identity works at a symbolic level that allows ambiguity and for it to mean different things to different people (Cohen, 1985). Identity is an embodied process unique to each individual resulting from time interacting in a given social and environmental context (Harvey, 2000). Depending on how they are used, cultural evolution theories do not necessarily essentialise groups or consider that groups have uniform ideas and beliefs, indeed variation is a central issue of study. But as population focussed theories the individual is rarely foregrounded.

3.7 Alternative models of cognition

Much of the theoretical debate about cultural evolution rests in conflicting views of cognition and the psychology underpinning theories of cultural evolution. Simplifying, there is a wide spectrum of views seeing human psychology as more fixed, more evolving or constantly plastic. Evolutionary psychology is at the fixed end of the spectrum seeing the mind as a collection of innate domain specific psychological mechanisms that developed in the environments humans faced during the Pleistocene (Acerbi and Mesoudi, 2015; Laland and Brown, 2011). Culture is not important for explaining human diversity in evolutionary psychology because culture is a product of the interaction of individual cognition with different environments (Mesoudi and Thornton, 2018).

An influential elaboration which draws on this approach, proposes that accurate copying of cultural traits does not occur as cultural evolution theories suggest, because at each transmission they are reconstructed. Instead, the evolved psychology has biases, 'cultural attractors' which shape the way they are reconstructed and perpetuate some traits more than others (Acerbi and Mesoudi, 2015; Sperber, 1996; Sperber and Claidière, 2008). A response to this is that cultural evolution theories do not see traits necessarily as discrete, they are probably fuzzy and processed, and their representation in another mind is likely wholly different. But if the change in behaviour is similar, then the models work. They also work even when biases are weak, making a big difference over long periods of time, and, moreover, selective forces in cultural evolution are likely stronger than selective forces in genetic evolution, where they are even weaker (Henrich, 2001; Henrich and McElreath, 2003; Richerson and Boyd, 2005). The 'cultural attractors' approach does not necessarily conflict with cultural evolution theories but represents a greater emphasis on the importance of guided variation and content biases (Acerbi and Mesoudi, 2015). The respective role and importance of these forces is a matter for empirical studies to determine, but there is likely to be a different balance of influences in different domains of behaviour and culture (Mesoudi, 2017; Sperber, 2019).

At the other end of the spectrum, human psychology can be seen as very plastic. For example Hayes (2019) draws on evolutionary developmental theory as well as evolutionary psychology and cultural evolution theories to propose an approach which sees much of human psychology as culturally inherited, and so potentially very fragile. The variety of comments on her target article (Heyes, 2019, pp.13-42) reinforces the challenge that cognitive evolution and the evolved human psychology is a very crowded and contested field. Cultural evolution theories generally see human psychology as somewhere in the middle of the spectrum, drawing on an evolved psychology that is generalised and flexible and also still evolving (Laland and Brown, 2011; Richerson and Boyd, 2005). The debate about cognitive evolution is also sometimes sidestepped. The human mind and psychology is poorly understood and there are significant disagreements about how information is transmitted, stored and

shapes behaviour (Richerson and Boyd, 2005). Adopting a more black box approach, the limitations and debates about cognitive evolution do not prevent the theories about social transmission and cumulative culture from being useful for research in the meantime (Richerson and Boyd, 2005).

3.8 How evolutionary?

At the heart of what cultural evolution theories are trying to explain is how human culture can be understood by applying ideas from Darwinian evolution. Darwinian processes are seen as operating as there is variation, competition, (giving rise to selection) and inheritance. Variation in cultural traits (e.g. artefact attributes); competition between traits so that their frequency in populations change; and inheritance through intergenerational continuation of these new patterns of traits in a population (Mesoudi et al., 2004; Laland and Brown, 2011). Cultural evolution theories provide the mechanisms for how selection occurs through social learning and transmission pathways, and how inheritance operates through niche construction, gene culture co-creation and cumulative culture.

However, the different social transmission biases or forces, although drawn from population genetics, operate in distinct ways unrelated to genetics. Cultural evolution theories see themselves as Darwinian, not neo Darwinian, they do not claim to be based on the Modern Synthesis of evolutionary theory (Mesoudi et al., 2004). Gene theory was not available for incorporation in Darwin's thinking and is not applicable in cultural evolutionary theory except where specifically integrated through gene-culture co creation and where drawing on cognitive evolution (Andersson et al., 2014; Laland et al., 2015; Mesoudi, 2011). How evolutionary this makes the theories is therefore to some extent a matter of definition and interpretation. The lack of a genetic component to cultural evolution theories can lead to a criticism that they are not really about evolution in a biological sense but just applying evolutionary approaches to population thinking (Andersson et al., 2014; Lewens 2012).

There are also criticisms that evolution is more complex than presented in cultural evolution theories. This is a challenge that is made particularly by evolutionary developmental (evo-devo) and development systems theories (Andersson et al., 2014; Griffiths and Gray, 1994; Laland and Brown, 2011). These stress that there are a range of interacting factors that jointly shape evolutionary trajectories, which are constructed, not inherited, and influences are context specific. Genes are just one of these factors, and developmental processes are another fundamental one, alongside a niche like conception of the organism-environment relationship (Andersson et al., 2014; Oyama et al., 2003). This way of thinking implies that gene culture co-creation, and particularly the idea of two streams of knowledge, involves an artificial separation of culture from biology (Lewens, 2012). The Extended Evolutionary Synthesis has been proposed to incorporate this complexity in an updated model of inheritance that includes a role for culture (Laland et al., 2015). Cultural evolution theories recognise

that complexity is greatly simplified in their models but tend to return to the issue of whether they are productive in research (Laland and Brown, 2011). This is tested through the research case study, introduced in Chapter 5. The key question of whether culture can usefully be said to evolve is then reconsidered in Chapter 9.

3.9 Summary

Cultural evolution theories provide a highly interrelated set of ideas that taken together provide a model of human complexity and an explanation for the origin, variation and persistence of culture. Key aspects relevant to empirical testing in the archaeological record are:

- The evidence for the importance of copying in culture through comparative studies of other animals and in cognitive evolution;
- The different transmission biases and pathways, ways of copying, in a population that give rise to different distributions, of variation, for example of artefacts;
- The creation of ecological, social and cultural niches and gene culture co-creation that fosters cumulative culture and the passing down of technology and traditions between generations, and;
- Group norms and other mechanisms that maintain within group similarities and between group differences that make it reasonable to hypothesize a lineage of artefacts over time.

Chapter 4. Towards a methodology - archaeological approaches to testing cultural evolution theories

4.1 Introduction

Theories of cultural evolution focusing on social learning and transmission mechanisms were developed mainly through mathematical modelling, while drawing on a range of other disciplines including biological and cultural anthropology, cognitive evolution and evolutionary psychology, and the archaeological and paleoanthropological record (e.g. Cavalli-Sforza and Feldman, 1981; Henrich and Boyd, 1998; Richerson and Boyd, 1985). In addition there is experimental evidence using game theory, and studies examining the operation of theories in contemporary societies (e.g. Handley and Mathew, 2020; Henrich et al., 2010; Rendell et al., 2010; Mesoudi, 2011).

In this thesis, the focus is on empirical testing using the archaeological record. Applying statistical and other analytical techniques to test theories of cultural evolution using archaeological evidence is not straightforward. The task is to identify the operation of cultural evolution processes and transmission forces on the basis of a partial archaeological record, inferring the processes that lie behind the creation, (or destruction) of artefacts and other remains (Shennan, 2011). But archaeology is where the physical evidence of intergenerational cultural processes is studied (Tostevin, 2019), and Richerson and Boyd (2008) suggest that when archaeologists have relatively fine-grained data on the evolution of artefacts then fitting an evolutionary model to the data is certainly worth attempting. In this Chapter archaeological approaches that apply the theories are reviewed, followed by an analysis of what drives artefact variation. This leads to a focus on two particular techniques: analysis of variation of artefact measures around central tendency; and phylogenetic analysis of artefact characteristics. These two techniques are developed into a research methodology in Chapter 6, following an introduction to the case study, and research questions, set out in Chapter 5.

4.2 Archaeological approaches drawing on evolutionary theories

Archaeological approaches drawing on evolutionary theories seek to explain artefact variation in terms of evolutionary factors, particularly environment, function (or selection) and social transmission. Human Behavioural Ecology, Evolutionary Archaeology and Dual Inheritance Theory (DIT) are the main evolutionary approaches applied, emphasising different combinations of these elements (Clark and Barton, 1997; Mace, 2014; Shennan, 2008). Human Behavioural Ecology has a strong track record in archaeology but is focussed on adaptation to the environment rather than the

role of culture (Mace, 2014; Shennan, 2008). Evolutionary Archaeology and DIT apply the tools and techniques most relevant to this research.

Evolutionary Archaeology takes the view that archaeological remains are like an extension of the human phenotype, and that variation in artefacts can be divided into functional and stylistic elements (Dunnell, 1980; Lycett, 2015; O'Brien and Lyman, 2000). Functional variation reflects natural selection while stylistic variation is neutral, affected by transmission processes such as random drift (O'Brien and Lyman, 2000; Shennan, 2008). Social learning is the mechanism by which both functional and stylistic variation is transmitted and histories or lineages of artefacts created (Lycett, 2015). The functional and stylistic separation proposed by Evolutionary Archaeology is criticised as artificial and that more likely there is a spectrum where selection and drift apply to different degrees (Shennan and Wilkinson, 2001), or can be seen alternatively as different types of biases (i.e. functional or aesthetic content bias) that influence the variation in artefacts (Lycett, 2015). The idea of the extended phenotype is a step that is transferred from biological evolutionary theory, (Laland and O'Brien 2010), although this is criticised given that descendants will not necessarily have the same material culture as successful ancestors (Mithen, 1997). Evolutionary Archaeology has been seen as overly focused on selection, but the incorporating DIT approaches has broadened this out and given it new impetus (Shennan, 2008; Riede, 2010).

DIT is used in archaeological contexts referring broadly to cultural evolution theories and specifically the way social transmission forces, such as conformity bias, can shape patterns of artefact distribution in the archaeological record (Eerkens and Lipo, 2007; Shennan, 2008). DIT is also used, drawing on cultural evolution theories showing culture can be neutral as well as adaptive, to develop the way neutral, random or drift processes operate in archaeological contexts (Eerkens and Lipo, 2005; Mesoudi, 2011; Neiman, 1995; Shennan, 2008). A key challenge to DIT is that microscale human transmission processes operating in short time scales, such as conformist transmission and prestige biases are not readily susceptible to empirical analysis of the archaeological record (Cochrane, 2009). It assumes the same forces acting in the same direction over long periods of time (Boyd et al., 1997; Shennan, 2011). Social transmission operates in ways similar to microevolution whereas archaeology operates more at the macro evolutionary level (Mesoudi et al., 2006). DIT is also criticised as having limited explanatory power, in effect describing traits distributions rather than the causes of them (Clark and Barton, 1997).

In practice archaeological approaches drawing on evolutionary theory overlap and are integrated with other approaches, for example with *chaîne opératoire* (Riede, 2011) or with cognitive evolution and

symbolic anthropology (Sterelny and Watkins, 2015). Although evolutionary psychology has been less influential in archaeology (Shennan, 2008), it is an influence on more cognitively focused approaches (e.g. Mithen, 1997); and cognitive evolution is the focus of, or incorporated in, archaeological or paleoanthropological approaches, often drawing on Dunbar's (1998) social brain hypothesis (e.g. Coward, 2010; Gamble et al., 2011).

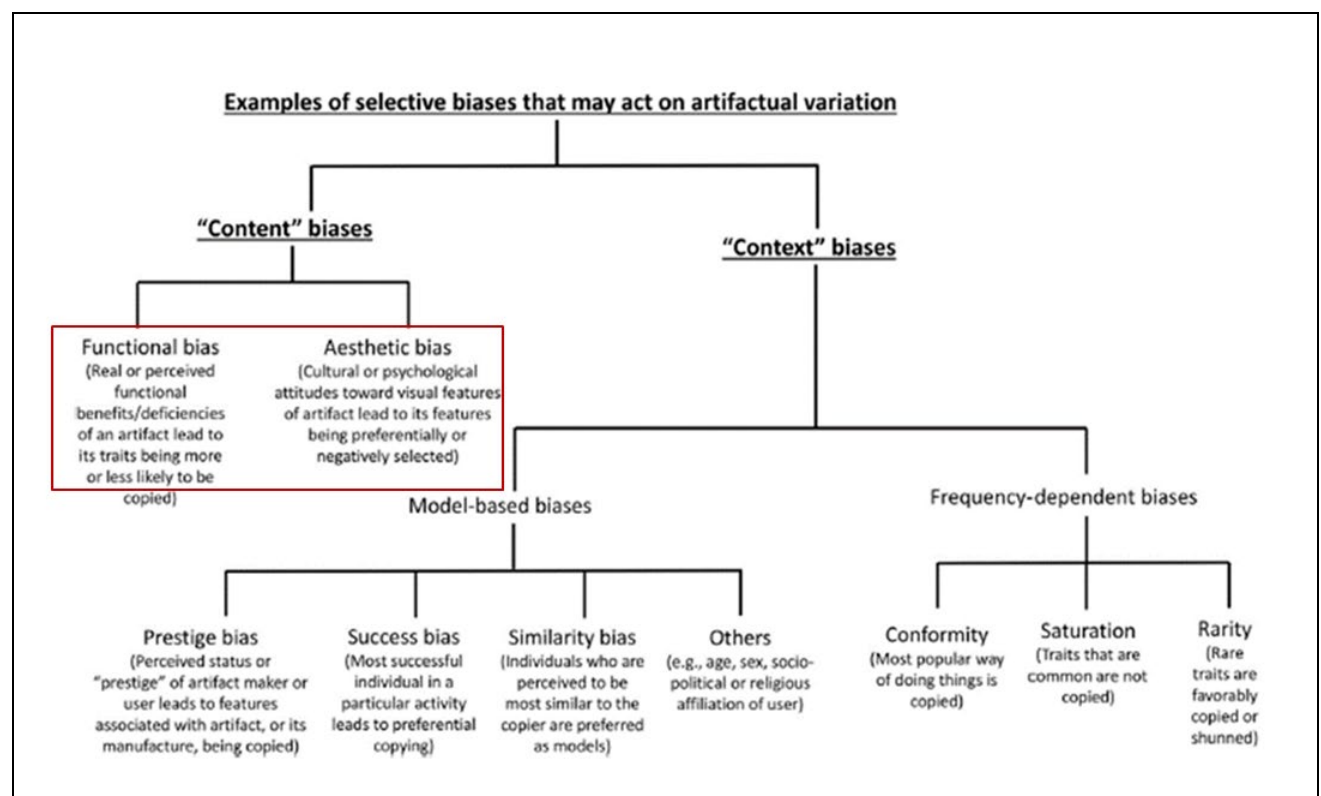
A challenge for all evolutionary approaches is distinguishing between what initially gives rise to variation (e.g. human perception, intention, innovation, or error) and the processes that result in the differential distribution of artefacts in time and space (O'Brien et al., 1998). These are often conflated but evolutionary approaches are focussed more on the latter, which is why they are criticised for underplaying the role of human agency (Ingold, 1990; Laland and O'Brien 2010). Cultural niche construction can be used in archaeology to integrate approaches and reconcile challenges. Niche construction and archaeology fit well because the agency of individuals often implicitly recognised by archaeologists is given greater theoretical underpinning than in other evolutionary approaches (Laland and O'Brien 2010). Niche construction softens and complicates the environment as a factor. It also complicates the idea of the artefact as extended phenotype because within niches evolutionary processes and selection are influenced more at the group or population level and by the sometimes strange (i.e. maladaptive or random) aspects of the cultural niche. In this context the artefacts replicative success does not operate simply according to the principles of natural selection.

4.3 Variation in artefacts

These archaeological approaches elaborate on environment, function and social transmission to extend and develop the influences on artefact variation. Understanding this variation is important for constructing and interpreting the analysis applied in this research. A useful starting point are DIT models of content and context biases or forces (e.g. Figure 4.1). Content and context can broadly be related to the interplay between cognition and social learning, a key theme of cultural evolution theories. However, the role of material culture, both as an integral part of culture and also influencing forms of social learning and behaviour more generally, has arguably been underplayed in the mathematically based theories of cultural evolution, and the links between information transmission and artefact expression are unclear (Lycett, 2015). The absence of artefacts from definitions of culture is a criticism that has been made of the theories (Lewens, 2012). There is also an epistemology of the human relationship to things, brought out in cognitive and paleoanthropological approaches, which proposes that the social has been overestimated (e.g. Hodder, 2017; Malafouris, 2010). In these approaches seeing, handling, making and using tools and artefacts is a powerful embodied experience and a significant, non-social, transmission mechanism.

In an artefact and archaeological context, therefore, content biases arguably need further elaboration and emphasis to reflect the importance of the role of things in themselves as well as socially mediated information. This can be achieved by the elaboration of the functional and aesthetic content biases suggested by Lycett in Figure 4.1 (Lycett, 2015, p.25), highlighted in the coloured box, which is not included in the original diagram (Henrich and McElreath, 2003, p.129). A focus on content biases reflects the importance of cognitive biases, and therefore incorporates the evolved psychology and its influence such as the idea of ‘cultural attractors’ (Sperber 1996).

Figure 4.1: A model of content and context biases that can influence the variation in artefacts and their traits, redrawn and modified by Lycett (2015) after Henrich and McElreath (2003). Highlighted in the box outlined in red is the elaboration of the functional and aesthetic content biases suggested by Lycett.



Using Figure 4.1 as a starting point, Table 4.1 sets out some of the other potential factors influencing artefact variation considered by archaeological approaches drawing on evolutionary theories. These no doubt incomplete factors do not cover variation following artefact creation such as use wear and discard behaviour, or what has been preserved at a site, and what part of that has been excavated (Clarke, 1973; Shea, 2013). They also overlap and duplicate each other in various ways, as influences on variation are complex and interrelated to a degree that cannot be readily presented or summarised.

Table 4.1: Potential factors in the variation in artefacts drawing from evolutionary theories.

Variation factor	Description
Content biases	- As well as affecting the variation within a group, content biases, particularly functional ones, could also have an effect on the success of the group, or be copied by another group, through migration of the concept, or concept bearer, and so affect wider variation (Mesoudi, 2011). - Content biases need to include ease of grasping the idea (meme like), ease of making, ease of copying - which are forms of content bias but are not strictly functional (Lycett, 2015; Sterelny, 2006b).
Context biases	- The different context biases in Figure 4.1 each give rise to different patterns and distributions of artefact variation (Henrich and McElreath, 2003; Lycett, 2015; Mesoudi, 2011; Richerson and Boyd, 2005). - Random drift is seen in neutral theory to be like another frequency dependent bias, not driven by a force but affected by demographic factors such as population size and migration (Shennan, 2011). These factors must likely affect all of the context biases.
Transmission pathways	- Cultural transmission has been modelled in different pathways which result in different patterns of variation. For example, vertical as in parent to child, oblique, horizontal, one to many, or many to one (Cavalli-Sforza and Feldman 1981; Mesoudi, 2011). - Transmission pathways are affected by encounter rates, how often interaction is likely to occur based on population density and migration (Grove, 2016).
Variation at the individual level	- Random mutation or innovation through copying error (Richerson and Boyd, 2005). - Guided variation, individuals modifying artefacts due to their own cognitive biases - traditional 'intentional change' (Mesoudi, 2011).
Environment (which in cultural evolutionary terms include the ecological, social and cultural niche created by humans)	- Ease of finding the raw materials (Lycett, 2016). - Raw material quality, workability and attrition (Lycett, 2016), (and so effect on preservation at the time, for copying). - The niche will have a direct influence on functional and other content biases, and so on variation. - The niche will affect the expression and success of the group (hence the artefact variation) more generally.
Level of selection or analysis	- What element or aspect of the artefact is the attribute under selection or that creates a content bias of design? This could be the lip thickness of a pot, or a particular pattern that occurs on different artefact types. - Artefacts can be part of a group that are part of a symbolic or functional whole that vary together, similar in concept to Boyd et al.'s hierarchically integrated systems, or many coherent units (Boyd et al., 1997).
Natural selection	- Artefacts that increase the biological fitness of their makers will spread (Mesoudi, 2011). - Variation is also affected by the unrelated (to the artefact) success or otherwise of the makers i.e. the group or subset thereof (Lycett, 2015).

However, the analysis also implies many linkages between the social group and the artefact that allow, in theory, and depending on context, a broad if messy lineage of artefacts, linked to the history of populations. As well as being central to the cultural evolution theories summarised in the previous Chapter, this hypothesis, or assumption, is commonly held by traditional archaeological approaches that are not overtly evolutionary. For example, the way that one generation of artefacts is modified in subsequent generations such that the population of artefacts has continuity, while also constantly changing in attribute pattern (e.g. Clarke, 1978). But it is also supported by studies looking at the early emergence and development of cultural communities, suggesting that the diversity of communities can be seen as branching, with fissioning resulting in divergence and the formation of new boundaries (Boyd and Richerson, 2010; Foley and Lahr, 2011; Mace and Jordan, 2011). The application of phylogenetic analysis, which assumes some element of branching, therefore seems reasonable.

At the same time variation in artefact attributes across time and space allows an analysis of the distribution and dispersion of attributes, by focussing on variation around central tendency. Cultural evolution transmission theories can be examined through measures of this variation (Eerkens and Bettinger, 2008). So a broad interpretation of theories allows an approach focussed on identifying the extent of any lineage type of relationship in a given archaeological record, and, using transmission theories, attempt to explain the forces that have shaped the variation observed (Shennan, 2011). This makes statistical analysis of variation and phylogenetic analysis of artefact lineages appropriate techniques to use, separately or in combination.

4.4 Statistical analysis of variation

Evolutionary approaches to the analysis of archaeological variation use the coefficient of variation and neutral theory to examine variation in artefact attributes to test predictions of cultural evolutionary theories.

4.4.1 The coefficient of variation

The coefficient of variation (CV) is frequently used to quantifying variation in an artefact distribution. It is calculated by dividing the standard deviation of a set of measurements by the mean of the measurements *100. It is a standardised measure of dispersal that corrects for differences in the absolute size of the variables being measured and so can be used to make comparisons both within and between sets of artefacts (Edinburgh, 2005; Eerkens and Bettinger, 2001; Garvey, 2018). Variation in traits reflects the strength of the social learning biases modelled in cultural evolution theories, as well as things like raw material quality and abundance, artefact makers' proficiency, and functional requirements. The number of people making the artefacts is also a factor. Items made by a few are more standardised than where large groups are involved. And large numbers of points made

over a short period will have a lower CV than those made occasionally over a longer period of time. (Eerkens and Bettinger, 2001). So the strength of a particular learning bias can be examined within the context of an understanding of the environment, or ecological, social and cultural context (Barton, 1997; Cochrane, 2009; Edinborough, 2005; Garvey, 2018).

Relatively low variation indicates tighter constraints on artefact form and relatively high variation, looser or no constraints (Garvey, 2018). An approach for comparing CVs to standard lower and upper measures was developed by Eerkens and Bettinger, (2001). For the lowest CV expected, reference is made to a threshold of human perception, the 'Weber fraction' - objects' measurements tend to differ by about 3% before the difference is perceptible to humans. When limited only by this sensory threshold artefacts should differ by an average of 3% in any dimension –giving a CV of c. 1.7, assuming a uniform distribution and a range of 6% around a sample's mean. Even lower CVs would suggest use of an external standard. Conversely, 'high' variation can be seen as relative to the CV of a distribution whose range is 200% of the mean (CV of c. 57.7), which is what we would expect if attribute values were chosen at random. Even higher CVs may be indicative of deliberate attempts to make each object distinct (Eerkens and Bettinger, 2001).

The coefficient of variation is a simple comparative tool requiring good contextual information to tease out environmental, functional and social transmission influences. Even if it is possible to effectively account for environment and function to allow a focus on social transmission within the complexity implied in Table 4.1, it is still quite a crude tool for linking patterns in variation to particular biases or forces to provide a useful explanation of that variation. Arguably drift and social transmission are not actively explained, and are seen as the residual explanation when the others have been discounted (Barton, 1997). It is best used in combination with other approaches that provide supporting or complementary insights.

4.4.2 Neutral theory

Neutral theory develops the idea of random drift, the cultural equivalent of genetic drift, as a transmission force. Where the cost benefit of different artefact attributes are neutral (i.e. their frequencies are not affected by or persist through relative advantage, for example different designs with similar costs), then random drift can be used to explain the attribute distribution (Bentley et al., 2004; Neiman, 1995). Random drift results in a distinct distribution, a small number of very popular traits and a large number of very rare traits in the population (Bentley et al., 2004; Mesoudi and Lycett, 2009), although it is likely there are other ways that this distribution may arise, not related to random drift. The model assumes a small number of individuals innovate (generate novel cultural traits) akin to genetic mutation, while the majority select another member of the population at random to copy.

The argument is that while individual acts of copying are not random, the overall effect is (Mesoudi and Lycett, 2009; Shennan, 2008). Neutral theory is plausible partly because the smaller populations of prehistory (and subsets of populations relevant to particular artefacts) make drift more likely.

Archaeologists using evolutionary approaches have suggested using neutral theory as a null hypothesis, a way to assess whether there is variation, and then exploring the variation that does not fit the neutral distribution (Cochrane, 2009; Shennan and Wilkinson, 2001). This is a substantial leap from the original conception in cultural evolution theories of random drift relating to the likelihood of a random error effect in small populations (Richerson and Boyd, 2005). It appears to be at odds with the evidence that copying is not in practice random (Mesoudi and Lycett, 2009). Experimental and theoretical approaches suggest frequency dependent biases such as conformity are more the norm (Henrich and Boyd, 1998; Mesoudi and Lycett, 2009). A null hypothesis privileges random drift when it is only one of many possible biases that should be tested for fit simultaneously (Richerson and Boyd, 2008). So just because a trait is neutral in relation to selection does not mean that drift is likely to best describe the reasons for the distribution of that trait (Barton, 1997). The use of neutral theory as a null hypothesis is perhaps an approach that suits archaeologists rather than cultural evolution theories they are drawing on. Table 4.2 summarises some examples of the use of the coefficient of variation and neutral theory relevant and useful for this research.

Table 4.2: Examples of the use of the coefficient of variation and neutral theory in archaeological studies of cultural evolution.

Variation study	Description
Bettinger and Eerkens (1999)	In this ground breaking study of the variation of points from the prehistoric North American Great Basin variation in points from two different areas was interpreted using Boyd and Richersons' (1985) transmission forces as showing that guided variation with less constraint and high diversity was operating in one area and prestige bias with more constraint and low diversity was operating in the other.
Garvey (2018)	CV and Eerkens and Bettingers' (2001) standard lower and upper measures were used in an analysis of arrow heads from a 13 th -14 th century community in New Mexico. Hypotheses were tested using simulated distributions of CVs to suggest that high fidelity vertical transmission was in operation, possibly indicating strongly held group affiliations.
Edinborough (2005)	An analysis of points from hunter gatherer societies in Southern Scandinavian over the period 10,000 - 6,500 BP was undertaken using a variety of techniques including CV, scatter plots, and discriminant analysis to identify trait variation within and between site phases. Discriminant analysis was used to independently classify point data into the most probable assemblage of origin and visualise the amount of intra- and inter-site trait variation.
Lycett and Gowlett (2008)	Discriminant analysis was used to examine and demonstrate regional patterning in Acheulean handaxes. CV was used to analyse handaxes from three regions and variation interpreted using modes of transmission

Variation study	Description
	modelled by Cavalli-Sforza and Feldman (1981) to suggest many-to-one transmission was in operation.
Cochrane (2009)	In a study of change in Fijian pottery from 3,000-3,500 years ago seriation and cladistics analysis of ceramic body and rim assemblages was initially undertaken. DIT suggested that CV decreases were explained by increasing conformist or prestige biases although the challenges of applying social transmission theories was indicated by the difficulty of demonstrating which bias was prevalent.

4.5 Phylogenetic analysis

Phylogenetic analysis involves examining the relationships between characteristics, or attributes that are related by descent, reconstructing evolutionary pathways that could have given rise to the observed record of characteristics (Mace and Jordan, 2011; Mendoza Straffon, 2016; Tehrani and d’Huy, 2017). Characters that are shared with an earlier ancestor are known as plesiomorphies. Phylogenetic analysis focusses only on shared derived characters or synapomorphies, characters shared by taxa and their most recent common ancestor, but by no other taxa (Mendoza Straffon, 2016; O’Brien et al., 2001). When characters develop in ways unrelated to descent, such as through horizontal transfer, hybridisation, convergent evolution, parallel evolution, or evolutionary reversals, they are called analogous features, or homoplasy. The principle of parsimony, the process that involves the smallest number of inferred changes, is used in phylogenetic analysis as an optimality criterion to help select between hypotheses explaining these different types of changes (Mendoza Straffon, 2016). The optimal tree produced minimizes the amount of homoplasy.

Applying a phylogenetic approach to cultural datasets implies that there is an element of branching in artefact histories, linked to the transmission of manufacture and use within a social group and down through generations. Its use in archaeology is therefore based on the ways that cultural and biological transmission are linked and play a role in the evolution of tool lineages (O’Brien et al., 2001). Phylogenetic analysis has been usefully applied to group related artefacts, examine in what order cultural lineages diverge and spread, look at rates of cultural change, and make inferences about ancestral states (Gray et al., 2007; Mendoza Straffon, 2016; Tehrani and d’Huy, 2017).

4.5.1 Challenges in the application of phylogenetic analysis to artefacts

The more varied ways culture develops through homoplasy, particularly borrowing and blending, compared to genetic evolution, is a fundamental challenge to using phylogenetics on cultural datasets (Gray et al., 2007; Mendoza Straffon, 2016; Tëmkin and Eldredge, 2007). The effectiveness of phylogenetic analysis depends on the relative frequency of the different modes of transmission in

play. It is going to work better where there is stable and more hierarchical systems of transmission, for example, Paleoindian points, and less well on more modern technologies such as the cornet (Tëmkin and Eldredge, 2007). Reversing the argument, phylogenetic analysis can be used to make inferences about these modes of transmission and what factors shaped the patterns seen and the extent to which there is branching (Mendoza Straffon, 2016; Tripp, 2016). Questions about horizontal transmission only make sense in the context of the idea that there is also lineage (Mace and Holden, 2011). Horizontal transmission comes in different forms and does not result in complete hybridisation as often as is assumed (O'Brien et al., 2013). A study was undertaken to test the argument about the effectiveness of phylogenetic approaches in culture by comparing its use in biological and cultural datasets (Collard et al., 2006). This found that the Retention Index (RI, the amount of synapomorphy or shared derived character states expected, as a proportion of the amount actually retained) was an average of 0.59 for 21 cultural datasets, compared to 0.61 for 21 biological datasets, suggesting they were similarly robust models for both types of data.

Ultimately, the trees, or cladograms, that are produced by phylogenetic analysis programs simply summarise a pattern of shared derived character distribution. They do not in themselves make any phylogenetic inference or explanation, that is, they are the product of an algorithm not of evolutionary theory. What exactly descent with modification means for cultural datasets remains an area of debate and requires researchers using cultural phylogenetic approaches to consider the particular properties and circumstances of their object of focus. It is up to the analyst to apply theory to the pattern produced and interpret the character state changes that are shown (Mendoza Straffon, 2016; O'Brien et al., 2001).

A second challenge is that the pace of cultural change, and the nature of the artefact attributes in the cases being studied, will affect the suitability of phylogenetic approaches. For phylogenetic analysis to work, the rate of change in characters needs to be neither too slow, which could mean not enough change for the construction of phylogenies; nor too fast, in which case changes will not be picked up in the archaeological record (Gray et al., 2007; O'Brien et al., 2001). For example, in Edinborough's (2005) analysis of Scandinavian projectile points, the inherent lack of morphological variation meant that phylogenetic analysis was not appropriate. Further, if an attribute is strongly determined by its function then the signal about its transmission may be confounded by similarities resulting from convergent evolution. Focusing phylogenetic analysis on attributes varying due to drift or transmission, rather than selection, helps avoid this potential confusion (Barton, 1997; Shennan, 2008).

A third more methodological challenge, is the selection and use of the outgroup. The outgroup is a taxa used to start, or root the phylogenetic tree and is crucial to giving character orientation or polarity to the analysis. It determines which states are ancestral (i.e. are shared with the outgroup) and which are derived (i.e. in the focal taxa), and frames the analysis of character state changes. The outgroup is usually an older ancestor or close relative of the group, the artefact that deviated earliest, but selection can be difficult and introduces a certain circularity to the process (Cardillo and Alberti, 2015; O'Brien et al., 2001; Tripp, 2016).

4.5.2 Phylogenetic studies of handaxes, arrow heads and points

Phylogenetic studies of points were notably pioneered by O'Brien et al. (2001). This study involved phylogenetic analysis of Palaeoindian points from the Southeastern United States, and comparison of this with other methods of tracing change through similarity, such as seriation. There is a strong school of phylogenetic studies focussed on North American points (e.g. Buchanan and Collard, 2007; O'Brien et al., 2001; 2014; Prentiss et al., 2016), complementing the studies of point variation referred to above (Bettinger and Eerkens, 1999; Eerkens and Bettinger, 2001; 2008). There are also studies related to South American and East Asian points (e.g. Cardillo and Alberti, 2015; Lycett, 2007) and also Acheulean handaxes across global regions (Lycett, 2011). There do not appear to have been phylogenetic studies of Neolithic points in Southwest Asia.

Two important methodological issues in developing phylogenetic analyses of points relate to the selection of taxa and determining character or attribute sets:

Creating the taxa. Using existing point typologies as a classification system is problematic as these have built in assumptions about characteristics. As a result approaches have been developed using more 'blind' classes of points based on a set of characters (O'Brien et al., 2001). O'Brien et al. terms this a paradigmatic classification and contrasts it with a taxonomic approach. In the study 621 points were classified using characters, then sorted into classes with the same string of characters, giving 491 classes. Only those with 4 or more specimens, a subset of 17 classes covering 83 points, were analysed (O'Brien et al., 2001). However, any system will have some preconceptions built in about the nature of the characters used, for example in terms of function (Edinburgh, 2005). Developing the taxa set in phylogenetic studies of points involves securing well preserved points that can ideally be rooted in a location and period and with enough variation to provide a clear phylogenetic signal. Studies use classes developed from characters, assemblages, and individual points to create taxa sets.

Character selection. Character sets used to define and analyse taxa are usually morphological which tend to be discrete, or metric which tend to be continuous. There is debate about the relative merits

of qualitative and quantitative characters, and the advantages of having a mix, but the distinction may not be as great as appears as there tend to be aspects of each type underlying both. Using absolute measurements such as length and width can introduce potential bias, due to the distorting effects of scale, raw material qualities, or the different extent points might have been retouched (Buchanan and Collard, 2007; Cardillo and Alberti, 2015; O'Brien et al., 2001). Each character is generally treated as independent but in reality they are probably linked in some way (O'Brien et al., 2001).

4.5.3 Assessing the quality of phylogenetic trees

The usefulness of phylogenetic analysis depends on the quality of the phylogenetic trees produced as well as how they are interpreted and contextualised. The quality of trees can be assessed in quantitative terms using measures of how well the tree fits the data. The length, score, or number of steps, is the total number of character state changes necessary to create a tree or cladogram. A lower score or length suggests a better fit of the data because it means there are fewer homoplasies, cases where the state has not been inherited. The relative amount of homoplasy is measured by the Consistency Index (CI), which is the number of character state changes expected given the data, as a proportion of the actual number in the tree produced. There is a significant inverse relationship between the CI and the number of taxa included in an analysis. The Retention Index (RI) is the amount of synapomorphy (shared derived character states) expected, as a proportion of the amount actually retained. This measure is used more than the consistency index, as it is less influenced by the number of taxa and character states, and is more comparable (Buchanan and Collard, 2007; Lipscombe, 1998; Tripp, 2016). RI ranges from 0, indicating complete homoplasy, to 1, indicating no homoplasy in the data. Values above c.0.6 indicate high levels of branching (Tripp, 2016).

Where there are a large number of similarly parsimonious trees resulting in the analysis, different types of consensus trees are used to combine the results in a summary tree (Cardillo and Alberti, 2015; O'Brien et al., 2014). Strict consensus is the most conservative and involves only using the elements that appear in all the set of trees created by the algorithm. This can lead to low levels of resolution. Majority rules or frequency differences consensus trees use the frequency a taxon is placed in a set of trees, and so involve more compromise (Lipscombe, 1998).

4.6 Summary

This Chapter examined archaeological approaches to testing evolutionary theories, and considered the challenges of explaining variation in artefacts given the many different influences explored in evolutionary approaches. The basis of considering a broad lineage of artefacts related to social groups allows a hypothesis that phylogenetic analysis may be useful and this approach has been used in

numerous studies of cultural evolution, including those of arrowheads or points. Analysis of the coefficient of variation also appears applicable in this context, although it requires good contextual information or follow up through other methods to provide meaningful insights. Using a combination of variation and phylogenetic analysis, of differences and similarities in attributes, appears complementary and forms the basis of the research methodology set out in Chapter 6.

Chapter 5. Case study introduction - the potential of an evolutionary approach to material culture from the early Neolithic of the Southern Levant

5.1 Introduction

This Chapter introduces the case study, which focusses on El Khiam points from three sites in the Pre Pottery Neolithic A (PPNA) of the Southern Levant. Cultural evolutionary models of social learning and transmission have been applied to interpret patterns in the archaeological record and so provide a further test of the predictions of the models (Garvey 2018). There is a similar intention here in the application of this case study. In this Chapter background is provided to the period, the sites and assemblages, and issues of debate. This allows research questions to be proposed based on the potential of the data described and drawing on the tools and approaches set out in the previous Chapter.

5.2 The Epipalaeolithic to Neolithic in the Southern Levant

A considerable body of theoretical and empirical work focusses on the transition from the Epipalaeolithic to the Neolithic in southwest Asia (e.g. Coward, 2010; Finlayson et al., 2011; Goring-Morris and Belfer-Cohen, 2016; Kuijt and Prentiss, 2009; Sterelny, 2014; Sterelny and Watkins, 2015; Watkins, 2010). This transition is conventionally seen as occurring about 12,000 years ago (Kuijt and Goring Morris, 2002), a period of increased social complexity and also of debate about continuity or change in the nature of that social complexity (Coward, 2010; Finlayson et al., 2011). It is a region and period of extensive and ongoing research and rich archaeological evidence and therefore potentially a fruitful one to draw on in this research.

The Southern Levant in the transition from the Epipalaeolithic to the Neolithic is conventionally divided into phases based on technological and stylistic criteria of stone tool assemblages and other material artefacts (Table 5.1). The late Epipalaeolithic and early Neolithic is seen as a mosaic of communities within regional networks (Finlayson et al., 2011; Kuijt and Prentiss, 2009; Rollefson and Gebel, 2004; Watkins, 2008). During the Epipalaeolithic, complex and symbolic architecture, technology, art and ornamentation and social networks saw intensification across the Levant (Maher et al., 2012). The increasing scale and intensity of sedentism in the Natufian, late on in the Epipalaeolithic, meant the developing importance of territory and boundary, both physically and as concepts (Belfer-Cohen and Goring-Morris, 2017). Although the end of the Natufian and the beginning of the PPNA is conventionally seen as a break, recent studies have emphasised that the PPNA was closely related to what came before (Belfer-Cohen and Goring-Morris, 2010; Finlayson et al., 2011).

Table 5.1: Historical sequence for periods and cultures in the Levant – Epipalaeolithic to Neolithic, adapted from Goring-Morris and Belfer-Cohen, 2011, Kuijt and Goring Morris, 2002, and Maher et al., 2012.

Period/cultural phase	Approximate date range (cal BP)
Epipalaeolithic	23,000-12,000
-Natufian	14,900-12,000
Neolithic	11,700-7,800
-Pre Pottery Neolithic A (PPNA)	11,700-10,500

The environment of the Southern Levant saw significant variation within close proximity, with a number of distinct ecological zones (Kuijt and Goring Morris, 2002). Many PPNA settlements were in the Jordan Valley, but some were in the hilly zone between the coastal plain and the Jordan Valley (e.g. Hatula) and others were more marginally located on the Jordanian escarpment (e.g. WF16) to the south (Figure 5.1). Although communities were self-contained and do not appear to have been in particularly structured or hierarchical relationships with each other, there were networks of connections within and between regions maintained through exchange and aggregations, and probably migration. This is evidenced in the Epipalaeolithic and increasingly in the PPNA (Belfer-Cohen and Goring-Morris, 2017; Watkins, 2008).

Within an overall similarity of material culture and ways of life there were distinct local traditions (Watkins, 2008). In terms of similarities, for example, a generalized hunter-gatherer and cultivator subsistence model (Edwards et al., 2004) and the El Khiam point, which is found across the wider Levant and is seen as the distinctive marker of the PPNA (Goring-Morris and Belfer-Cohen, 2016; Shea, 2013). At the same time there were significant differences between communities for example in architectural forms, site layouts and assemblage composition (Finlayson and Makarewicz, 2017; Helmsley, 2008; Sayej, 2007). There is also evidence of sub regional patterns, for example, traditions in Southern Jordan different to those further North in the Levant (Makarewicz and Finlayson, 2018). There is debate about what sort of social structures operated in the communities of the late Epipalaeolithic and the Neolithic, how they developed, and particularly to what extent they were egalitarian (Wright, 2014). Variation between communities and regions seems apparent in most aspects, so this may have also applied to gender roles and social organisation, with family, extended family, moieties or variations of these likely adopted (Belfer-Cohen and Goring-Morris, 2011; Peterson, 2010; Wright, 2014).

Figure 5.1. Map showing the position of WF16, Dhra', Netiv Hagdud and other sites of the PPNA in the Southern Levant, adapted from Wicks et al, 2016.



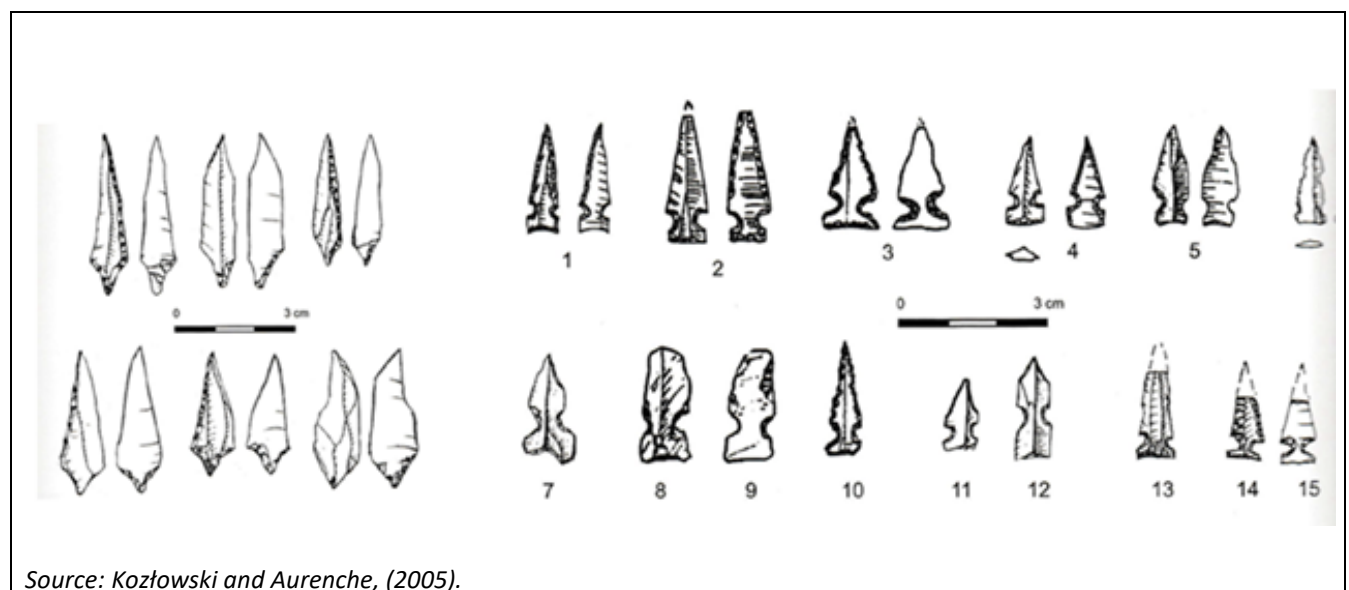
5.3 Stone tools, assemblages and the El Khiam point

Lithic assemblages are groups of stone tools from the same archaeological site, or context (Shea, 2013). Groups of assemblages that seem similar are referred to as industries, or sometimes ‘cultures’, but these similarities (and differences) are hard to pin down, particularly given the uncertainty around what has been preserved at a site, and what part of that has been excavated (Clarke, 1973; Shea, 2013). Material assemblages in the PPNA include a wide range of chipped stone, ground stone and bone tools and the remains of tool production, as well as a range of other often more decorative artefacts made from incised or polished stone, or shells. Points are an important part of the chipped stone assemblage along with a great range of other tools, some given names suggesting or evocative of function such as scrapers, borers and sickles (Nadel, 1997; Sayej, 2007; Shea, 2013). There is limited

understanding of the reasons for the variation in the types of tools and technology found in the lithic assemblages of the PPNA (Kuijt, 2001).

The El Khiam point, a small symmetrical point with a distinctive bilateral notch, has been found across the wider Levant, from Abu Maadi in the Sinai to Mureybit in the Euphrates Valley (Nadel et al., 1991; Shea, 2013). The first appearance of symmetrical points is at the end of the Natufian in the Harifian of the Negev (Goring-Morris and Belfer-Cohen, 2016) but the El Khiam point, seen as the hallmark of the PPNA, is more regular, and with its edges more extensively and consistently worked or retouched (Figure 5.2). Other similar points often appear alongside the El Khiam but in lesser numbers, particularly the Salibiya (no notch), and the Jordan Valley (a prong or tang instead of a notch). The distribution of El Khiam and Harif points across the wider Levant is mapped in Appendix 1.

Figure 5.2: A group of Harif points (left) from the Negev, and a group of El Khiam points (right, 1-15) from across the wider Levant.



Source: Kozłowski and Aurenche, (2005).

There is a lack of evidence and a debate about the origin and spread of the El Khiam point. A detailed seriation analysis of Neolithic points from the Levant found it difficult to create a chronological sequence of sites where El Khiam points were present (Gopher, 1989). Some propose that its origin is in the Southern Levant, (Belfer-Cohen and Goring-Morris, 2014) and Finlayson et al. (2011) suggest this might have been through links with the Harifian in the Negev. But others hypothesise it may have spread from the Northern Levant through exchange networks (Nadel et al., 1991). More broadly there are questions about the El Khiam point as a marker of a culture and as a typology. There is a critique of culture history where archaeological 'cultures' form the basis of a historical narrative, for example

the succession of the PPNA to the PPNB (Rollefson and Gebel, 2004; Watkins, 2008). There is also a critique of the way typologies can be overused in archaeology, and can become fixed as representations of cultures, instead of a focus on the actual variation that the record evidences (O'Brien and Lyman, 2000; Riede, 2010). The El Kham point has to a degree been implicated in both these ways of looking at things.

5.4 Archaeology, context and comparison of the three sites

The case study focuses on assemblages of El Kham points from three sites – WF16, Dhra' and Netiv Hagdud. They are all significant settlements of the PPNA, set in different environments, with distinctive archaeology and extensive lithic and other assemblages, including detailed data on El Kham points available for analysis. A description and comparison of the three sites across a range of aspects is set out in Table 5.2. This shows some important differences as well as similarities. For example, WF16, the earliest site, is the most isolated geographically, and also has a distinct site layout and architecture that is in some ways reminiscent of Harifian forms (Finlayson and Makarewicz, 2017; Mithen et al., 2019). Netiv Hagdud the latest site, is also the largest, has the most complex assemblage, and appears to evidence the greatest intensity of cereal processing (Gopher, 1997; Helmsley, 2008; Nadel, 1997). Dhra' is distinct again but in some ways is closely related to WF16, for example in terms of communal architectural structures, but in others, appears to be positioned between WF16 and Netiv Hagdud, for example in terms of isolation, and intensity of cereal processing, as well as in dating (Finlayson and Makarewicz, 2017; Goodale et al., 2010).

The dating of these sites (summarised in Table 5.2) is difficult but also important for this study because the dating sequence supports the direction of the phylogenetic analysis and the interpretation of the results. In particular the dating of WF16 is crucial. A detailed analysis of 25 radiocarbon dates from the 2008–2010 excavation and re-analysis of 21 dates acquired earlier was undertaken (Wicks et al., 2016). This involved addressing the challenge of radiocarbon dating old wood, in this case likely Juniper, that has a very long lifespan (in some cases 1,000 years or more) which therefore adds further uncertainty to estimations. An offset of 825 to 1,370 years was incorporated into Bayesian chronological models to account for this effect. The dating of phases for WF16 has therefore been thoroughly analysed but remain tentative (Mithen et al., 2019).

Table 5.2: Archaeological context and comparison of the sites of WF16, Dhra' and Netiv Hagdud.

Aspect	WF16	Dhra'	Netiv Hagdud
Location and environment	Located just below the Mediterranean zone that extends to the south of Jordan along the western edge of the Jordanian escarpment. To the west, c.30km away, is the Negev while mountains rise steeply to the east. It is the most marginal and isolated of the three sites (Mithen et al., 2019).	Located in the Jordan Valley at the southern end and east side of the Dead Sea, situated on an alluvial terrace at the base of cliffs that rise to the Jordanian plateau. WF16 is c.60km to the south and Jericho a little more than that to the north (Goodale et al., 2007).	Located in the lower Jordan Valley it is at the western edge of the Salibiya basin. The basin is bounded by the Samaria Hills to the west and the Gilgal Ridge to the east, and contains two other PPNA sites, Gilgal and Salibiya IX, with the site of Jericho c.12km to the south (Hovers, 1997).
Archaeology	Identified in 1996, initial test and evaluation phases 1997-2003 were followed by systematic excavation 2008-10, with a main area of 600m ² excavated (Mithen et al., 2019).	Identified in the late 1970s, with investigations then and in the mid-1990s, and a systematic excavation 2001-04. This focussed on a main area of 200m ² and five other areas including a deep sounding (Goodale et al., 2007).	Identified in the mid-1970s and systematically excavated in 1983-86, with a main area of c.500m ² and a deep sounding to a depth of 3.8m (Bar-Yosef and Gopher, 1997).
Site dating	Based on an analysis of 46 radiocarbon dates WF16 is divided into three phases (Mithen et al., 2019; Wicks et al., 2016). Phase 1, is tentatively dated to between 11.84–11.30 ka cal BP a period of c.540 years. Phase 2 is c.11.30–10.80 ka cal BP and Phase 3, c. 10.80–10.24 ka cal BP. This sequence makes it the earliest site, and also the longest span of continuous use or occupation in the order of 1,600 years.	The site is dated by seven radiocarbon dates (Hemsley, 2008). These were converted into cal BP dates consistent with those for WF16 by using the same calibration curve (IntCal13 in OxCal 4.4), giving means of 11.62-10.91 ka cal BP ($\pm$ 12.12-10.43 at 95% confidence). This indicates a c.700 year range of occupation, with a focus of occupation some 250-300 years later than WF16, but overlapping with Phase 1 perhaps for 300 years or so, and with Phase 2 for the remainder of occupation.	The site is dated by ten radiocarbon dates from the deep sounding (Hemsley, 2008), which were converted in the same way as for Dhra'. The dates cluster between 11.23 and 10.71 cal BP (with a $\pm$ range from 11.75-10.25) An outlier takes the earliest date back to 11.60 $\pm$ 468. This indicates a c.500 year range and a focus of occupation in the region of 400 years later than Dhra' but overlapping for maybe 300 years.

Aspect	WF16	Dhra'	Netiv Hagdud
Site layout and architecture	Site area 0.6ha. The settlement consists of more than 30 subcircular semi-subterranean structures with walls of pisé, with a resemblance to Harifian forms but little evidence of residential structures. A feature of the site is the diversity in the size of structures, including a very substantial communal building that dominates the site, and what are understood to be communal storage buildings. The site has tightly demarcated boundaries, intentionally maintained. Possibly less sedentary than the other two sites given periodic structure usage and abandonment (Finlayson and Makarewicz, 2017; Mithen et al., 2019).	Site area c.1ha. A large settlement containing what are interpreted as storage buildings, workshops, and potentially dwellings. Three types of structure are repeated but most notably buildings with raised floors to keep the contents dry and cool are interpreted as communal storage structures. The site has tightly demarcated boundaries intentionally maintained (Finlayson and Makarewicz, 2017; Kuijt and Finlayson 2009).	Site area 1.5ha. A large settlement with 27 reported structures constructed from mud mortared field stones supporting a mudbrick superstructure. These structures identified as likely residential in nature, and also a pattern that indicates more distinct households and even potentially different types of resident groups. There are also potential storage structures and/or the possibility of in-residence storage (Hemsley, 2008).
Population estimates	Population estimates are very approximate and imply a year round occupation that may not have been the case. Cartolano, (2016) suggests 54-270 people with a mean of 172. It has the smallest site size of the three, and potentially also where periodic aggregation was more prevalent (Mithen et al., 2019).	Cartolano, (2016) suggests 41-202 people with a mean of 129. Birch-Chapman, (2017) suggests 133-298 people with a mean of 191. Birch-Chapman uses a sophisticated methodology based on a storage provisions formula, (and based on a site size of 0.45ha). WF16 and Dhra' may have had roughly similar 'populations' but with a larger site size it is also possible Dhra's was larger.	Cartolano, (2016) suggests 135-675 people with a mean of 429. Birch-Chapman, (2017) suggests 215-268 people with a mean of 241 (focussing on the earliest phase and using a site size of 0.75ha). It seems reasonable to consider that the 'population' at Netiv Hagdud was most likely higher than at the other two sites.
Assemblage	A rich and varied assemblage. Points and perforators are frequent in the chipped stone, and ground-stone artefacts also abundant. A wide array of more artistic or symbolic items including incised stone, marine shell, beads and pendants. Items with stylistic similarities both with elsewhere in Southern Levant, for example in the use of similar wavy line designs at WF16 and Netiv Hagdud, and further afield	A very extensive chipped stone assemblage but apparently less extensive in other aspects at least based on current reported finds. A notably large number of points and perforators, and used or retouched blades and flakes. Also a feature are the number of sickles with evidence of intensive use. A large ground-stone assemblage, numerous beads and also shells are reported (Finlayson et al., 2003; Goodale et al., 2007; 2010).	A very rich and extensive assemblage. Points are less and sickles more abundant than at the other sites both in absolute terms and proportionately, while perforators remain common. There is a large array of grinding stone tools. Like WF16 a wide range of more artistic or symbolic items including incised stone, marine shell and beads. An extensive presence of obsidian has been interpreted as meaning Netiv Hagdud was a key point in a

Aspect	WF16	Dhra'	Netiv Hagdud
	with the Northern Levant (Gopher, 1997; Mithen et al., 2019).		Levantine wide obsidian distribution network (Birch-Chapman, 2016; Gopher, 1997; Nadel, 1997; Yellin, 1997).
Subsistence	A mixed economy of hunting and gathering with some cereal processing. Faunal remains suggesting that <i>Capra</i> sp., likely ibex or wild goat, were important along with smaller mammals and birds including birds of prey. The predominance of <i>Capra</i> sp. is in contrast to the predominance of gazelle at most PPNA sites. Plant remains are those of wild cereals, pulses, and fruit and together with the ground-stone tools and likely storage structures indicate cereal collection and processing probably occurred (Mithen et al., 2019; Smith, 2005).	Evidence of increasing intensity of cereal collection, cultivation and processing compared with WF16 based on the storage and food processing structures and sickle usage to enable the accumulation of significant food surplus (Goodale et al., 2010; Kuijt and Finlayson, 2009). Few faunal remains reported but the abundance of points, albeit with usewear analysis suggesting use as perforators as well as projectiles (Smith, 2005), indicate hunting was also important.	A mixed economy of hunting and food production. Wild barley was the main plant food on the site, representing about 90% of the identified grass remains, but also evidence of emmer wheat, oat, lentil, legumes, fig, plus fleshy fruits and nuts. The large numbers of sickles and grinding tools, indicate likely cultivation and intense processing of non-domesticated plants. A wide spectrum of animal species also exploited the most common being the gazelle comprising over 50% of the on-site biomass (Helmsley, 2008; Kislev, 1997).

5.5 Three El Khiam assemblages: sources and sampling

A summary of points classified as part of excavations from each of the three sites is at Table 5.3. The basis and source of the samples of El Khiam points taken from the assemblages and used in this study is detailed in Table 5.4.

Table 5.3: Analysis and comparison of classified point numbers and types from Wf16, Dhra' and Netiv Hagdud, showing El Khiam points as the predominate type found across all three sites.

	WF16	Dhra'	Netiv Hagdud
Total points	257	641	120
El Khiam	204	534	55
-Samples extracted	126 (Note 1)	65	55
Salibiya	22	80	25
Jordan Valley	4	11	16
Other	11	16	24 (Note 2)
Source	Mithen et al. (2019) and Pirie (2007)	Goodale et al. (2007)	Nadel (1997)

Note 1: WF16a 57 points and WF16b 69. These 126 points do not relate directly to the total of 204 El Khiam points because of the inclusion of previously unclassified material (see Table 5.4)

Note 2: Netiv Hagdud 'El Khiam?' category included in Other.

Table 5.4: The basis and source of El Khiam point samples used in the case study.

Sample	Source
WF16a	This sample was extracted by Smith (2005) based on the earlier 1997-2003 excavation (Table 5.2). 64 El Khiam points were recovered and 57 of these were included in the sample. They were selected on a random basis from all areas and most contexts, although insecure contexts were excluded with the aim of being representative of the occupation at the site and variation within the assemblage (Smith, 2005). This sample is all from the Phase 1 type assemblage or the earliest occupation of the site (Smith, S. 2020, personal communication, 30 July).
WF16b	This sample was selected at random by Collier (in prep.) from the 140 El Khiam points classified in the 2008-10 excavation (Table 5.2) plus previously unclassified points from that excavation, and comprises 69 points which are understood to come mainly from Phase 1, which accounts for the vast majority of points (Mithen et al., 2019; Smith, S. 2020, pers. comm.). This takes the combined WF16a and b sample to 126 (which does not relate directly to the total of 204 El Khiam points classified in Table 5.3 because of the inclusion of previously unclassified material).
Dhra'	The Dhra' sample was extracted by Smith (2005) in a similar fashion to WF16a, based on the 1994 and 2001-02 excavation assemblages, i.e in the midst of the

Sample	Source
	2001-04 excavation (Table 5.2). At the time of sampling there were 333 El Khiam points classified and 65 of these were included in the sample. Again they were extracted on a random basis from different contexts, although the excavation was on going at that point. The current total number of El Khiam points classified from Dhra' is 534 (Table 5.3), so overall, the Dhra' sample covers a much smaller proportion of the classified population than at the other two sites.
Netiv Hagdud	The data for this sample was taken directly from Nadel (1997). The analysis of the chipped stone assemblage in Nadel (1997) includes all excavated material. All categories were counted yielding 162,656 flint artefacts of which 4,058 were classified as tools and 120 as points, with 55 of them El Khiam. There are measurements (length, width and thickness) of all 55 points (Nadel, 1997, Appendix 4.2), but images cover only 34 of these (Nadel, 1997, Figures 4.5 to 4.7) and they are not linked individually to the listing in the Appendices. The 55 points form the starting point for this analysis.

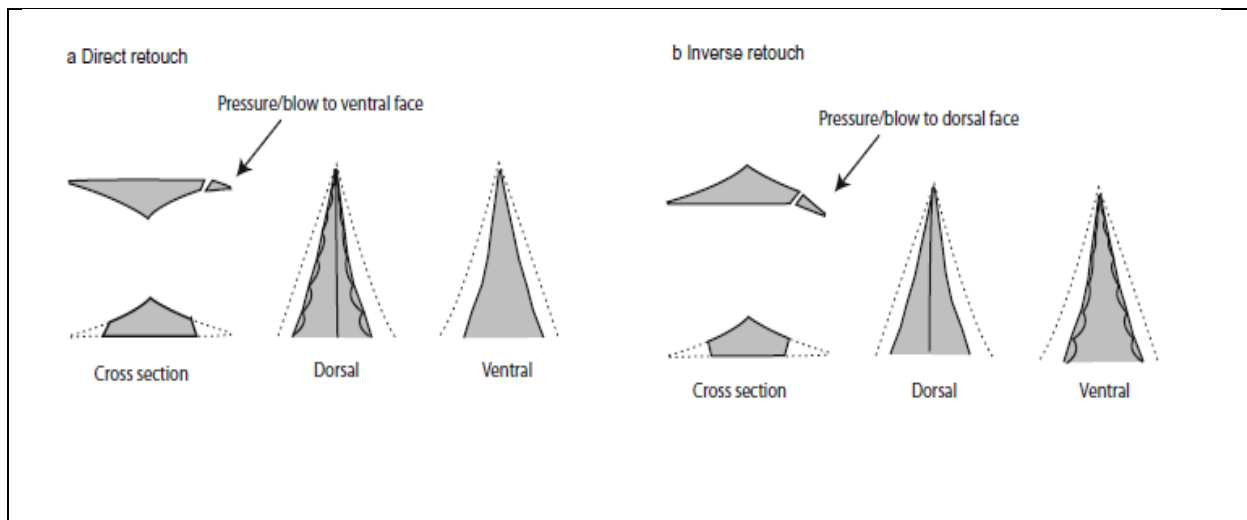
This summary indicates these samples are a valid starting points for further analysis, bearing in mind that like all such archaeological samples they are biased by what has been preserved at the site (likely related to the reason for discard), and what proportion of the assemblage has been excavated and classified. The condition of the points is affected by usewear, reasons for discard, and the post-depositional environment as well as the processes of recovery and curation. Analysis by Smith (2005) showed that for the WF16a and Dhra' samples at least these factors do not prevent meaningful analysis and the attributes that provide the focus for this analysis remain readily identifiable even in different conditions of preservation. Metrical attributes may well be differentially affected by use and attrition which might have an impact on variation analysis, which needs to be considered.

5.6 Point attributes – the approach in Smith (2005; 2007)

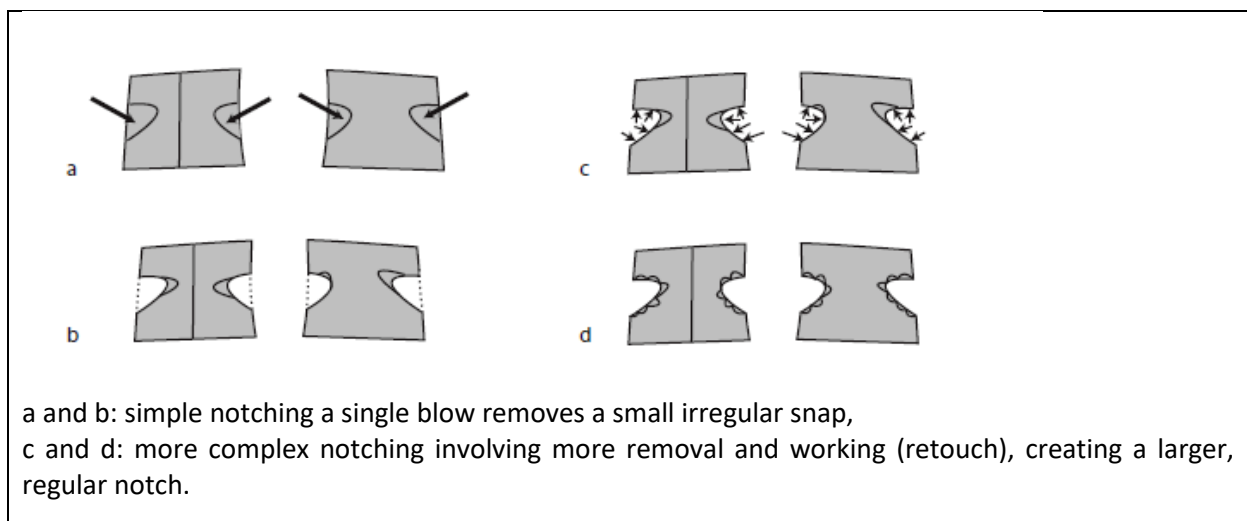
The point attributes for this study are driven by the analysis of WF16 and Dhra' chipped stone artefacts by Smith (2005). This focused on an analysis of usewear to investigate how the artefacts might actually have been used, treating with caution those functions that are normally assumed by the typology and avoiding assumptions about stylistic and functional elements. The analysis of El Khiam points considered how they were produced and focussed on three key areas of edge working or retouch; the tip, the base and the notches, looking at the shape of these as well as the processes used to create them. For example in making the base of points, there might be only couze retouch, which essentially just thins the base, or further working or retouch of the base which can be only on one side or face, or both faces of the base (bifacial). Illustrated examples of these retouch attributes for the tip and the notch are shown in Figure 5.3, and descriptions of each of the six attributes used in phylogenetic analysis are given in Table 6.4.

Figure 5.3: Illustration of different retouch attributes for point tip and notch (after Smith, 2005).

a) Direct or inverse retouch used to form point tip



b) Snap or retouch techniques of notching



Smith's analysis (2005; 2007) showed that based on these morphological and retouch attributes the methods of point manufacture at WF16 and Dhra' were different – distinctive approaches were employed at each site. For example, at WF 16 most of tips are formed by inverse retouch, whilst at Dhra' direct retouch is more common; and the snap technique of notch production is frequently used at WF16 but rarely for Dhra' points where notches were usually formed by a series of retouch scars.

The analysis also demonstrated that at both sites points were used either as perforators or projectile, points in generally equal proportions.

Smith (2005), notes that the variability in the morphological and retouch attributes do not appear to be strongly functionally determined. More generally, given the very different environments across the wider Levant in which the El Khiam point are found, purely functional reasons for its adoption and spread are unconvincing (Smith, 2005). Similarly, in discussing the emergence of the El Khiam point, Watkins (2008) comments that point types change quickly, are shared widely and types supersede each other often without any clear technical advantage. It is reasonable to hypothesise, therefore, that the patterns of morphological and retouch attributes of El Khiam points that are the subject of this research may primarily reflect social transmission forces.

5.7 Research questions

Building on the data and analysis in Smith (2005) and extending this to Netiv Hagdud by analysing data from Nadel (1997) forms the starting point of this research. Whether the differences in point manufacture identified between WF16 and Dhra' applied elsewhere was a question raised in Smith (2005). This Chapter has touched on the debate about the origin and spread of the El Khiam point. A comparison between the three sites of WF16, Dhra' and Netiv Hagdud, and debates about the nature of social structure and interaction between communities in the early Neolithic have also been covered, raising questions about the relationships between the sites, and about social transmission, social structure and community identity within and between the sites. This research considers the potential of evolutionary approaches to shed light on these issues based on phylogenetic analysis, and analysis of the coefficient of variation (CV). This will provide a further test of the predictions of cultural evolution models and so allow reflection on the issue of whether culture can usefully be said to evolve.

Research questions on these issues fall into four related areas:

- 1) The origin and spread of the El Khiam point:** Does phylogenetic analysis reflect distinct patterns in attributes between sites, and any direction or progression between points from different sites, which, based on the dating of WF16 as the earliest site, might provide insight into the origin and spread of the El Khiam point?
- 2) Attribute changes and the mode of transmission between sites:** What does phylogenetic analysis of key changes (synapomorphies) in attributes tell us about the mode of transmission between sites, and possible reasons for attribute changes?

- 3) Social learning environments within sites:** What do patterns in the coefficient of variation of attributes say about the strength of different social learning biases modelled in cultural evolution theories, and so the learning environment and group interaction within different sites?
- 4) Social structure and community identity in the Neolithic:** What might these questions together, set in the context of other studies of the period, indicate about social structure and community identity in the Neolithic?

The methodology applied to address these questions is set out in the next Chapter.

Chapter 6. Case study - research methodology

6.1 Introduction

This Chapter sets out the methodology used to address the research questions identified in Chapter 5, developing the archaeological approaches to testing cultural evolution theories assessed in Chapter 4. This starts with the steps taken to create and validate the samples of El Khiam points used in the analysis and is followed by a description of the methodology, set out for each of three stages which cumulatively build the analysis:

- Stage 1 is a descriptive analysis comparing metrical attributes of the El Khiam point samples using scatterplots and discriminant analysis. This introduces the samples and metrical data using visual techniques, as well as providing other foundational statistical analysis.
- Stage 2 applies statistical analysis of variation in metrical attributes, and particularly using the coefficient of variation to explore comparatively the variation within and between the case study sites.
- Stage 3 draws on the results of Stages 1 and 2 to apply phylogenetic analysis to a combination of morphological and metrical point attributes to analyse the extent and pattern of branching of the point samples related to sites.

Figure 6.1 shows the way this cumulative approach addresses the thesis research questions.

Figure 6.1. How thesis research questions are addressed by different elements of analysis.

Research Question		Analysis	
1	The origin and spread of the El Khiam point: Does phylogenetic analysis reflect distinct patterns in attributes between sites, and any direction or progression between points from different sites, which, based on the dating of WF16 as the earliest site, might provide insight into the origin and spread of the El Khiam point?	Phylogenetic analysis	Descriptive analysis
2	Attribute changes and the mode of transmission between sites: What does phylogenetic analysis of key changes (synapomorphies) in attributes tell us about the mode of transmission between sites, and possible reasons for attribute changes?	Phylogenetic analysis	
3	Social learning environments within sites: What do patterns in the coefficient of variation of attributes say about the strength of different social learning biases modelled in cultural evolution theories, and so the learning environment and group interaction within different sites?	Variation analysis	
			
4	Social structure and community identity in the Neolithic: What might these questions together, set in the context of other studies of the period, indicate about social structure and community identity in the Neolithic?		

6.2 Data formation and validation

The samples of El Kham points from WF16, Dhra' and Netiv Hagdud used in this research were not raw data but had already been assessed and used in different ways (detailed in Table 5.4). This section sets out the further steps taken to validate and manipulate the samples employed before analysis. In general, analysis was undertaken on complete points to enable comparison of consistent attributes. So incomplete points were removed from the WF16a, b and Dhra' samples, which was straightforward as this was detailed in sample data spreadsheets. For the WF16a and Dhra' samples the spreadsheet containing the sample data was reconciled back to summary tables in Smith (2005) which are drawn on in certain cases, allowing slightly larger samples sizes for some metrics by including incomplete points, while still ensuring a like for like comparison.

The WF16b sample comes from the potentially less scrutinised or validated source of a current dissertation (Collier, in prep.), so a detailed comparison with WF16a was undertaken. Figure 6.2 is a scatterplot of width by length for the two samples, which shows a fairly even distribution for both across the graph. Length and width correlate well, with the WF16b sample showing a higher coefficient of determination (R^2). WF16b data is in whole millimetres which creates a little lumpiness in the results seen in the width measures in Figure 6.2. In particular for the thickness measures, because they are so small, granularity is lost and comparison becomes less meaningful. This can also be seen in Table 6.1 where all measures show a remarkable consistency between the two samples, apart from on thickness (although the means are still close).

Figure 6.2: Grouped scatter of length by width for WF16a and b samples of complete points, showing a similar distribution.

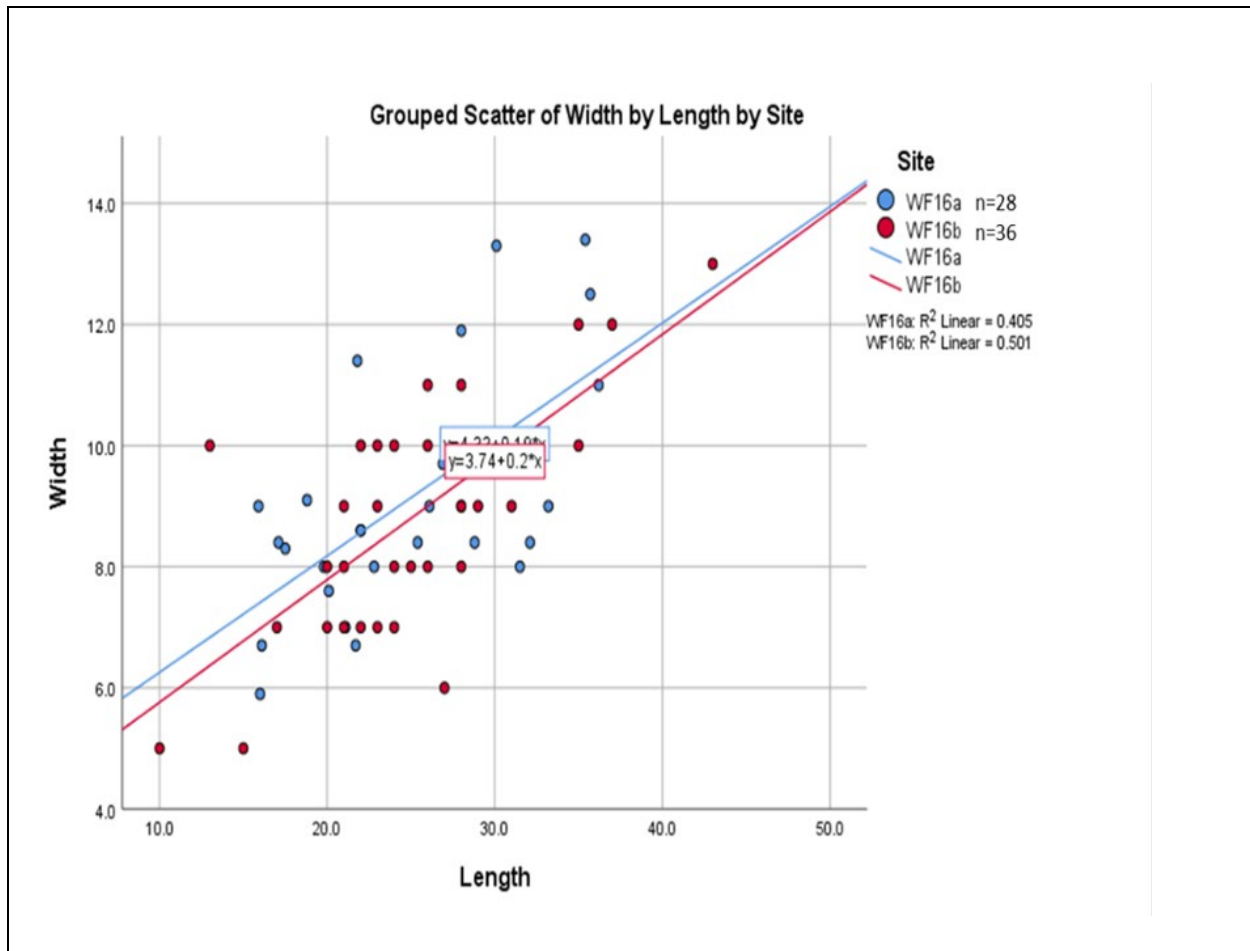


Table 6.1: Mean, standard deviation and coefficient of variation across metrics for complete points from the WF16a and b samples, showing consistency between them.

Sample	Measure	Base(retouched)				
		Overall			Width	Thickness
		Length	Width	Thickness		
WF16a	Sample size	28	28	28	40	40
	Mean	25.01	9.14	2.21	8.63	1.51
	s.d.	6.41	1.93	0.51	1.72	0.47
	CV	25.63	21.12	23.08	19.93	31.13
WF16b	Sample size	36	36	36	29	29
	Mean	25.31	8.86	2.22	8.59	1.66
	s.d.	6.53	1.87	0.72	1.70	0.61
	CV	25.82	21.10	32.47	19.81	37.09
Units in mm.						
Note: WF16a Base (retouched) sample size larger as it includes incomplete points .						

Comparison of the morphological and retouch attributes used by Smith (2005) again show strong consistency between the two WF16 samples, although couze only is more predominant as base retouch in the WF16b sample (Appendix 2). There is a marked contrast in attributes between WF16 and those from the other two sites which is explored later in phylogenetic analysis (Table 7.3). These findings allow the two WF16 samples to be treated as one for aspects of the subsequent analysis. It also provides useful supporting evidence of the attributes from Smith (2005), given that much of the analysis in this research hinges on the difference between WF16 attributes and those of other sites.

For the Netiv Hagdud sample, data was extracted directly from Appendices and Figures in the published source (Nadel, 1997). Those points classed as complete and also those with 1-2mm missing from the tip (Nadel, 1997, p.136, break type 'a') were included to ensure a reasonable sample size and as means and standard deviations were provided by the authors for the complete plus 'a' category. Small tip losses and use wear mean exact distinctions may be spurious but nevertheless this is a compromise that is considered in the analysis of results. Points classified as 'El Khiam?' (meaning some uncertainty), were also excluded. Table 6.2 summarises how the samples and sub samples created relate to the original source samples, and how they are used in the analysis.

Table 6.2: How samples and sub-samples are related to the total of El Khiam points classified and used throughout the analysis.

Samples	WF16a	WF16b	Dhra'	Netiv Hagdud
Samples extracted (Table 5.4)	57	69	65	55
Complete points (used in descriptive and variation analysis)	28	36	32	25/26 (Note 1)
	64			
Complete and retouched points only (unretouched points removed)	20	29	20	-
Phylogenetic analysis sample	20	-	19 (Duplicate removed)	15 (Note 2)

Note 1: In one case data is missing for width.

Note 2: Points analysed from images and reconciled back to complete point data, excluding any unretouched ones (see 6.5.4).

6.3 Descriptive analysis

Descriptive analysis forms Stage 1 of the analysis with the aim of introducing the El Khiam point samples through graphical depiction of the metrical attributes of the points using scatterplots and discriminant analysis. Scatterplots simply display the complete point sample dimensions to show within and between site variation. Discriminant analysis is a classificatory technique which has been used in archaeological contexts to look at the extent metrical characters group or classify artefacts, for example points into assemblages (Edinborough, 2005) and Acheulean handaxes into regions (Lycett and Gowlett, 2008). The requirements and process of discriminant analysis give rise to a range of statistical analyses and results that add to the descriptive analysis of the three assemblages as well as results that can be used in subsequent analysis.

Metrics available for discriminant analysis were limited by the Netiv Hagdud data to length, width and thickness measures. The length width (L/W) and thickness length (T/L) ratios were added to extend this while also inevitably adding an element of duplication. L/W is a measure used in other archaeological studies of points (Goring-Morris, 1987; O'Brien et al., 2001). T/L was assessed as the best predictor of point durability in an experimental study of arrow head points (Cheshier and Kelly, 2006).

Size adjustment is seen as an important step in both discriminant and phylogenetic analyses to address the issue of absolute size differences biasing the results (Buchanan and Collard, 2007; Cardillo and Alberti, 2015; Lycett and Gowlett, 2008). Without size adjustment some of the patterns found in analysis may largely reflect differences in raw material rather than more socially transmitted 'shape'. Although points from all three sites were made from different types of flint (Nadel, 1997; Smith, 2005), Dhra' points are generally larger than those from the other two sites and there is evidence that Dhra' points were made from larger cores compared with other Neolithic sites (Goodale et al., 2007). On the other hand there is no correlation between the type of flint and the size of El Khiam points at Netiv Hagdud (Nadel, 1997).

Size adjustment of the five metrical attributes was undertaken using the geometric mean method. This, like the arithmetic mean, is a measure of central tendency which has the effect of equalising volumes in a sample giving a scale-free measure (Jungers et al., 1995; Lycett et al., 2006). It is a formula provided in excel spreadsheets, facilitating calculation. Each attribute measure is divided in turn by the geometric mean of all the variables for each point. While smoothing the differences between raw attribute measures, it remains a question whether geometric conversion fully adjusts for raw material bias. It has been challenged as an approach by some (Buchanan and Collard, 2007). Particularly given

the limited metrics available it seems unlikely that size and shape factors can be fully separated and accounted for in this way. This is partly why discriminant analysis is used here as a descriptive technique, while the coefficient of variation explicitly allows for inter sample comparison (Section 4.4.1), and the morphological and retouch attributes used in the phylogenetic analysis are not linked to raw material qualities (Smith, 2005). Discriminant analysis is conventionally used as a follow on once multivariate analysis of variance has shown that the groups (sites) differ significantly on a combination of the metrics in order to explore where the differences lie (Field, 2018). In this case test statistics from multivariate analysis showed a significant result for the geomean adjusted metrics (Appendix 3), confirming discriminant analysis was appropriate.

6.4 Variation analysis

Variation analysis is a relatively simple technique requiring a set of sample attribute measurements for which the mean and standard deviation can be calculated. The coefficient of variation (CV) is simply calculated by dividing the standard deviation by the mean *100. Given the site and sample size numbers all of these measures were relatively easily calculated in Excel. WF16a, Dhra' and Netiv Hagdud data sources included standard deviations in data tables so these were compared to Excel calculations as a validation check. Analysis based on the mean and standard deviation implies a reasonably, or nearly, normal distribution in the samples. Normality was tested for all five measures of length, width, thickness, L/W and T/L across the three samples (size = 25, 32 and 64, Table 6.2). The null hypothesis of non-normality was rejected in all cases (Shapiro-Wilk > 0.05), except for thickness and T/L of WF16, T/L for Dhra' and L/W for Netiv Hagdud (Details and boxplots are at Appendix 4). The issue with the thickness metric of the WF16 sample is related to the lumpiness of the whole unit measurements of the WF16b sample, because WF16a on its own did not show the same result. Boxplots of the three main measures of length, width and thickness also support an assessment of normality. They show a few more outlying metrics but these were not removed to try and improve statistical results because there was no rationale to do so, especially given this is not raw data. These outliers might represent errors but more likely represent real more extreme values. Overall, the samples data is sufficiently normal for the use of CV analysis, but throughout the variation analysis more reliance is placed on measures relating to length and width and to some extent L/W.

A further source of data is introduced in variation analysis through comparison of the three subject sites with points from Harifian assemblages in the Negev, in order to explore the potential of linkages proposed between the Harifian and WF16 (Finlayson et al., 2011). Metrical data on Harifian assemblages was extracted directly from tables in the published source (Goring-Morris, 1987), and are detailed in Appendix 5.

6.5 Phylogenetic analysis

Phylogenetic analysis is a more complex technique than variation analysis and requires a number of steps to be completed before analysis can be undertaken. The relatedness of El Khiam points across the region more broadly is generally assumed or at least considered likely, which makes them a suitable case for phylogenetic analysis. Simultaneous emergence or convergent evolution of El Khiam points seem improbable (although the variation within the overall form might well be). The starting point was developing the morphological and retouch attributes used by Smith (2005) into characters for phylogenetic analysis, given that they had already provided a basis for discriminating between the El Khiam points at Wf16 and Dhra'. Following character development, taxon definition and outgroup selection need to be considered.

6.5.1 Point characters and character states

A review of phylogenetic studies of points was used to identify common approaches and rationale for point characters and character states (Table 6.3). Comparison with the morphological and retouch attributes used by Smith (2005) which are focussed on the working edges and hafted elements of points, showed some areas of commonality such as base and tip shape but the more granular level of retouch attributes does not appear to have been applied before. The rationale for character selection in phylogenetic studies of points is to create point classes that reflected variation due to transmission mechanisms, rather than other processes, such as lithic re-sharpening (Edinborough, 2005). This was not the original purpose of the attributes selected by Smith (2005), but nevertheless they appear in principle to be very suitable as markers of such mechanisms.

Table 6.3: Examples of character systems from phylogenetic studies of points used to identify common approaches and rationale.

Study	Character system
O'Brien et al., (2001, 2014)	Size and shape of points, for example location of maximum blade width, with a focus on hafting, for example tang features. Eight characters with 1-2 to 1-6 states.
Prentiss et al., (2016)	A larger number of characters (25) with a more binary approach to character states i.e. has or has not a given blade length range or point angle.
Buchanan and Collard, (2007)	11 morphometric characters using precise measurement techniques and 4 qualitative characters seen as important by O'Brien et al. (2001) which were base shape, outer tang angle, tang tip shape and fluting.
Cardillo and Alberti, (2015).	6 discrete and 5 morphometric continuous characters, including base shape and shoulder type, and length and width.

A mix of morphological and metrical attributes is commonly applied and seen as useful in achieving well resolved phylogenies (Cardillo and Alberti, 2015). Also it was useful to add metrical attributes to the morphological and retouch attributes used by Smith (2005) to increase the number of characters in total. As mentioned, size adjustment is an important step in phylogenetic analyses to address the issue of absolute size differences biasing the results. Ratios are also used to avoid direct measurement (Buchanan and Collard, 2007; O'Brien et al, 2001). Morphometric approaches, using for example computerised landmark measurements, were not practical given the data available on the Netiv Hagdud points, so geometric mean adjusted ratios of L/W and T/L were applied. L/W is used in phylogenetic analysis of points by O'Brien et al., (2001, 2014) and considered as an indicator of aerodynamic properties in relation to metrical analysis of Harifian points (Goring Morris, 1987); T/L as mentioned above is seen as a predictor of point durability (Cheshier and Kelly, 2006) and emerged as an important factor in the discriminant analysis (Section 7.2.2). The characters and character states developed for the phylogenetic analysis are shown in Table 6.4.

Table 6.4: Characters and character states developed for the phylogenetic analysis.

Character no.	Description	Character State	Explanation
1	Base shape	1. concave 2. straight 3. irregular 4. other	The shape of the base of the point. For example in Figure 1.1 the base shape of the point on the left is concave and the one on the right is straight.
2	Base retouch	1. direct 2. inverse 3. bifacial 4. only couze 5. other	Base retouch is the reworking of the dorsal face of the point which is conventionally the primary view of the point (showing direct retouch), ventral face (inverse retouch) or both faces (bifacial). Only couze retouch essentially just thins the base.
3	Tip delineation	1. convergent 2. shouldered 3. other	Tip delineation is the shape of the tip which is either more pointed (convergent) or with a more shouldered shape.
4	Tip retouch	1. direct 2. inverse 3. alternate 4. other	Tip retouch is like base retouch, reworking of the dorsal or ventral faces (Figure 5.3a). Alternate is where one side of the point is reworked on the dorsal face and the other on the ventral.
5	Notch type	1. retouch 2. snap 3. other	Snap notch is where a single blow creates a simple irregular notch, while retouch notch involves more removal and reworking creating a larger regular notch (Figure 5.3b).
6	Notch direction	1. direct 2. inverse 3. bifacial 4. alternate 5. other	Notch direction is like base or tip retouch, focussing on which faces the snap or retouch has been undertaken.
7	Geomean adjusted length to width ratio	1. 0.68 – 0.82 2. 0.83 – 0.97 3. 0.98 – 1.12 4. 1.23 – 1.27 5. 1.28 – 1.43 6. 1.43 – 1.57	n/a
8	Geomean adjusted thickness to length ratio	1. < 0.20 2. 0.021 – 0.028 3. 0.029 – 0.035 4. 0.036 – 0.042 5. 0.043 – 0.049 6. 0.050 – 0.056	

6.5.2 Taxon definition

Phylogenetic studies of points use different approaches to create the taxon or unit of analysis (Section 4.5.2). A variety of approaches were trialled including classes and sampling but in practice mainly individual points were used as taxa. The classification approach used in O’Brien et al., (2001, 2014)

involved creating character strings (e.g. of eight numbers with different character states like those in Table 6.4) and then identifying duplicates to create 'classes' which are therefore in principle not typology based. In this case only one duplicate was identified across 55 points (whether analysed using just the morphological and retouch characters or all eight). So although an objective of the analysis was to see how point characters related and behaved in relation to their sites of origin, analysis of the point strings and repeated trials of phylogenetic analysis showed remarkable uniqueness of individual points. Individual points, or a sample of them, did not readily appear to be representative, or capture the diversity of the population of points. Using individual points provides a very granular level of analysis that is true to the data but creates a more complex phylogenetic analysis to undertake and to interpret, particularly in relation to the analysis of character changes or 'evolution' of character states.

6.5.3 Outgroup selection

The outgroup is usually an older ancestor or close relative of the group, the artefact that deviated earliest, but selection can be difficult and introduces a certain circularity to the process (Cardillo and Alberti, 2015; O'Brien et al., 2001). There is no obvious outgroup for this taxa set as the El Khiam point emerged, seemingly as a new and different point type, without any clear origin (paragraph 5.3). Harifian points are very dissimilar in terms of the morphological and retouch attributes under analysis here. A hypothetical outgroup taxa with attributes of an early WF16 form was mainly used in analysis, based on discussion with Sam Smith (April 2020). In addition a typical or 'archetypal' attributes outgroup was also trialled, and a neutral, all 'other' character states outgroup was used as a control to provide results with a non WF16 based outgroup. The character states for these three outgroups are shown in Table 6.5. The 'archetypal' outgroup produced similar results to the early form one, demonstrated through examples at Appendices 6 and 13. Importantly, the neutral outgroup also produced results that were not dissimilar, providing additional support for the directionality of the phylogenetic analysis (Appendix 7). Focal taxa (i.e. actual points) were also trialled. WF16 actual points gave similar results as well as some of the Dhra' ones. However, equally, some Netiv Hagdud points and Dhra' shouldered ones tended to reverse the polarity/direction of the tree. Given the lack of a clear outgroup the use of these WF16 based solutions are predicated on the fact that WF16 has the earliest dates of the three sites (Section 5.4).

Table 6.5: Outgroups used for phylogenetic analysis showing two WF16 attribute based outgroups and one neutral outgroup using ‘other’ as the character state. Given there were no appropriate measurements for these hypothetical outgroups, L/W and T/L were designated as a question mark in the character string used.

Character	WF16 early form attributes	WF16 typical or ‘archetypal’ attributes	Neutral (all ‘other’)
1. Base shape	Straight	Straight	Other
2. Base retouch	Other	Direct	Other
3. Tip delineation	Convergent	Convergent	Other
4. Tip retouch	Inverse	Inverse	Other
5. Notch type	Snap	Snap	Other
6. Notch direction	Other	Bifacial	Other
7&8. L/W and T/L	No measurements	No measurements	No measurements
String	251225??	211223??	453435??

6.5.4 Matrices of taxa and characters

To create matrices of taxa, unretouched points and those with no notch data were removed from the WF16a and Dhra’ samples applied to the descriptive and variation analyses above. WF16b points were not included in this stage as WF16a data is considered more robust, and to keep the numbers of taxa down. Sample size issues do not apply here as each point is a valid separate taxa in phylogenetic analysis. So unretouched points were removed to help reduce and simplify the analysis and based on the findings (Section 7.3.1) that unretouched points are less constrained, which is potentially relevant to transmission. This left 39 points, 20 from WF16 and 19 from Dhra’ once the duplicate was removed (D2x in analysis). Netiv Hagdud characters were analysed from scale drawings in Nadel (1997). This was undertaken and compared to an independent analysis by Sam Smith, with very consistent results. Unretouched cases or ones with several missing characters were excluded, although in a few cases, where there were only one or two ambiguous or unusual characters not in the character system, a question mark was used. The scale drawings were not cross referenced to the tabulated measurements in Nadel (1997) that were used in variation analysis, so for the metric characters, approximate measurements using the scale drawings were used to match points to the more accurate tabulated data. This left 15 Netiv Hagdud points to add to the analysis (Table 6.2). From the total of

54 points, matrices of the taxa and characters, unweighted, were created for analysis (Appendix 8 details the steps in matrix creation).

6.5.6 Phylogenetic software

There are many different phylogenetic software programmes, but for standard cultural phylogenetic approaches and particularly those focussed on points, parsimony algorithms predominate. This is because these studies are generally concerned with investigating hypotheses underpinned by the idea of descent with modification in the artefact. PAUP* and TNT (Trees for New Technology) are both programmes commonly used for cultural phylogenetics. For smaller numbers of taxa (below 20-30 taxa), a 'branch and bound' or implicit enumeration search can be undertaken which ensures that all trees optimal under the parameters set will be found. Branch and bound searches operate through only checking the trees that are likely to be the shortest. For larger taxa numbers heuristic ("trial-and-error") methods are required (Buchanan and Collard, 2007; Cardillo and Alberti, 2015; Goloboff et al., 2008; O'Brien et al., 2001; Tripp, 2016).

In this research TNT was used to generate phylogenetic trees as it is a programme solely designed for maximum parsimony analysis. Various parameters were explored within heuristic 'Traditional' and 'New Technology' searches such as the number of initial additional sequences and changing the number of trees saved in a replication. The 'New Technology' search tool is for more difficult data sets with special and combined algorithms that seek out a better answer through various shortcutting routes. A general purpose software, Mesquite, was used to create matrices and to analyse the trees produced in TNT as it has useful features for visualizing and editing trees. Therefore matrices were created in Mesquite, exported for running searches in TNT then imported back into Mesquite for analysis and presentation.

6.6 Summary

This Chapter set out the way the samples used in this research, which were all derived from existing studies, were further validated and manipulated to provide a starting point for analysis. The research methodology was set out in three stages covering descriptive, variation and phylogenetic analysis. The stages of analysis build cumulatively, so that elements from each stage are taken forward into the next and the complexity of analysis increases. Phylogenetic analysis is the focus for questions about the origin and spread of the El Kham point and for analysis of attribute changes between sites, while variation analysis is central to the question of social learning environments within sites. All the analysis stages are taken together to explore the broader issue of social structure and community identity in the Neolithic.

Chapter 7. Case study - variation and phylogenetic analysis of El Khiam points

7.1 Introduction

This Chapter presents the analysis of El Khiam points from the three sites of WF16, Dhra' and Netiv Hagdud, examining the issues and research questions raised in Chapter 5, and using the methodology set out in Chapter 6. The analysis involves looking at similarity and difference in attributes of the El Khiam points: similarity through looking at shared, derived characteristics in phylogenetic analysis, focussing on the morphological and retouch attributes used by Smith (2005), and differences through variation analysis of point metrics within and between the three assemblages. The structure of the analysis is in three stages that build on each other as follows:

1. Descriptive analysis
2. Variation analysis
3. Phylogenetic analysis

7.2 Descriptive analysis

This stage is intended to introduce the samples of El Khiam points from WF16, Dhra' and Netiv Hagdud through graphical depiction of within and between site variation using scatterplots and discriminant analysis.

7.2.1 Scatterplots of metrics from the three assemblages

Scatterplots of length width and thickness and correlation across the three assemblages, with WF16 and b samples combined, provide a visual description of within and between assemblage variation (Figures 7.1 and 7.2). The figures show that while the samples intermingle across the graph they are also grouped: Dhra' points are longer and wider while Netiv Hagdud points are shorter, narrower but also thicker, and WF16 points cluster more tightly together. WF16 points correlate better on width/length while Netiv Hagdud ones correlate best on thickness/length. Regression is used here not to imply any causal link but to compare the extent of relatedness between metrics from different assemblages.

Figure 7.1: Grouped scatter of width by length of complete points from the three assemblages showing the overall distribution, and some grouping by site, for example Dhra' points are generally a little bigger, and WF16 points correlate most strongly in terms of width/length.

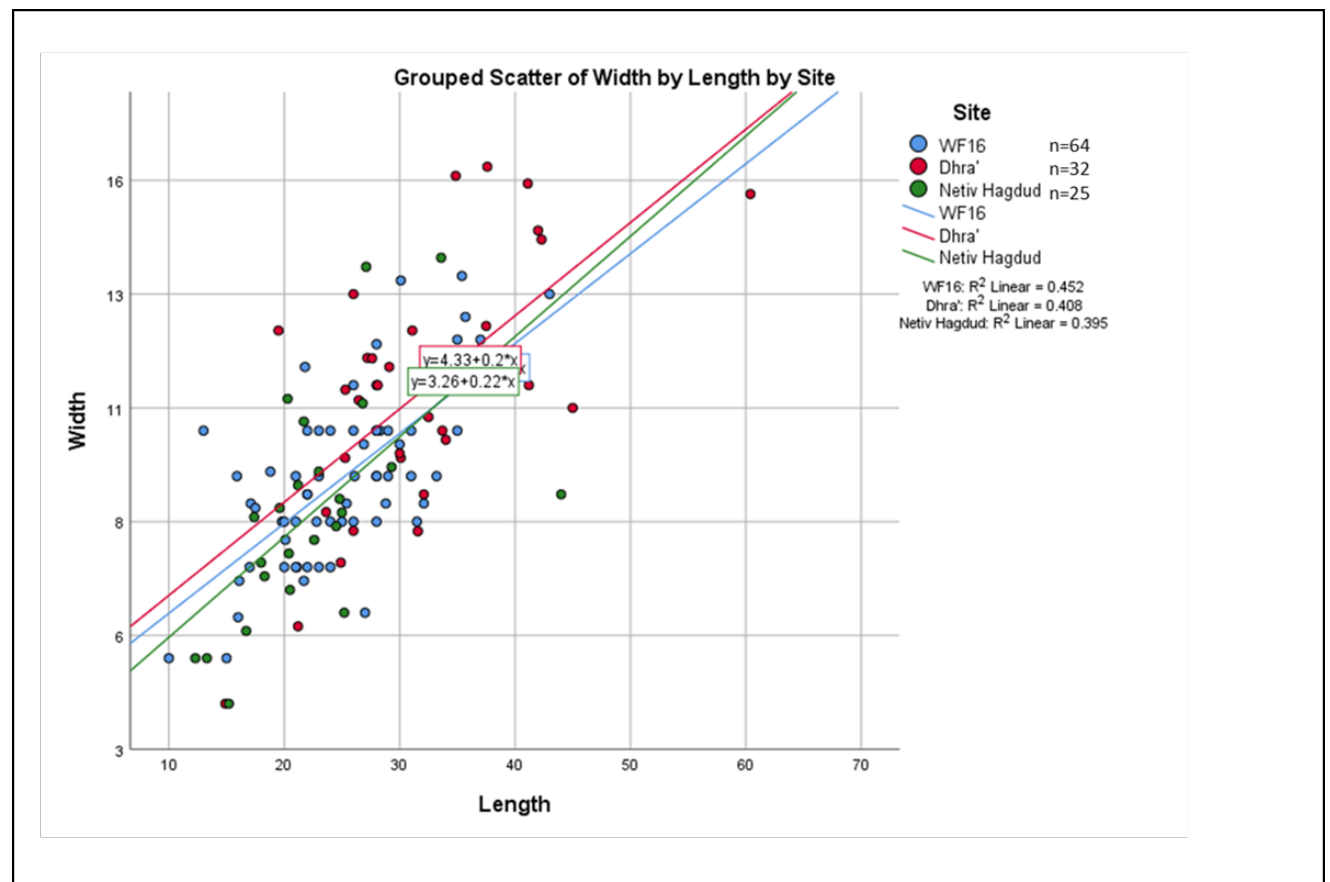
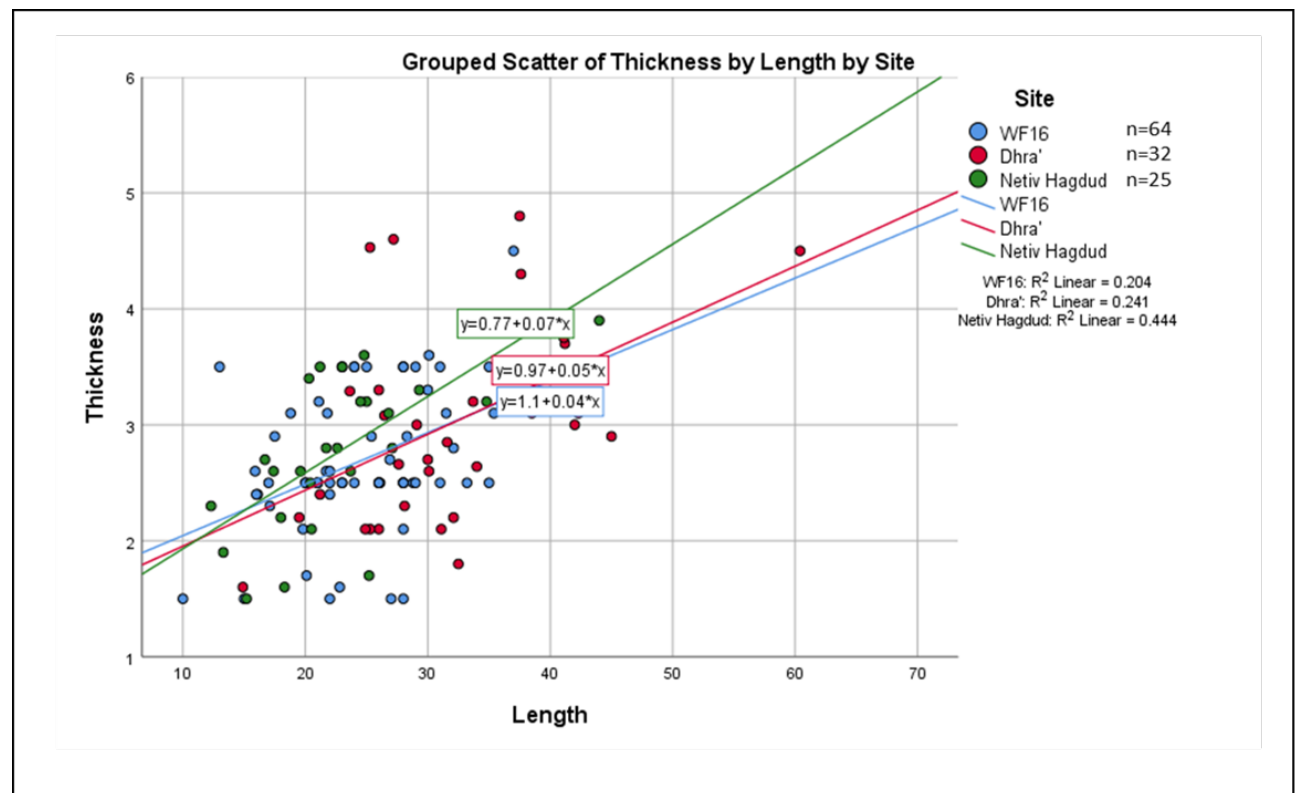


Figure 7.2: Grouped scatter of thickness by length of complete points from the three assemblages showing for example that Netiv Hagdud points are generally shorter and fatter and correlate more strongly on thickness/length, and also shows the effect of the lumpiness in the thickness measures of the WF16b sample.



7.2.2 Discriminant analysis

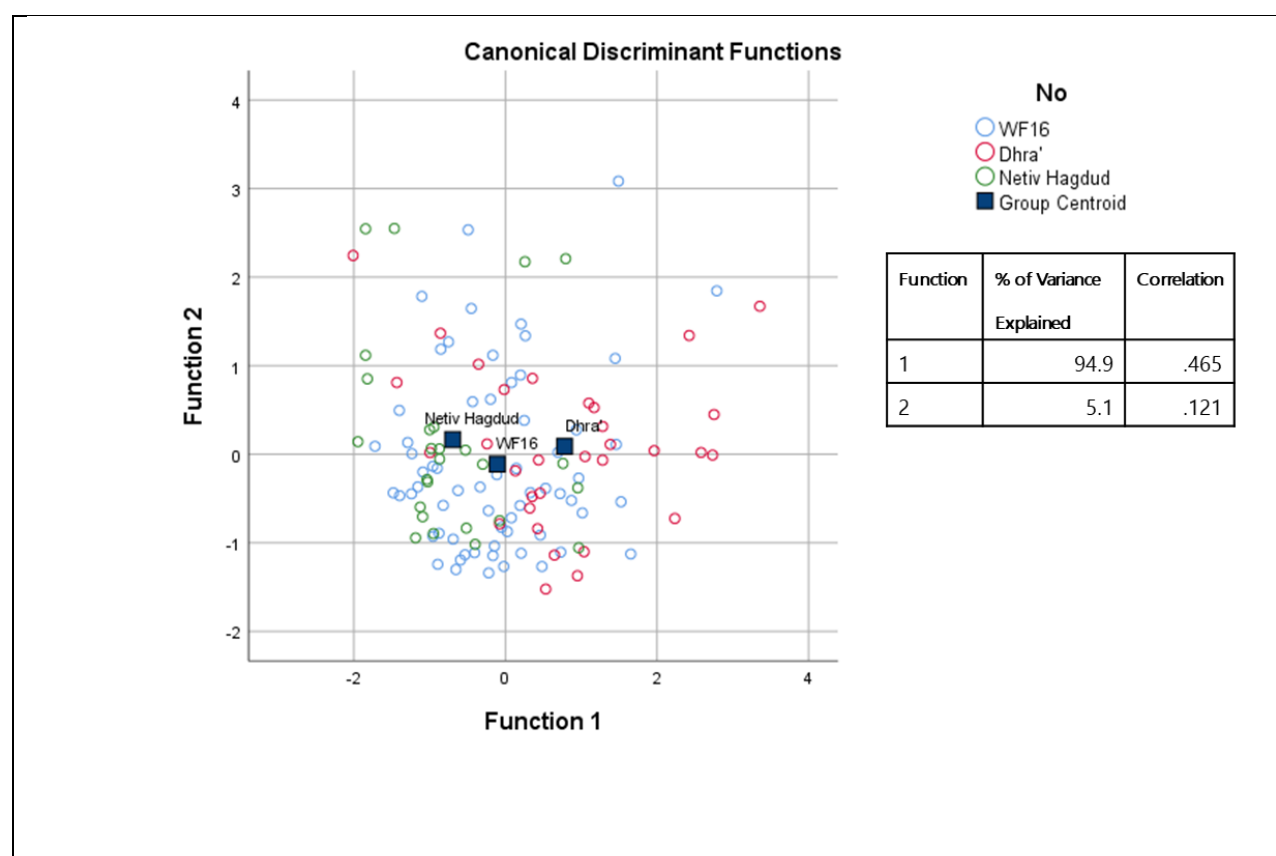
Discriminant analysis is a classificatory technique which is used here to examine and visualise the amount of variation within and between the three sites combining the metrics in one analysis. In conducting discriminant analysis there are also a number of conditions and assumptions not all of which were met in full when all five of the metrical attributes were used. In particular:

- Means of variables should be statistically different between groups (sites). Geometric length, width and T/L means were statistically different but thickness and L/W were not.
- Variables should be normally distributed. Statistical tests and review of histograms and Q-Q plots showed geometric converted length, width and thickness were normally distributed but W/L and T/L were less so. Size adjustment by the geometric mean improved the normality of distributions (and the statistical fit of the results), although not by a great deal.
- Within-group variance-covariance matrices should be equal across groups. This condition was not met when all the variables were included but was met when just length, width and thickness used, giving a not dissimilar overall result (Appendix 9). Similarly there were

indications of multi-collinearity when all variables were included (Variance Inflation Factor (VIF) levels between 4.4 and 8.4 where >5 indicates possible problems and >10 serious problems) but not when just length, width and thickness used (Appendix 9).

However discriminant analysis remains fairly robust when these assumptions are violated, especially when not using the model to make predictions about new cases (Field, 2018). Figure 7.3 shows the result of discriminant analysis for the five metric attributes size adjusted by the geometric method. Length, width and T/L provided the strongest discriminatory factors in the model, in that order. Given that the purpose of discriminant analysis is to maximally separate the groups (i.e. it is looking for the differences) the results show a modest but statistically significant difference between the assemblages (61.5% of cases were correctly classified, Wilks' Lambda = 0.001). Dhra' is more distinct in terms of distance apart, while WF16 points fits the model closer reflecting less variation. Netiv Hagdud seems less distinct as it is closer to WF16 but also points do not fit the model so well, although they discriminate better on thickness. Overall the descriptive analysis suggests that points group moderately together by site while overlapping significantly into a wider single regional distribution. Given the variation in the points within assemblages, the patterning between sites, while modest, still seems remarkable.

Figure 7.3: Discriminant analysis of five metric attributes size adjusted by the geometric method using complete points from the three assemblages, showing the discrimination between the sites resulting from the analysis model.



7.3 Variation analysis

In this stage the focus is on analysis within and between the assemblages using the coefficient of variation (CV) and approaches based on using CV (Section 4.4.1).

7.3.1 Comparison of WF16 and Dhra' points

The initial step is a comparison of mean, standard deviation and CV across metrics for WF16a and Dhra' samples (Table 7.1). WF16a only is used here because this avoids distortions due to the thickness measurement issues with the WF16b sample (Section 6.2) and because these two samples were collected on a particularly consistent basis (Smith, 2005).

Table 7.1: Comparison of the mean, standard deviation and coefficient of variation across metrics for WF16a and Dhra' samples showing higher variation in the Dhra' metrics.

Sample	Measure	Overall			Tip		Base			
		Length	Width	Thickness	Width	Thickness	Retouched		Unretouched	
							Width	Thickness	Width	Thickness
WF16a	Sample size	28	28	28	32	32	40	40	8	8
	Mean	25.01	9.14	2.21	0.9	0.78	8.63	1.51	7.84	1.73
	s.d.	6.41	1.93	0.51	0.65	0.49	1.72	0.47	2.22	0.68
	CV	25.63	21.12	23.08	72.22	62.82	19.93	31.13	28.32	39.31
Dhra'	Sample size	32	32	32	42	42	41	41	10	10
	Mean	31.9	10.87	2.51	0.72	0.76	8.99	1.79	10.17	1.83
	s.d.	8.84	2.84	0.87	0.53	0.56	1.89	0.67	2.55	0.87
	CV	27.71	26.13	34.66	73.61	73.68	21.06	37.65	25.11	47.23

Source: Smith (2005). Units in mm.

Note: Sample sizes for tip and base differ to overall as the measures are taken directly from tables in Smith (2005).

The comparison indicates the following:

- There is consistently higher variation within the Dhra' sample compared to WF16a across all the measures (except unretouched width). The results suggest tighter constraints, such as more consistent transmission, over the manufacture of points at WF16.
- The number of people making an item can also be a factor. Items made by just a few people are more standardised than where large groups of people are involved. Here the subsets of people within each group/site can be hypothesised as having been at a similar scale (Table 5.2). It is very unlikely that all the points were made by just a very few people given they are sampled across sites with durations of hundreds of years.

- There is generally a middle range of CV, compared to the standard proposed by Eerkens and Bettinger (2001) of between 1.7 and 57.7 (Section 4.4.1). Tip thickness and width are the exception, with very high CVs above the 'random' measure, suggesting that in manufacture or measurement variations are not perceptible or accurate because the differences are so small when mean tip width and thickness are less than 1mm.
- Width (overall and retouched base) is the most constrained measure, likely reflecting important functional constraints, related to hafting for example.
- Retouched bases are significantly more constrained than unretouched ones, which might be expected if retouch is a stage in the process of manufacture. However, this may not necessarily be the case (Nadel, 1997; Smith, 2005). The sample sizes for the unretouched points are small, although if combined they would still support the finding of showing less constraint than retouched ones.

7.3.2 Comparison of points across all three assemblages

The limited metrics available from Netiv Hagdud means the comparison across all three assemblages is just on overall length, width and thickness with L/W and T/L added (Table 7.2).

Table 7.2: Comparison of the mean, standard deviation and coefficient of variation across complete points from the three assemblages showing a general pattern of increasing CV from WF16, through Dhra' to Netiv Hagdud.

Site	Measure	Overall			L/W	T/L
		Length	Width	Thickness		
WF16	Sample size	64	64	64	64	64
combined	Mean	25.18	8.98	2.22	2.82	0.09
	s.d.	6.43	1.89	0.63	0.55	0.03
	CV	25.53	21.02	28.50	19.58	30.41
	WF16a CV			23.08		27.07
Dhra'	Sample size	32	32	32	32	32
	Mean	31.9	10.87	2.51	3.01	0.08
	s.d.	8.84	2.84	0.87	0.65	0.03
	CV	27.71	26.13	34.66	21.63	33.39
Netiv Hagdud	Sample size	26	25	26	25	26
	Mean	23.05	8.33	2.29	2.84	0.10
	s.d.	6.94	2.48	0.68	0.71	0.03
	CV	30.11	29.77	29.69	24.90	25.15
Combined three assemblages	CV	29.88	26.39	31.02	21.34	30.86
<i>Units in mm.</i>						

The comparison indicates the following:

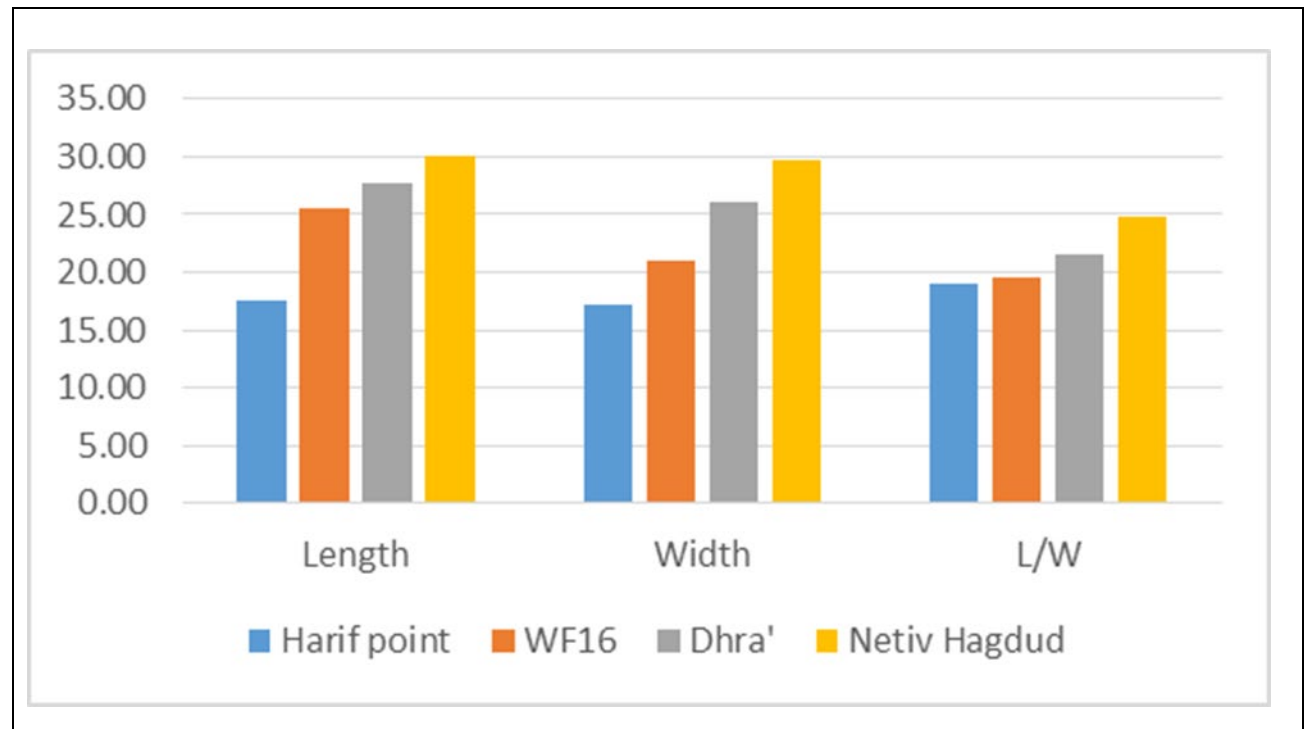
- While the means reflect the findings of the descriptive analysis with Dhra' points larger, Netiv Hagdud ones smaller and WF16 in the middle, the increasing CVs show a pattern of decreasing constraint from WF16, through Dhra' to Netiv Hagdud.
- The exception is on thickness, where WF16 is still the most constrained, but Netiv Hagdud has a lower CV than Dhra'. Interestingly, points at Netiv Hagdud are thicker compared to their overall size than at the other two sites and this metric is also more constrained. WF16a sample CVs on thickness are added in Table 7.2 for comparison because of the measurement issue with thickness for the WF16b sample, but irrespective, for the T/L metric Netiv Hagdud has a lower CV than at the other two sites.
- It is possible that the Netiv Hagdud points in the sample missing the top 1-2mm skew the results for length, but it is worth noting that the CV for width and thickness are very similar to that for length, but slightly higher as seems to be a pattern across assemblages.
- The analysis shows the benefit of using CV as the comparative indicator. Although the Dhra' sample generally has higher standard deviations, it has lower CVs than Netiv Hagdud for 3/5 metrics. Mean and standard deviation, it is argued, are correlated (Eerkins and Bettinger, 2008) so Dhra's standard deviations are larger just because the sizes are larger. But CV standardises the comparison.
- As CV standardises for size differences, these CV differences are unlikely to be due to raw material issues, and as the subsets of people within each group/site can be hypothesised as having been at a similar scale (Table 5.2) the numbers of people making the points is also unlikely to be a factor. Given functional difference was considered unlikely in the spread of El Khiam points (Section 5.5), social transmission forces seem reasonable to explore further.
- As a control, the overall CV across all three assemblages was calculated and compared to pairings of site CVs. These were consistent with expectations based on the individual site results. For example, the CVs of the WF16/Dhra' pairing are lower than the overall three assemblage CVs except for thickness and T/L, and for the Dhra'/NH pairing CVs are higher than the overall CVs across all measures.

7.3.3 Comparison with Harifian points from the Negev

Comparison of the three assemblages with points from Harifian assemblages in the Negev is interesting in the light of the suggestion of a cultural linkage of the Harifian with WF16 (Finlayson et al., 2011). Harifian assemblages are sometimes seen as best related to the Late Epipalaeolithic, although overlapping with the early Neolithic (Shea, 2013), but arguably largely contemporary to the

early occupation of WF16 (Finlayson et al., 2011). Data on Harifian assemblages (Goring-Morris, 1987), which only included length, width and L/W, was converted into CVs, averaged across 19 assemblages (Appendix 5) and compared with the three case study sites (Figure 7.4).

Figure 7.4: Comparison of the coefficient of variation for length, width and L/W of Harifian points with those from WF16, Dhra' and Netiv Hagdud, showing a pattern of increasing CV.



The comparison indicates there is a consistent pattern of increasing CV (reduced consistency or constraint) from the Negev average, through WF16 and Dhra' to Netiv Hagdud, although there is an overlap in some cases between WF16 and individual Harifian assemblages (Appendix 5). It is interesting that the Harif points appear more rough and ready, less symmetrical, less attractive perhaps, than the El Khiam ones but are actually more constrained in terms of length and width (Figure 5.2). By way of further comparison, an analysis of points from hunter gatherer societies in Southern Scandinavia (Edinburgh, 2005) over the period 10,000 - 6,500 BP shows CVs, (as well as an irregular appearance), similar to those of the Harif points (Appendix 5).

In this case the number of people making the points could well have been a factor. The Harifian sites reflect occupation by mobile hunter gatherer bands which may have been groups of 20-25 (Goring-Morris, 1987) compared to the larger numbers at the case study sites (Table 5.2). There is however a remarkable consistency across the 19 Harifian assemblages, and in many cases high sample sizes (Appendix 5). Again, given the consistent use of sites over a prolonged period, it is unlikely that all the

points were made by the same few people, but were likely made by many different small groups of people.

Goring-Morris (1987) attributed the standardisation in the attributes of Harifian points to the need for control of aerodynamic properties and suggested that the relationship between length and width was a good indicator of this. So alternatively the pattern of reducing constraint across the assemblages might reflect different subsistence strategies. The evidence about subsistence strategies in the three case study sites (Table 5.2) suggests these involved larger scale processing of cereals (particularly so at Netiv Hagdud) compared to the strategies used by the mobile hunter gatherers of the Harifian (Goring-Morris, 1987). Use wear analysis of El Khiam points at WF16 and Dhra' suggests points were used as perforators as much as projectile points at these sites (Smith, 2005). So while recognising that hunting was still important at all the sites, a different mix and balance of subsistence strategies might also account for the pattern of declining constraint. Either or both of these explanations suggest a contrast between more functional requirements in the Negev points with potentially more socially driven variation in the El Khiam ones which will be considered further in Chapter 8.

7.4 Phylogenetic analysis

In this stage the focus is on analysis of the similarity or relatedness of point attributes within and between the assemblages using the methodology outlined in Section 6.5. Analysis was first undertaken using the points from pairs of sites, then all three sites together, and finally the character changes in the trees were examined.

7.4.1 Analysis between pairs of sites

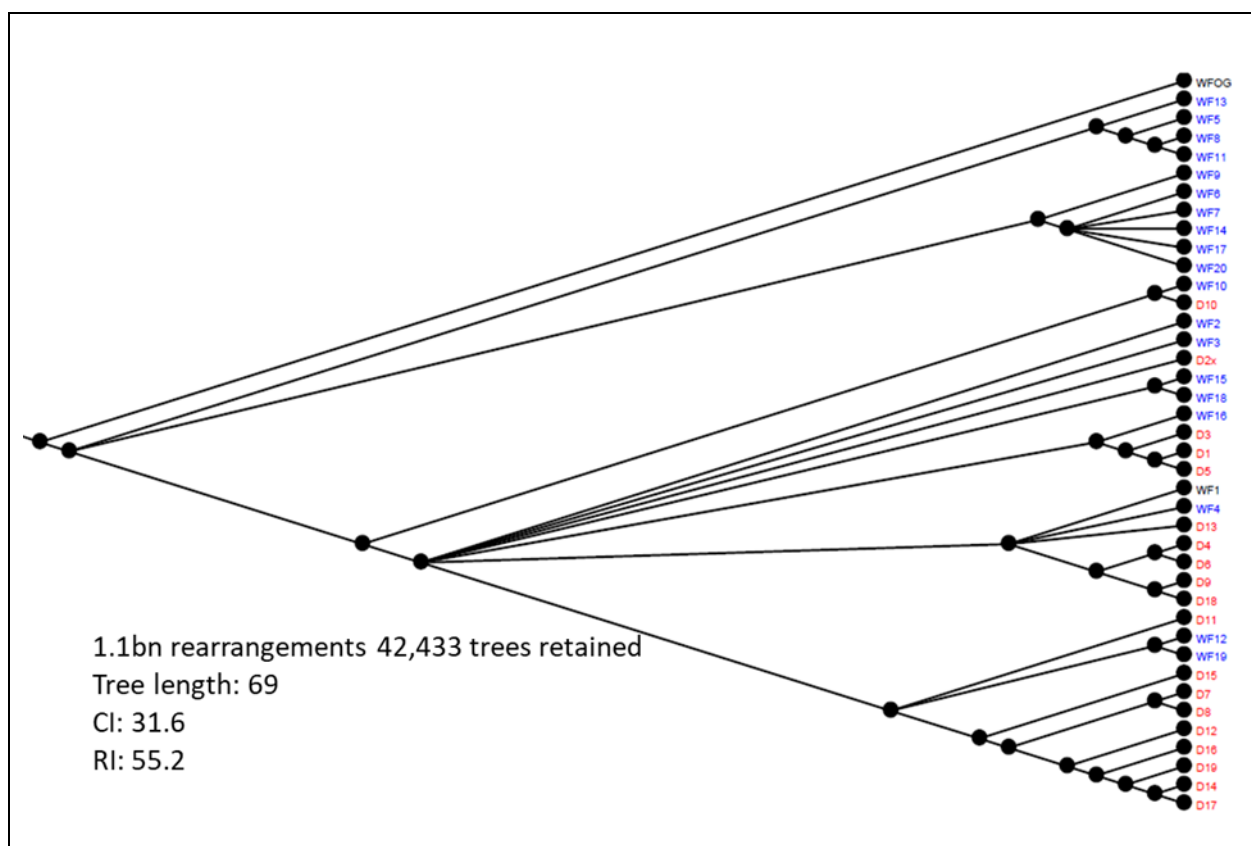
Phylogenetic analysis between each pair of sites was undertaken using the WF16 early form of attributes as the outgroup (Section 6.5.3). The results are shown in Figures 7.5a-c. The trees shown are frequency differences consensus trees which are consensus trees with the most compromise (Section 4.5.3). Consensus trees are used because Traditional TNT searches often produced large numbers of equally parsimonious trees (numbers are shown in each chart); and frequency consensus trees are used because the number of taxa and the resolution of the phylogenies means that clarity and meaning are sometimes lost with stricter consensus trees. However majority rule consensus trees produced similar results in some cases (examples are shown in Appendices 10 and 13).

The Retention Index (RI) for the trees range from 55.2 to 62.0 which compares with the mean RI of 59.0 returned by Collard et al.'s (2006) 21 cultural datasets (Section 4.5.1). This is quite a range, which may partly reflect the different relationships between sites (see below). To provide assurance that

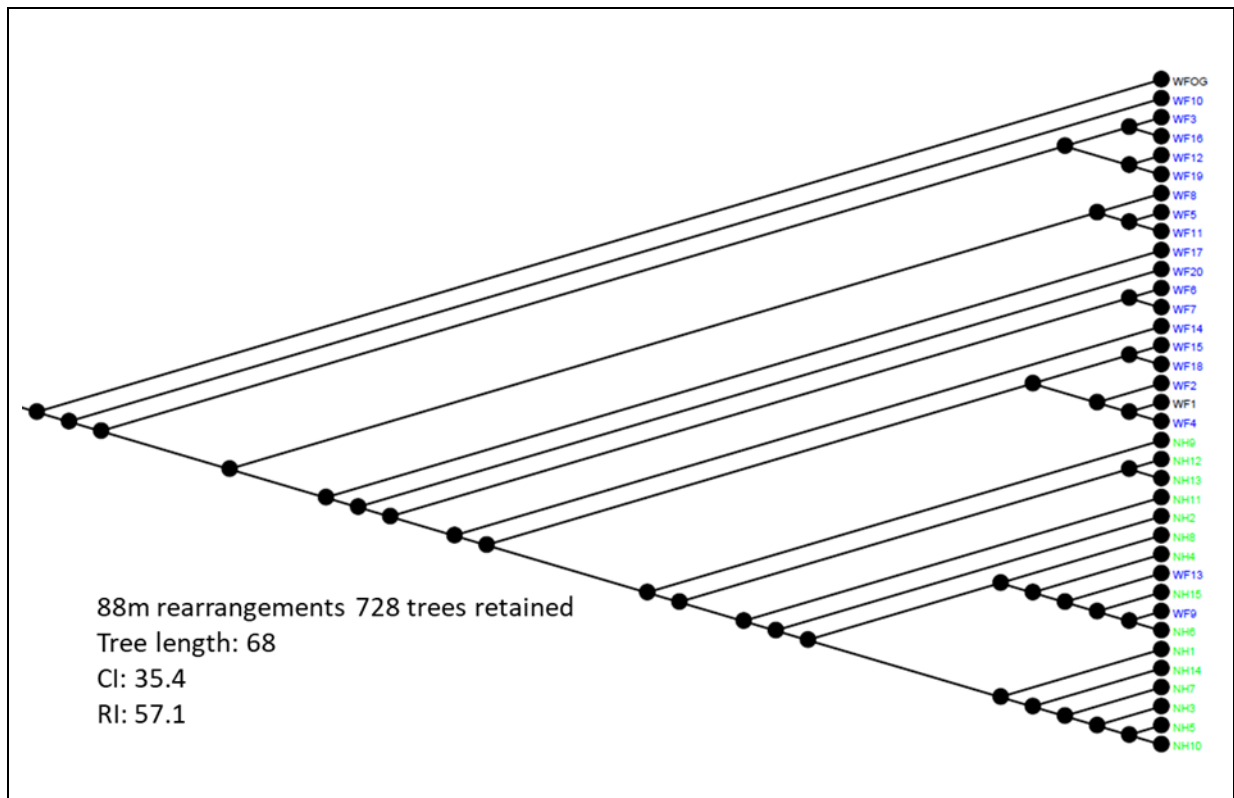
these differences in RI are not significant in terms of how they are used in this analysis, Appendix 6 shows one of five trees from a 'New Technology' search which relates to the same pair (WF16 and Dhra') as the lowest RI of 55.2 reported, but these five all have an RI of 61.2. The majority rule consensus tree for these five has an RI of 57.8 (Appendix 13). Given the consistent outcome from different searches and that the key point of interest is simply the patterning between the points from each site rather than exactly where each point lands, these are very useful results.

Figure 7.5: Frequency differences consensus trees showing the results of phylogenetic analysis of points from pairs of sites using TNT traditional search (6 additional sequences 10,000 trees saved per replication).

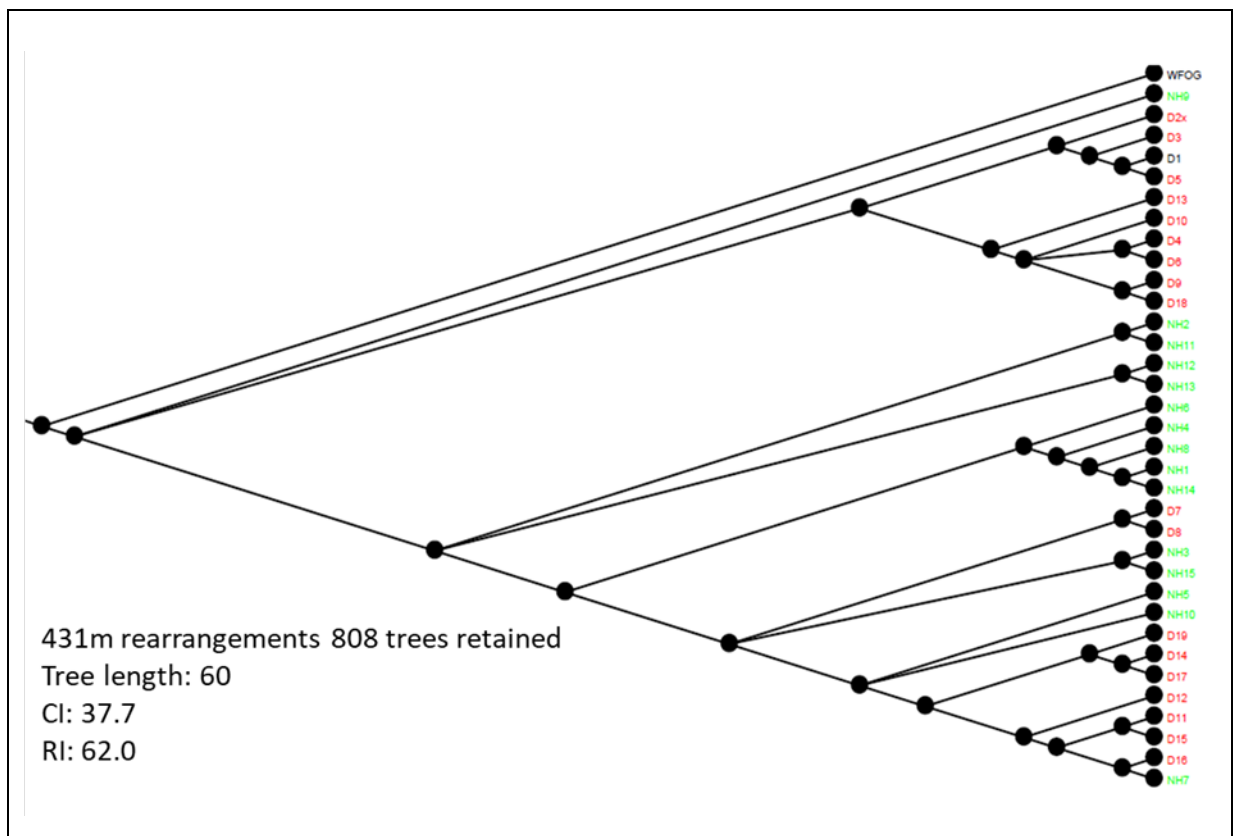
a) WF16 (blue) and Dhra' (red)



b) WF16 (blue) and Netiv Hagdud (green)



c) Dhra' (red) and Netiv Hagdud (green)



The phylogenetic trees indicate the following:

- Taxa positioned next to each other have the closest relationships based on derived character state changes. There is a progression or 'evolution' through character state changes in the taxa from top (at the outgroup) to the bottom of the tree.
- There is a clear pattern of character state changes from WF16 to each of Dhra' and Netiv Hagdud, which seems remarkable given the unique string for each taxa, although the patterning could be anticipated between WF16 and Dhra' given the differences found by Smith (2005).
- There are more complex or ambiguous changes in the WF16 and Dhra' tree compared to the WF16 and Netiv Hagdud one, even taking account of the higher number of taxa involved. This is reflected in the greater mixing, the larger number of less well resolved taxa (polytomies), and also reflected in the number of rearrangements tried and the lower RI.
- The Dhra' and Netiv Hagdud tree shows an interesting pattern with overall a cleaner more resolved tree, with two main clades of Dhra' points either side of most of the Netiv Hagdud points. This will be considered further in the character analysis below.

Overall this supports the analysis in Smith (2005) showing a consistent pattern of different attributes between sites, and extends it to Netiv Hagdud points. The similar results found using the neutral outgroup (Appendix 7) provide additional support to the directionality identified in the analysis. Analysis was also undertaken with the two metrical characters removed (examples at Appendix 11). In summary, similar patterns were created but the consistency of patterning between particularly Netiv Hagdud and Dhra' points was reduced and the maximum number of equally parsimonious trees that can be saved was reached (60,000) suggesting too many alternative ways of ordering the matrix. This indicates that using only six characters is too few for a good phylogenetic analysis, which is why two metrical characters were added, giving eight in total (Section 6.5.1). All of the examples from other studies used at least eight and up to 25 characters (Table 6.3).

7.4.2 Analysis of three sites combined

Phylogenetic analysis was undertaken on points from all three sites with the results shown in Figure 7.6. The RI at 61.9 is a strong result. Again a range of searches and outgroups were used with consistent results.

Figure 7.6: Frequency differences consensus tree showing the results of phylogenetic analysis of points from WF16 (blue), Dhra' (red) and Netiv Hagdud (green) using TNT traditional search (6 additional sequences 10,000 trees saved per replication).



The phylogenetic tree indicates the following:

- The tree looks a little like a blend of the trees from the pairs of sites, which supports the consistency of the results.
- There are a pair of WF16 clades at the top followed by a more mixed Dhra' and WF16 set of clades followed by more tight groupings of Netiv Hagdud and Dhra' points. Overall this provides support for the hypothesis of the spread of El Khiam points from WF16, bearing in mind that any direction shown in the phylogenetic analysis is dependent on the outgroup selection.
- The more mixed Dhra' and WF16 set of clades in the middle of the tree might be interpreted as a phase where WF16 and Dhra' points were closely related followed by more distinct phases of Netiv Hagdud and Dhra' points. There appears a greater distinction between WF16

points and Netiv Hagdud ones suggesting that this was a step or stage further on which implies transmission through or earlier to Dhra' than Netiv Hagdud, although this is more ambiguous.

- The expectation would not anyway be of a linear progression from site to site but a diffusion across the region. In the 10,144 trees that make up the consensus there are many where Netiv Hagdud clades, and the tight clade of Dhra' points at the foot, are further up the tree (while maintaining their clade grouping), so this aspect of the results should be interpreted with some caution.

These results are explored further in the analysis of character changes and the shared, derived characteristics (synapomorphies) that underpin the phylogenies.

7.4.3 Character analysis

The character states for the morphological and retouch characters for each of the sites is summarised in Table 7.3. This shows the combined WF16a and b attributes (Appendix 2 shows the split).

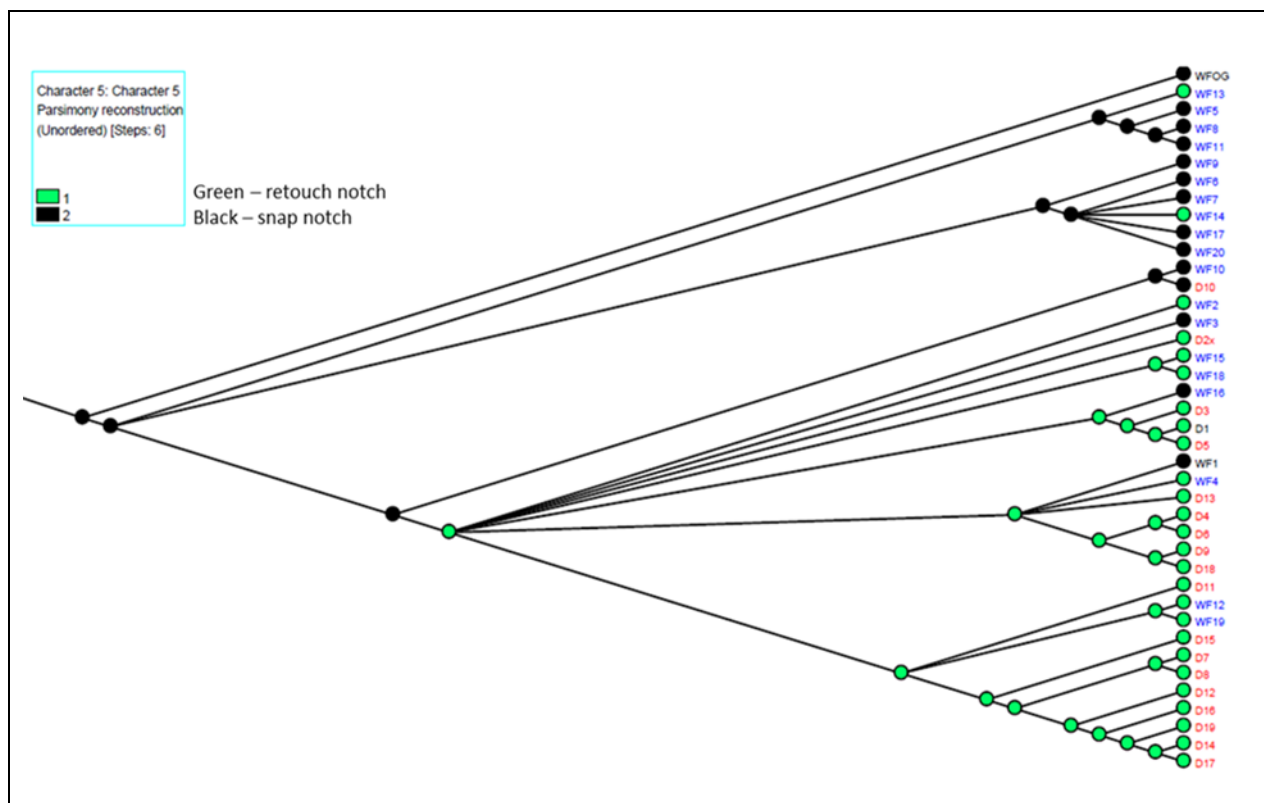
Table 7.3: Analysis of character states for morphological and retouch attributes by site with the predominate mode in bold, showing distinct patterns between sites.

Character	WF16 n=49	Dhra' n=19	Netiv Hagdud n=15
Base shape	Straight 33 Concave 11 Irregular 4 Convex 1	Concave 15 Straight 4	Straight 12 Concave 3
Base retouch	Only couze 25 Direct 14 Bifacial 5 Inverse 5	Direct 13 Bifacial 3 Inverse 2 Only couze 1	Direct 10 Bifacial 3 Only couze 2
Tip delineation	Convergent 40 Hooked 5 Shouldered 4	Convergent 10 Shouldered 9	Convergent 10 Shouldered 5
Tip retouch	Inverse 40 Direct 6 Alternate 2 No retouch 1	Direct 9 Inverse 5 Alternate 5	Direct 12 Bifacial 2 Inverse 1
Notch type	Snap 41 Retouch 8	Retouch 18 Snap 1	Retouch 14 Snap/retouch 1
Notch retouch	Bifacial 36 Inverse 8 Alternate 4 Direct 1	Bifacial 12 Alternate 5 Inverse 1 Direct 1	Direct 7 Bifacial 6 Mixed 2

The table shows the different patterns of point attributes and process of manufacture between the three sites. These patterns are remarkably distinct, with WF16 the most distinctive of the three. These patterns must have remained stable over hundreds of years to be so clear based on samples that are understood to have been taken across site phases. These distinct patterns underpin most of the structuring of the results of the phylogenetic analysis shown in Figures 7.5 and 7.6 above. The pattern of consistency within and change between sites suggests that attribute changes are linked to the way points (and the methods used to make them) were transmitted between sites. Clear phylogenetic results also helps confirm the attributes are not strongly functional (Section 4.5.1).

Phylogenetic analysis provides an ordering and route map through the character changes based on an analysis of shared derived characters and the most parsimonious route through these. The transition in character states in the trees of pairs (Figure 7.5) show a number of clear shifts. For example a shift from snap notch to retouch notch in the WF16 and Dhra' pair (Figure 7.7). There are also notable shifts from early use of couze only base retouch to direct, and from inverse to direct tip retouch.

Figure 7.7: The consensus tree shown in Figure 7.5a (WF16 - blue and Dhra' - red) with the character state for character 5 (black – snap notch, green – retouch notch)

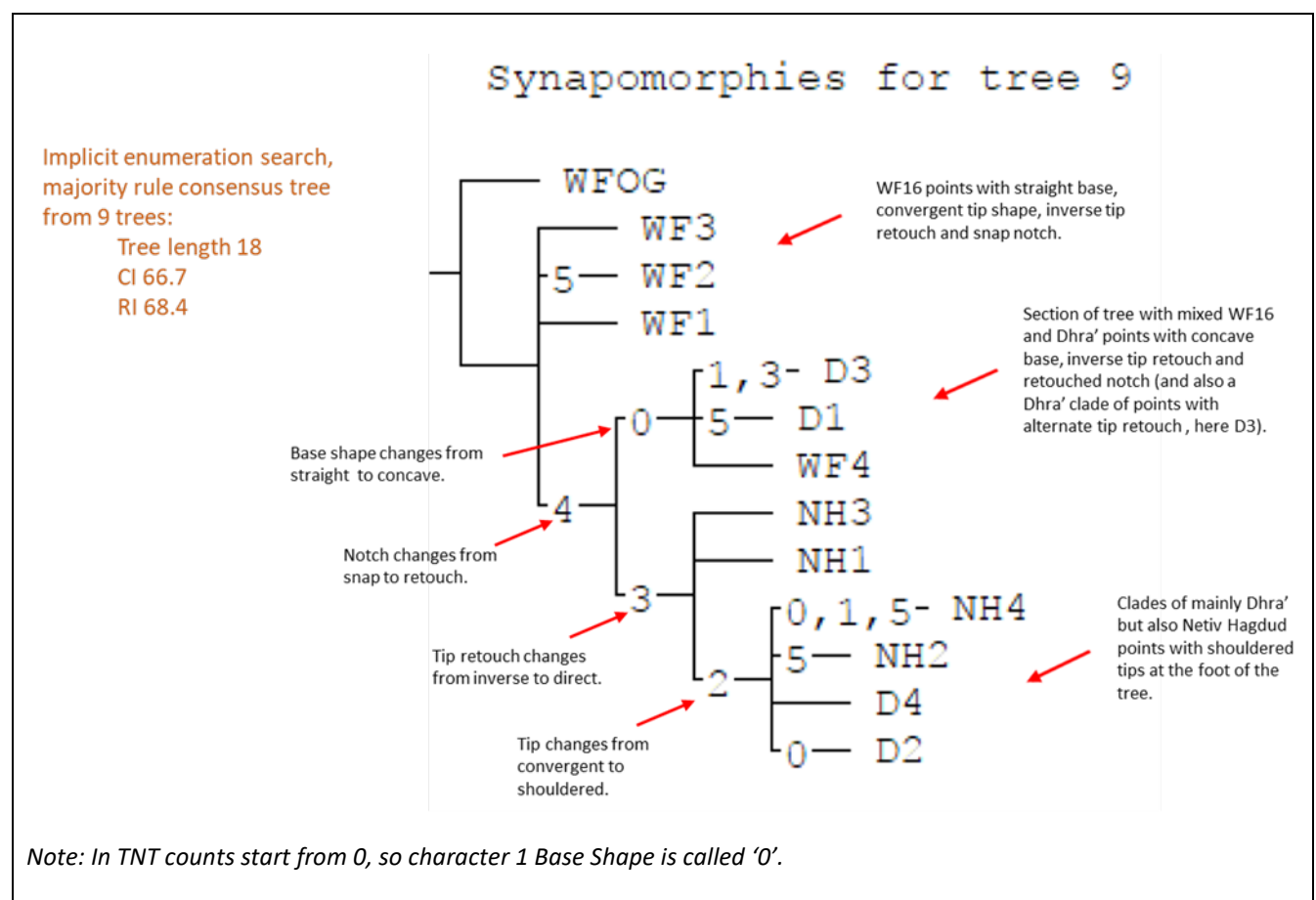


However, because of the large number of taxa (points), the large number of equally parsimonious trees and the influence of metric characters, the character state changes in morphometric and retouch attributes across the three sites are not that easy to disentangle or to display. Therefore a simplified

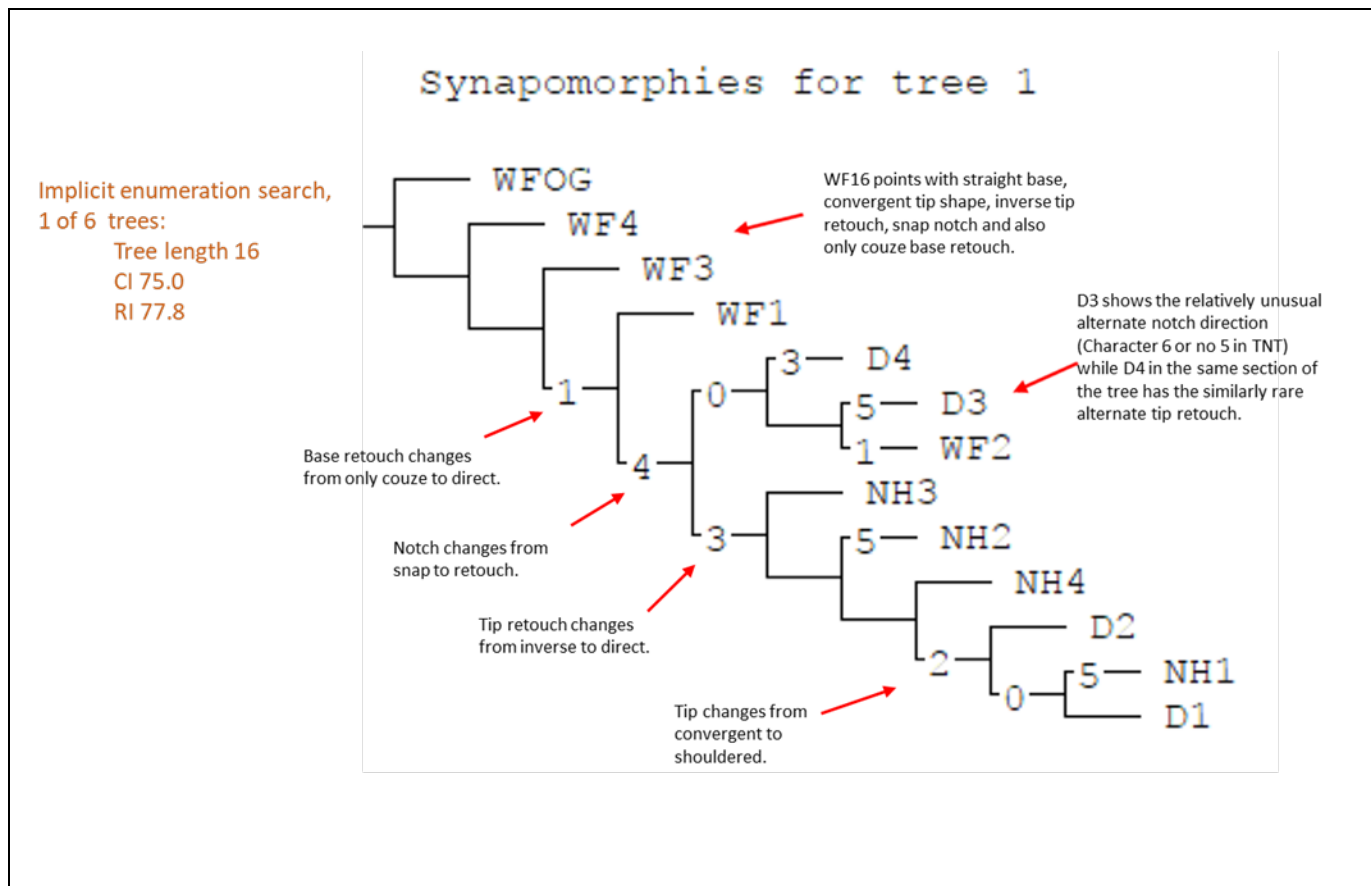
experimental phylogenetic analysis was undertaken in which four points for each site with the characters weighted according to their prevalence shown in Table 7.3 were created and analysed phylogenetically. There are many permutations possible for the experimental tree, and not all of these were tried, but all the ones that were tried created similar trees. Two of the resulting trees, with synapomorphies analysed in TNT, are shown in Figure 7.8. The two different matrices used to create these are at Appendix 12. Because of the limited number of taxa, implicit enumeration searches could be used to identify all the possible optimal trees.

Figure 7.8: Synapomorphies shown on experimental phylogenetic trees, with description of key character changes.

a) Matrix 1 - majority rule tree from nine trees



b) Matrix 2 - one of six trees



The experimental trees illustrates the following:

- The key character state changes shown are the early change of notch from snap to retouch and the later changes of tip retouch from inverse to direct and tip delineation from convergent to shouldered. There is also appears to also be an early shift from couze only to direct base retouch and a less significant change of base shape mainly for Dhra' points, but also some WF16 ones, from straight to concave.
- The notch and base shape changes create a section of the tree, mirroring the actual one at Figure 7.6, where there are mixed group of WF16 and Dhra' points with concave bases, inverse tip retouch and retouched notches (and also a Dhra' clade of points with alternate tip retouch, and also some with alternate notch direction), supporting the idea of an intermingling or transition of points between the sites, and perhaps an experimental phase.
- The consistent and early appearance of the synapomorphic change in notch character, which appears more influential than the base shape and couze only base retouch change, highlights the 'evolutionary' importance of this character.

- The tightly grouped clade of points at the foot of the tree is driven by the change from convergent to shouldered tip delineation and it appears to be a later change, after the change in notch type, and perhaps also after the change from inverse to direct tip retouch. These are mainly Dhra' points but there are also Netiv Hagdud ones, suggesting perhaps a later interaction between these two sites, although there are also four (out of 49) shouldered points at WF16.
- The change from inverse to direct tip retouch is the other main character change apart from the notch that shapes the tree in its shift from WF16 to Dhra' and Netiv Hagdud points. In Figure 7.6 this occurs before the change to shouldered points but this is not, as mentioned above, always consistent in actual trees. Complete actual phylogenetic trees showing these synapomorphies, buried alongside a complex picture of other ones, is shown in Appendix 13, one from the WF16/Dhra' pair and one from a three site tree.

An interesting complication is that the WF16b sample has a higher proportion of bases with couze only retouch than WF16a (Appendix 2), although both are much higher than at the other two sites, suggesting that couze only is an early distinctive character of WF16 points. This higher proportion overall was used in the experimental analysis according to the proportions in Table 7.3 but the influence of this attribute does not come through as strongly in most of the phylogenetic analysis which is based on the WF16a sample alone.

7.5 Summary of key results

Taking all the analysis together the key results are shown under each of the relevant research questions (Table 7.4).

Table 7.4: Key results of descriptive, variation and phylogenetic analysis linked to research questions.

1. The origin and spread of the El Khiam point: Does phylogenetic analysis reflect distinct patterns in attributes between sites, and any direction or progression between points from different sites, which, based on the dating of WF16 as the earliest site, might provide insight into the origin and spread of the El Khiam point?
• Descriptive analysis shows that points share some characteristics which group them by site, while overlapping significantly into a wider single regional distribution. • Phylogenetic analysis shows there is a distinct pattern of character state changes that results in the grouping of points by site, with WF16 attributes being the most distinct. • Based on a WF16 outgroup, character state changes show a progression from WF16, through Dhra' to Netiv Hagdud which supports the hypothesis of the spread of El Khiam points from WF16. • Earlier changes create a mixed group of WF16 and Dhra' points suggesting an intermingling or transition phase between the two sites. The phylogenetic trees show

more mixing between WF16 and Dhra' and greater resolution between these two sites and Netiv Hagdud, implying greater spatial, temporal or social distance. • The progression is correlated with the pattern of increasing CV across sites and is supported by similar directionality shown when using the neutral outgroup.
2. Attribute changes and the mode of transmission between sites: What does phylogenetic analysis of key changes (synapomorphies) in attributes tell us about the mode of transmission between sites, and possible reasons for attribute changes?
• Analysis of synapomorphies shows there are key changes of notch type from snap to retouch and couze only to direct base retouch earlier in the progression, and later changes of tip retouch from inverse to direct and tip delineation from convergent to shouldered. These key changes reflect a shift from the more unusual attributes of WF16, to attributes that are more shared, while still remaining distinct by site. • The changes from snap to retouch notch and inverse to direct tip retouch are the two key synapomorphies that shape the tree overall with the snap to retouch notch change appearing to be the most clear cut and influential. • The pattern of consistency within and change between sites suggests stable patterns of El Khiam making process at each site and that attribute changes are linked to the way points (and the methods used to make them) were transmitted between sites.
3. Social learning environments within sites: What do patterns in the coefficient of variation of attributes say about the strength of different social learning biases modelled in cultural evolution theories, and so the learning environment and group interaction within different sites?
• CV analyses show a pattern of reducing consistency or constraint from WF16, through Dhra' to Netiv Hagdud, within the context shown by phylogenetic analysis that there is homogeneity in how points are made at each site. • Width (overall and retouched base) is the most constrained measure, which might be linked to the requirements of hafting. • As CV standardises for size differences, CV differences are unlikely to be due to raw material issues, and as the subsets of people within each of the three case study sites were likely of a similar scale the numbers of people making the points is also unlikely to be a factor. • A comparison with Harifian points indicates these are even more constrained than the ones from the three case study sites although there is an overlap in some cases between WF16 and the Harifan assemblages. Possible explanations suggest a contrast between more functional requirements in the Harifian points with potentially more socially driven variation in the El Khiam ones.

The final research question on social structure and identity in the Neolithic involves looking at the results and interpretation of all the questions together and in the context of other studies of the period. This is covered in the next Chapter, which provides an interpretation and discussion of the results of analysis, taking each research question in turn.

Chapter 8. Case study interpretation - the implications of the results of analysis for social structure and community identity in the Neolithic

8.1 Introduction

In this chapter the results of analysis are interpreted in the light of wider archaeological evidence, studies of the emergence of Pre Pottery Neolithic A (PPNA) communities, and theories of cultural evolution, taking each research question in turn. This provides a basis to assess the implications of the results for social structure and community identity in the Neolithic.

8.2 The origin and spread of El Khiam points

Does phylogenetic analysis reflect distinct patterns in attributes between sites, and any direction or progression between points from different sites, which, based on the dating of WF16 as the earliest site, might provide insight into the origin and spread of the El Khiam point?

The origin and spread of the El Khiam point needs to be set in a regional context. The distributions of points based on metrics shown in the descriptive analysis (Figures 7.1-7.3) give a sense of an overall regional distribution within which there is weak but real patterning between communities. The morphological and retouch characters for each of the sites (Table 7.3) are more distinct but still show an integrated pattern across the three sites. They also indicate a similar process of manufacture, of a regular routine practiced across the region, and shared ideas of what makes a good, attractive point. This accords with the conception of the late Epipalaeolithic and early Neolithic as a mosaic of communities within regional networks (Section 5.2). Within this context, the phylogenetic analysis provides good evidence for the spread of El Khiam points from WF16. There is a distinct pattern of character state changes showing a progression from WF16, through Dhra' to Netiv Hagdud which supports the hypothesis of the spread of El Khiam points from WF16. This progression is correlated with the pattern of increasing coefficient of variation across sites and is supported by similar directionality shown when using the neutral as well as the WF16 early form outgroup.

The spread from WF16 to Dhra' and then Netiv Hagdud is also supported by more detailed analysis of character changes. The phase early in the phylogenetic trees where there are a mixed group of WF16 and Dhra' points with concave bases, inverse tip retouch and retouched notches (and also a Dhra' clade of points with alternate tip retouch), suggests an intermingling or transition of points between the sites (Figures 7.5a, 7.6 and see particularly the section of the tree indicated in Figure 7.8a with mixed WF16 and Dhra' points). This is followed by more distinct phases of Netiv Hagdud and Dhra'

points and a weaker suggestion of a later interaction between Dhra' and Netiv Hagdud in the intermingling of direct tip retouch and shouldered points at the foot of the tree (Figure 7.6). The dating of the sites, albeit very approximate, fits with such a suggestion, with a focus of occupation at Dhra' some 250-300 years later than WF16, but overlapping with Phase 1 perhaps for 300 years; and a focus of occupation at Netiv Hagdud in the region of 400 years later than Dhra' but overlapping for maybe 300 years. (Table 5.2).

The expectation would not necessarily be of a linear progression from site to site but more likely a diffusion across the region, probably in many complex ways. However, a review of images of points from Gilgal 1, a PPNA site in the lower Jordan Valley (Dag, 2010, pp.56-57), not far from Netiv Hagdud (Figure 5.1), shows point characters similar to Netiv Hagdud, but with some aspects closer to Dhra' (more concave bases and shouldered tips). Gilgal I is dated between Dhra' and Netiv Hagdud (Dag, 2010), consistent with this character pattern. The phylogenetic analysis is here limited to three sites and adding further sites would provide a more detailed picture. However, the analysis suggests perhaps that Dhra' was closely related and a step in the spread of El Khiam points from WF16, while Netiv Hagdud was later and probably following diffusion elsewhere, at sites such as Gilgal I. Given the pattern of intermingling of points between WF16 and Dhra' it is tempting to consider the idea that sub groups or elements of the people of the WF16 area might have migrated to or been part of the establishment of Dhra'. Although consistent with the dating, this is clearly very speculative.

WF16 attributes are the most distinct, for example in terms of the snap notch, couze only base retouch and inverse tip retouch (Table 7.3), and also the most constrained in terms of coefficient of variance (CV). This might indicate a social isolation that is consistent with WF16's apparent relative temporal and geographic isolation (Table 5.2). Kuijt and Prentiss (2009), applying niche construction theory, suggest that in the late Natufian there was a fragmentation, a 'cracked niche' in communities, coupled with stability in lithic technology meaning less need, incentive or inclination to change. In such a context change would more likely be driven from smaller, more isolated populations (Goodale et al., 2007; Kuijt and Prentiss, 2009). There is also the proposal of greater continuity across the end of the Natufian, and with the Harifian, in more isolated communities in Southern Jordan such as WF16 suggested by Finlayson et al. (2011). These studies provide a context consistent with the origin and spread of El Khiam points from WF16. The closeness and overlap of Harifian and WF16 CVs is interesting in the light of the phylogenetic results and an intriguing hint of support for an origin in the Negev, but no more than that. The points from WF16 seem to have a pattern embedded within them that suggests they are already a developed form. However, innovation in cultural evolutionary terms

is not so much the invention but the spread, the adoption of that invention by a population (Henrich, 2010; Powell et al., 2010). In that sense WF16 might be seen as a key site of adoption.

8.3 Attribute changes and mode of transmission between sites

What does phylogenetic analysis of key changes (synapomorphies) in attributes tell us about the mode of transmission between sites, and possible reasons for attribute changes?

Overall the similarities in process of manufacture and point attributes outweigh the differences between sites, so transmission was relatively faithful, despite occurring over a period of perhaps 1,000 years. The analysis of synapomorphies (Figure 7.8) shows, however, that there are key changes, particularly of notch type from snap to retouch and couze only to direct base retouch earlier in the progression, and later changes of tip retouch from inverse to direct and tip delineation from convergent to shouldered. These changes reflect a shift from the more unusual attributes of WF16, to attributes that are more shared, while still remaining distinct by site. The pattern of consistent point types maintained over long periods within sites, and changes in attributes occurring between sites, suggests that these changes are linked to the way points (and the methods used to make them) were transmitted between sites. Random drift, horizontal transmission and content bias (Sections 4.4.2, 3.2 and 4.3 respectively) are useful concepts from cultural evolution theory for examining this transmission pattern.

Random drift. Whether the El Khiam point spread through exchange, at periodic aggregations, or fissioning and migration of parts of communities, it is likely that at key moments a smaller number of people were holding the physical and mental model of what an El Khiam point was. Random (or strictly stochastic) drift is the cultural evolution model analogous to genetic drift where ‘errors’ in small populations mean changes are preserved and those changes maintained as populations increase (Henrich, 2004; Richerson and Boyd, 2005). Those ‘errors’ might equally be decisions to make a point a particular way - guided variation (Richerson and Boyd, 2005), or combining traits from different cultural models of points (Powell et al., 2010). But overall, stochastic drift may well have been more influential in the character changes during transmission, for example the greater prevalence of concave bases and shouldered tip points at Dhra’. The shouldered points at WF16 may have been brought back from Dhra’ or might have been made at WF16 but either way they did not become the pattern adopted at WF16, but did become the pattern at Dhra’.

Horizontal transmission. The model of horizontal cultural transmission developed by Cavalli-Sforza and Feldman (1981) is useful to consider in respect of the variation that may have occurred at the

point of transmission, where change is accepted and can be rapid (Figure 8.1, second column). Alternatively the variation seen at different sites within the overall similarity of form might be the result of local innovation or reinvention (convergent evolution). But the consistent pattern at each site, and the frequent existence of a few cases at one site of a common attribute at another suggests it is less likely that it was reinvention and more likely the differential spread of existing attributes.

Figure 8.1: Model of cultural transmission (after Cavalli-Sforza and Feldman 1981) which shows modes relevant to transmission between sites (horizontal) and within sites (many-to-one).

Modes of cultural transmission				
	Vertical or parent-to-child	Horizontal or contagious	One-to-many	Concerted or many-to-one
				
Transmitter	Parent(s)	Unrelated	Teacher/leader/media	Older members of social group
Transmittee	Child	Unrelated	Pupils/citizens/audience	Younger members of social group
Acceptance of innovation	Intermediate difficulty	Easy	Easy	Very difficult
Variation between individuals within population	High	Can be high	Low	Lowest
Variation between groups	High	Can be high	Can be high	Smallest
Cultural evolution	Slow	Can be rapid	Most rapid	Most conservative

Content bias. The idea of content biases is also a useful and complementary way to look at the mode of transmission. The form of El Khiam points as regular, symmetrical and attractive artefacts, in contrast to earlier ones (Figure 5.2), invokes the possibility of an aesthetic content bias as a strong influence on its traction and spread, as well as the functional content bias of a hafted tool that worked. The notch in particular, as an aesthetic and functional innovation, may have been attractive. Content biases are seen as crucial in the spread of innovations (Henrich, 2001; Mesoudi, 2011) and content bias is more likely in horizontal transmission where group social norms and learning (context) biases are less influential.

Even though the variability in El Khiam point attributes does not appear to be mainly functionally determined (Section 5.5), the attributes examined still provide some hints about function. As mentioned under random drift, transmission processes might have facilitated a limited role for guided variation in respect of the key attribute changes or synapomorphies. Width (overall and retouched base) is the most constrained CV measure, which is also true in other studies (Garvey, 2018; Goring-Morris, 1987). This likely reflects important functional constraints, linked perhaps to aerodynamics and hafting (Edinburgh, 2005; Goring-Morris, 1987), although these points were used as perforators as much as projectile points (Smith, 2005). The notch appears to be a novel hafting technique that is used alongside continuing hafting approaches for other points such as the Salibiya. Hafting is a crucial component of lithic projectile manufacture, argued to be more time consuming than the knapping process itself (Bar-Yosef, 1987). The function of course is expressed not in the point but in the whole hafted tool which has not been examined here. But the notch is clearly important in the origination of El Khiam points and the shift from snap to retouch an important 'evolutionary' change identified. This shift is perhaps a more consistent and reliable way of manufacturing the notch. It is the closest to a change in one of the characters that might be considered a logical next step. It may not be directly functional but is associated closely with that important, time consuming, functional attribute. In a similar way, the change from couze only base retouch to direct might also be seen as a next step, and the inverse to direct tip retouch, seems perhaps a more obvious way of doing things. In a sense it is the WF16 ways of doing things that seem more particular, and supports the idea of origination, and of relative isolation.

8.4 Social learning within sites

What do patterns in the coefficient of variation of attributes say about the strength of different social learning biases modelled in cultural evolution theories, and so the learning environment and group interaction within different sites?

The comparison of CVs with Harifian points suggested a contrast between the more functional requirements in the Negev points with potentially more socially driven variation in the El Khiam ones (Section 7.3.3). The indication of a direction in the phylogenetic analysis from WF16, through Dhra' to Netiv Hagdud, makes the parallel trend of increasing CV (or reducing constraint) from site to site identified by the variation analysis more interesting and compelling. While recognising the risk of reading too much into a limited data series, it is interesting to consider the archaeological and other correlates of this trend that might help explain the shift from more constrained to less constrained CVs (Table 8.1).

Table 8.1: Correlates for the reducing levels of constraint from WF16, through Dhra' to Netiv Hagdud, providing the basis to suggest the social environment in these communities becoming progressively less tight knit and more open to other influences.

Correlate	Comment
Isolation	There is a trend towards less isolated, likely more connected, communities across the three sites, although all three sites have evidence of regional network connections (Table 5.2).
Place of points in assemblage	Points are frequent in the chipped stone assemblage at WF16, very abundant at Dhra' but are less prevalent at Netiv Hagdud both in absolute terms and proportionately to the rest of the assemblage. Points are a much less important part of a more complex assemblage at Netiv Hagdud. (Tables 5.2 and 5.3).
Population	Population estimates are very approximate but suggest similar levels at WF16 and Dhra' and higher levels at Netiv Hagdud (Table 5.2).
Subsistence strategies	Although hunting was important at all three sites there is a case that there are shifts in subsistence strategies including increasing intensity of cereal processing (5.2). Sickles were an important tool for harvesting cereals, and sickle blade numbers reported in Goodale et al. (2010) are 0 at WF16, 73 at Dhra' and 162 at Netiv Hagdud. Cereal processing also occurred at WF16 and Beit Tamir sickles found from what are seen as later phases (Mithen et al., 2019) but the numbers are perhaps crudely indicative of different strategies.
Architecture and site patterning	WF16 and Dhra' both have what are understood as communal structures including communal storage, little in the way of residential structures, and tight site boundaries, intentionally maintained. However the architectural forms are different, with three repeated types at Dhra' and more variation at WF16. At WF16 the effect is of a more shared and dynamic environment and also with a resemblance to Harifian forms (Finlayson and Makarewicz, 2017; Mithen et al., 2019). At Netiv Hagdud there is a larger settlement with structures identified as more likely residential and also a pattern that indicates more distinct households and even potentially different types of resident groups (Hemsley, 2008). These features suggest a shift across the three sites from a more communal ethos to less communal and more sedentary.

These correlations do not represent factors or causes of increased measures of CV although they are correlated with each other in ways that are likely linked. However in looking for explanations for why human groups might manufacture points with greater or less precision or consistency these correlates might broadly suggest communities becoming less tight knit and more open to other influences. The EL Khiam point means more to the communities at WF16 and Dhra', which are also both more communal in ethos. They care more collectively about their El Khiam points. An alternative explanation for the increasing CVs across the three sites is stochastic drift. Becoming less constrained because they could - within the context of the three communities the points were functional enough

within wider limits of constraint. This is unlikely as drift can occur at any time and therefore would be expected to create more variation within each site given the long periods of time from which the samples have been taken (Henrich, 2004). The distribution of attributes does not fit the drift model well where there should be a large number of very rare traits in the population (Mesoudi and Lycett, 2009). The consistency of the phylogenetic direction with the pattern of reducing constraint also gives greater weight to an explanation based on the correlates in Table 8.1.

These patterns of constraint can be interpreted using cultural evolution theories of social transmission, drawing on the idea of a shift from a communal ethos to something less tight knit. The collective preservation of attributes over long periods of time appears highly conformist, and in terms of the modes of transmission identified by Cavalli-Sforza and Feldman (1981), consistent with a many-to-one mode at WF16, and also at Dhra' (Figure 8.1, column 4). In modelling terms this mode means there is low variation between individuals and low innovation, a conservative social mind set. This seems likely to occur in the circumstances of the younger generation learning alongside a group of experienced point makers in a communal environment, such as at WF16 and Dhra', as opposed to more vertical transmission where household structures are more embedded. Given the contextual evidence of the correlates (Table 8.1, and also Table 5.2) this interpretation of CV constraint at WF16 and Dhra' can be argued to meet the challenge of matching micro evolutionary processes to macro evolutionary evidence with some conviction.

Netiv Hagdud appears a very different case to the other two sites. Larger, more connected, close to other sites and potentially more household based with an assemblage of a very different order (Table 5.2). The CVs are not all consistent, with thickness and particularly T/L (Table 7.2) more constrained; in addition the Salibiya points at Netiv Hagdud, (although a small sample n=18) also have much more constrained CVs. This may suggest overall more complex transmission, and more blended modes, or different modes in different pockets of the community, at different times. Of course multiple patterns will generally characterise transmission (Eerkens and Lipo, 2007). And the chances of a single pattern dominating over long periods of time seems low. But the evidence from Table 8.1 does suggest a less tight knit group at Netiv Hagdud and a place where the El Khiam point does not mean as much to the inhabitants.

8.5 Social structure and identity in the Neolithic

What might these questions together, set in the context of other studies of the period, indicate about social structure and community identity in the Neolithic?

The case study and discussion above provide a basis to propose some wider implications of the analysis for social structure and community identity in the Neolithic. These involve developing the idea, consistent with cultural evolution theories, that the different but stable pattern of El Khiam making process at each site (Section 7.4.3) show how social groups can develop very distinct senses of ‘the way we do things around here’. In particular, the analysis of the social transmission and learning environment at the sites can be developed to examine social structure, while social transmission, demography and the analysis of morphological and retouch attributes of points can be combined to examine aspects of community identity.

8.5.1 Social structure

In the context of the variety of ways that groups might have organised themselves, such as moieties by age or gender (Belfer-Cohen and Goring-Morris, 2011), the idea that a many-to-one transmission mechanism (Figure 8.1) might have been operating suggests that learning with a group of experienced point makers could well have been the norm, particularly at WF16 and Dhra’. The scale of point production at Dhra’ appears so industrial an apprentice within a guild model might even seem appropriate (Sterelny, 2011). The importance of oblique transmission, learning from adults other than ones parents, is emphasised in a review suggesting that the idea that cultural transmission is predominately vertical has now been superseded with a model where vertical parentally transmitted knowledge is modified at a later age by horizontal or oblique transmission in ways related to age or skill transmission cohorts (Mesoudi, 2017). This clearly has a resonance here but the highly conservative learning environment at WF16 and Dhra’ is also likely a manifestation of a social organisation unique to the time and place.

The idea of a social structure where parents, and so households, were less influential can be linked to the evidence of the architecture and site layout at each site (Tables 5.2 and 8.1). This suggests that the people using WF16 and Dhra’, compared to Netiv Hagdud, had a more collective social structure, and where different sub groups of the community had a stronger role in the structuring of daily life. At WF16 the site layout and building arrangements suggest purposes and habits of life relating to the whole community rather than a residential and household structure (Finlayson and Makarewicz, 2017). At Netiv Hagdud the household is appearing to take on a stronger role, with more distinct

households and potentially different types of resident groups (Hemsley, 2008; Rosenberg 2008). This transition, from something that can be described as egalitarian to something more complex, appears strongly parallel to a similar, but also unique, transition documented at Çatalhöyük East later on in the Neolithic, where a mix of egalitarian and more complex arrangements is suggested in control over access to food processing tools, with evidence of increasing inter-household competition over time (Wright, 2014).

Maintaining a particular way of doing things over long periods of time is consistent with cultural evolution theories of niche construction and social norms, where habits and traditions are preserved and become embedded, even when they might not appear adaptive (Section 3.5). As noted earlier, the social isolation indicated by WF16's more constrained CV and the unique emergent properties of its points such as the couze only base retouch and snap notch, appears consistent with its relative temporal and geographic isolation. The interaction between these aspects of isolation are hard to unpick, but the result was that particular ways of doing things could develop and be maintained in unique and almost strange ways. This social/geographic isolation was not related necessarily to the site itself, which may well have been one of periodic aggregation, but to the territory and community or groups related to WF16. In some ways this might have had more in common with the seasonal and radial pattern of groups living across a known territory seen in the Harifian of the Negev (Goring-Morris, 1987) than with the more sedentary way of life that Netiv Hagdud seems to represent (Hemsley, 2008).

8.5.2 Community identity

Points and other lithic tools of this period have been regarded as symbolic or emblematic, for example when included in burials, or as prestige items, made from rare types of stone and unused (Barkai, 2011; Goring-Morris and Belfer-Cohen, 2001). These explanations do not appear to apply in the case of the sampled El Khiam points, although Watkins (2008) makes the case that the possession of El Khiam points was part of a system of competitive emulation and symbolic display. On the face of it El Khiam points seem too small, and the differences in attributes in particular not readily identifiable, for them to be symbolic in an overt sense, such as being emblematic. In cultural evolution theory, for artefacts to be emblematic and a means of displaying identity, there should be more constraint where there is a greater proximity with others, where boundaries need to be marked (Garvey, 2018, Shennan and Wilkinson, 2001). Of the three sites this need would appear to have been greatest at Netiv Hagdud, marking a difference with Jericho and other nearby communities. However, this appears to be where, based on the analysis of CV and social transmission detailed above, that the El Khiam point

means the least and is least constrained. This supports the argument that El Khiam points are not emblematic.

However, El Khiam points still seem important to their communities, particularly at WF16 and Dhra'. The differences in morphological and retouch attributes identified by Smith (2005) between WF16 and Dhra' do not apply to other lithic artefacts such as awls and borers, which seems to elevate the El Khiam above other common tools. The importance of El Khiam points is perhaps better seen in terms of the wider development (or strictly, application) of symbolic community at the beginning of the PPNA. Symbolic community was important in managing the stresses of larger numbers of people living together for longer periods (Sterelny and Watkins, 2015) drawing on the ideas of cognitive limits to group size, and that we are only able to sustain relationships with around 150 other people (Dunbar, 1998). The estimates of group sizes for the case study sites (Table 5.2) suggest they may have been dealing with this threshold in a way that did not apply to the same extent to other earlier groups (Sterelny and Watkins, 2015) or to the Harifian bands in the Negev. Although WF16 may well have been an aggregation site that was not occupied all year round, the scale of the occupation did mark a shift from that seen in sites in the Negev, and the PPNA more generally saw an increase in the number and scale of sites (Cartolano, 2016; Goring-Morris, 1987).

This demographic change can also be linked to cultural evolution theories that larger and denser populations, an increased pool of social learners, are required for more complex artefacts and technology to be maintained (Section 3.5). The form of El Khiam points as regular, symmetrical and attractive artefacts, in contrast to earlier ones (Figure 5.2), appears to meet this criteria of more complex technology. What was different about the El Khiam points were their 'elaborate and highly stylised forms' (Watkins, 1992, p68). More information is encoded within El Khiam points than earlier ones, particularly through the morphological and retouch attributes examined in phylogenetic analysis. This does not mean that points were emblematic, but making them - doing something complex, communally, in a way that is identified as the way things are done in this group - supported community identity when this was becoming more important. This is consistent with cultural evolution theories relating to the extended mind and social norms (Sections 3.5 and 3.6). The complexity and attractiveness of El Khiam points was both maintained through larger populations, such as those at WF16, and helped cognitively to manage the stress of living in them.

The site specific processes of production and the link to local group formation is reinforced by consideration of the similarities and differences in attributes of the Salibiya point, which appears in lesser numbers alongside the El Khiam in all of the assemblages (Table 5.3). In a number of respects

the distinct local manufacture processes of WF16 and Dhra' were applied to Salibiya points, giving rise to some of the same morphological and retouch attributes, while discriminant analysis of metrical attributes places Netiv Hagdud Salibiya points very close to their Netiv Hagdud El Khiam equivalents (Appendix 14). In many ways therefore, El Khiam and Salibiya points are more similar to each other at each site than they are different to each other according to the typology commonly used. These similarities, and their respective proportions in assemblages, would suggest that they are like alternatives in a 'tool box' of points. It might therefore be more useful to talk about a WF16 or Dhra' point, rather than El Khiam or Salibiya one. This challenges the use of the El Khiam point as a marker of a culture and as a typology, both of which tend to underplay the actual variation, the similarities and differences, that the analysis undertaken in this research demonstrates.

8.6 Conclusion

This analysis has involved looking at similarities and differences in attributes of the El Khiam points and examining these across three sites. This has identified how attributes of one element of Neolithic culture, the El Khiam point, were maintained within and spread between different sites. Distinct ways of doing things in different places, taken together with the idea of the spread of the El Khiam point from WF16, suggest that there were likely different pathways and processes of development, of evolution or emergence of Neolithic ways of life. It seems unlikely there was a wave of Neolithic processes going in one direction and taking all before it, such as might be indicated by large scale invasion of territories. A spread of the El Khiam point not primarily related to function supports the idea of a content bias, artefact diffusion, rather than a spread based on the replicative success of the bearers (Cochrane, 2001). The El Khiam point may well have spread from WF16, but other elements such as architecture, subsistence strategies likely spread in different ways. The connections implied by the more artistic or symbolic items in the assemblages, such as incised stone or obsidian, are multidirectional (Table 5.2). Overall there appears a very mosaic pattern of development across the three sites, indicating groups interacting through exchange, aggregation and perhaps migration.

The analysis has shown that insight can be gained from the use of variation and phylogenetic analysis, which appear to have been underused to date as tools to study the Neolithic in the Levant. They could usefully be applied further in exploring the many aspects of the Neolithic that remain to be elucidated. El Khiam points from other sites across the wider Levant (Appendix 1) could be analysed to see how the point characters compare. For example, assessing the prevalence at other sites of what appear to be the more ancestral point characters of snap notch and couze only base retouch could extend the analysis of the origins of the El Khiam points to a more regional basis.

Chapter 9. Does culture evolve? The implications of this research for theories of cultural evolution

9.1 Introduction

This Chapter looks at the broader implications of this research drawing together themes and issues raised throughout the thesis. In particular it considers what the results tell us about theories of cultural evolution, whether culture evolves, and the nature of human culture.

9.2 How useful are theories of cultural evolution in this case?

Theories of cultural evolution provide a useful and compelling framework of analysis for the case study. In broad cultural evolutionary terms the preservation of the processes of point production that are characteristic of each site is based on a psychology of imitation (mixed with less frequent innovation) and a social learning tendency of conformist transmission that creates and maintains within group similarities and between group differences. Conformity bias (of which the many-to-one model is an example) was particularly evident at WF16, but is there at the other sites in the consistency of point production processes over many centuries. It is seen as the predominant social transmission mode (Section 3.2). In the transmission between sites (or more strictly beyond the territory of a social group) the models of horizontal transmission and stochastic drift, together with the potential for some guided variation also fit the case study well. The mathematical models underpinning cultural evolution theories show how these patterns of trait behaviour can be predicted, lending more substance to empirical observations and intuitions. These are areas where theories appear to provide the strongest arguments and the most explanatory power.

The application of phylogenetic analysis, drawn from biological evolution, is also a useful technique in this case, demonstrating patterns in the development of derived characters that indicate the pathway of development and spread of the El Khiam point and hint at the relationships between sites. The limited functionality of the morphological and retouch attributes used as characters, the extent of change in these, the conservative preservation and stability of method at each site, and the geographical and chronological distance between sites, all help provide a clear signal in the archaeological record that allows the branching or diffusion element of transmission to come through in the phylogeny. There may be an element of borrowing back, for example perhaps on shouldered points (Section 7.3), but this does not prevent a clear branching pattern to emerge. It suggests that a lineage approach to cultural analysis works in this case.

Many archaeologists and historians would broadly accept the idea of what is seen in the record is groups passing down traditions that change over time (e.g. Clarke, 1978). This is descent with

modification to a degree, an indication of variation and inheritance. What the theories perhaps most usefully do is add selection. The transmission biases and pathways which provide mechanisms for the selection of one trait over another. They also provide the theoretical arguments for the maintenance of group boundaries and how these operate in subtle ways to create the condition in which lineages of culture can occur. The results suggests lineage and cumulative culture are useful ways of looking at cultural evolution. Central to cultural evolution theories is the idea that artefact variation persists over time in ways that are not simply related to changes in the external environment, that there is heritability of cultural variation at the population level (Boyd et al. 2013). This is demonstrated in the case study through the productive use of phylogenetic analysis, where the clear and consistent branching indicates the attributes are not strongly functional (7.4.3). Cultural evolution theories are therefore appropriate to apply in practice, at least in relation to the Neolithic.

A debate remains about the relative role of influence of content and context biases (3.7). The case study provides evidence that contributes to this debate through examination of the way similar El Kham point attributes are maintained over long periods within sites but vary between sites. Content bias is more likely in horizontal transmission where group social norms and learning biases are less influential, while context biases are more likely to prevail for within group transmission. There will always be a bit of both but this is an example of the way roles and influences will be different in different circumstances.

A theoretical strength of cultural evolution theories is the strong focus on understanding the origins of cumulative culture because the processes of its emergence, both cognitive and cultural, appear to have shaped much of what comes after. Applying the theories to more recent history appears, at least at first glance, to be less useful. The extent of complex and recursive borrowing and blending, for example the reintroduction of extinct traits, means that a lineage based approach seems less likely to be useful, as shown for example in the development of the cornet (Tëmkin and Eldredge, 2007). However phylogenetic analysis was applied successfully to the development of the skateboard (Prentiss et al., 2016). It would be interesting to examine this. If there was descent with modification at some point, at what point and when does it become less useful and why?

9.3 Limitations

While cultural evolution theories provide a useful framework for the analysis of the case study, the picture provided remains a very partial understanding of the social life and culture of the communities related to the three sites. This is no doubt due in large part to the limitations in the available evidence, rather than limitations of the theories themselves, but there are some dimensions that provide a window into why the theories do not quite seem to nail it, and cannot be expected to, given real

human complexity. There is, for example, as discussed in the introduction to Dual Inheritance Theory (Section 4.2), a difficulty in pinning down a transmission bias unambiguously to a pattern in the archaeological record. Although the many-to-one model does seem to fit well particularly at WF16, it is not so clear what transmission forces explain the pattern seen at Netiv Hagdud. This reflects the challenge of matching micro evolutionary processes to macro evolutionary evidence.

As population focussed theories, and even though they are based on individual decision making processes, the individual is rarely foregrounded, and the role of individual creativity, and the way emotions drive behaviour, is lost in the overall feel of the results both here, and more generally (Asma and Gabriel, 2019; Enquist et al., 2011). Niche construction theory, although there in principle to help put this back, rarely does this in practice (Hodder, 2017). Niche construction approaches tend to look at the effect of culture on genes, while the effect of culture on culture has been studied less (Andersson et al., 2014). Cultural evolution theories are all about the effect of the social, the group, on culture, but the way humans shape each other's lives and are responsible for them seems to need a philosopher and artist such as Simone de Beauvoir to express (de Beauvoir, 1948).

Finally, the important role that things, artefacts, play in human cognitive evolution and culture also appears underdeveloped in the theories. Critiques, often drawing on phenomenological thinking, suggest the social has been overestimated (Hodder, 2017; Malafouris, 2010). For example, in an alternative approach, the importance of the relationships of things such as groundstone tools with people and with other tools led to changes in diet in the Epipalaeolithic to Neolithic (Hodder, 2017). Cultural evolution theories have incorporated more about the artefact in recent studies, for example, a study focussing on the evolution of technology (Boyd et al., 2013). But these do not capture the meaningfulness of things to people and the patterns of relationships of things with other things that is an essential part of understanding culture (Hodder, 2017; Latour, 2005). On a more straightforward level cultural evolution theories are no substitute for the intimate knowledge gained about artefact creation by *chaîne opératoire* approaches such as applied by Smith (2005) and a crucial building block of this research.

Few studies try to bridge the gap between more anthropological and more evolutionary approaches - an exception is an attempt by Riede (2005) to reconcile an agentive interpretive approach such as developed by Bourdieu (1977) with evolutionary archaeology. But no approach is going to capture human complexity in its entirety and it would be interesting to combine evolutionary approaches with others such as complexity theory (Bentley and Maschner, 2007), or network analysis (Collar et al., 2015) together with more anthropological ones such as Bourdieu (1977) and Latour (2005).

9.4 Does culture evolve?

The results, particularly the phylogenetic analysis, support the idea that there is cultural evolution in a Darwinian sense, that there can be elements of descent with modification in cultural traits. But the way selection operates appears very different from genetic evolution. It seems improbable that the copying in culture, while remarkable, is as faithful as in genetic evolution, and selective forces in culture are argued to be stronger than in the genetic field, which shifts the balance of how change works. Cultural evolution happens faster and is more directed (Richerson and Boyd, 2005). The randomness of biological evolution is arguably another distinguishing factor, set against the human intentionality in artefact creation, although there are random elements to social learning processes, and outcomes, apart from immediate ones, are rarely the ones people set out to achieve (Lycett, 2015; Ortner, 1984).

As stated earlier (Section 3.8), whether culture evolves depends partly on the definition. If gene theory is essential to the definition, then culture does not evolve, even allowing for the cognitive evolution and gene culture co-creation elements that are integral to cultural evolution theories. However developments in evolutionary thinking have shifted the emphasis away from genes. Development Systems Theory puts genes alongside other resources an organism uses in development to redefine evolution but still applies variation, competition and inheritance (Griffiths and Gray, 2003). Epigenetics allows external factors to alter gene expression and provide room for behavioural flexibility without altering the genetic code (Ragsdale and Foley, 2018). In this way of thinking organisms are constructed during development, not programmed by genes (Fuentes, 2016; Laland et al., 2015). This shifts biological evolution closer to the strange way in which culture appears to develop that is neither exactly intentional nor exactly random, but involves complex interactive processes operating across many levels.

A different challenge is that the idea that the origins of human culture might be subject to an underlying causal principle such as evolution is contested (Ingold, 2007; Lewens, 2012). There is a debate about whether underlying principles or scientific laws can be applied to unique contingent events of the past (Stout, 2018). Historical accounts of the past may also be a simplification, a model of causes, but generally do not suggest that there are principles like natural laws that underpin those causes and that allow prediction, which is what evolutionary models do (Stout, 2018). However, evolutionary approaches to culture in many cases embrace the idea of a contingent, historical past (e.g. Edinborough, 2005; O'Brien and Lyman, 2000; Richerson and Boyd, 2005; Stout, 2018). A perspective setting evolutionary processes within a context of history as unique contingent events can be a helpful way to look at cultural evolution in that it emphasises that changes are always influenced

and constrained by what went before. It can be argued, therefore, that historical methods and evolutionary models are complementary not competing. Everything is contingent, specific to a time and context, including biological evolution. Natural laws are likewise contingent but expressing the best and most useful model we can construct for doing a particular job (Richerson and Boyd, 2005). In this way evolution, like culture, is a model, which is why it cannot fully capture human complexity. Set within this understanding of both evolution and culture as models of complexity, this allows a conclusion that culture can reasonably be said to evolve.

9.5 The nature of human culture

The preservation and change of distinctive patterns of El Khiam point manufacture across the three case study sites provide an insight into the nature of human culture. These distinctive processes are not, or not principally, functional, but nor are they stylistic exactly, or random, as they are consciously chosen methods of manufacture. They can be seen as broadly neutral in terms of function, although there may well be a functional tinge to some of the elements as suggested for the snap notch (Section 8.3). But if neutral, drift is not the force that explains its distribution or maintenance. These non-functional differences are illustrative of what makes human culture so strange and wonderfully varied. The technological achievements of human societies are remarkable but the broad spectrum of more or less neutral traits, that appear as random choices or habitual elaboration, and the maintenance of these over long periods, can be argued are equally special. This resonates with ideas about the technological choices societies make from the universe of all possible techniques and how the logic for these choices generally escapes us (Killick, 2004; Lemonnier, 1986).

Function is clearly important, the points have to be useful and work. But there are many ways in which that can happen, as in the idea of multiple stable equilibria. Culture can be seen as the variety of less functional attributes attached in different ways to more functional ones, or which are linked together in groups, or preserved in some other way in the cultural niche, for example through social norms. Boyd et al.'s (1997) hierarchically integrated systems, or many coherent units are just some possible models of how cultural elements might be structured and linked, but there are no doubt many others, perhaps countless. There can be numerous complex or tangential relationships to function, as artefacts, and cultural phenomena more generally, are integral wholes that are not easy to break down. Gould and Lewontin (1979) maybe overdid the critique of adaptionist theories, but they are surely right that the relationship between parts are hard to separate and interfaces are complex.

Darwin's account of evolution included reflections on the difficulty of understanding the functions of parts given the development of the organic whole, and, prefiguring phylogenetics, the importance for

classification of characteristics that are not functional (Darwin, 1859). Darwin's understanding of maladaptation is argued to be one of his most important achievements (Richerson and Boyd, 2005), and perhaps the underappreciated key to cultural evolution. A criticism made of cultural evolution theories is that if culture is only a proximate level explanation of behaviour then it is not influential compared to ultimate more functional evolutionary explanations (Richerson et al., 2016). The complexity proposed by evolutionary developmental theory and niche construction add in many more feedback loops that break down the proximate-ultimate distinction (Laland et al, 2011). This is important for underpinning the way that culture may not always be adaptive, but can be influential. Evolutionary as well as structural functionalist or symbolic explanations try too hard to find a functional explanation. Cultural evolution theories provide an evolutionary explanation that can embrace the weird and wonderful.

9.6 Summary

This Chapter has discussed and concluded on what the results of the case study tell us about theories of cultural evolution, whether culture evolves, and reflected on what they mean for the nature of human culture. The next and final Chapter provides a brief overall conclusion to the thesis.

Chapter 10. Thesis conclusion

Cultural evolution theories have been used to interpret patterns in the archaeological record and so provide a further test of the predictions of the theories, which was the aim of this research. The archaeological approaches used to test the theories, variation and phylogenetic analysis, were productive techniques that allowed a very granular approach to the El Khiam points from WF16, Dhra' and Netiv Hagdud. The stability in the patterns of attributes maintained at each site over long periods of time underpinned the directionality identified in the phylogenetic analysis and the matching pattern of increasing coefficient of variation across the three sites. These results provided the basis to consider the mode of transmission between the sites, and the learning environment within them.

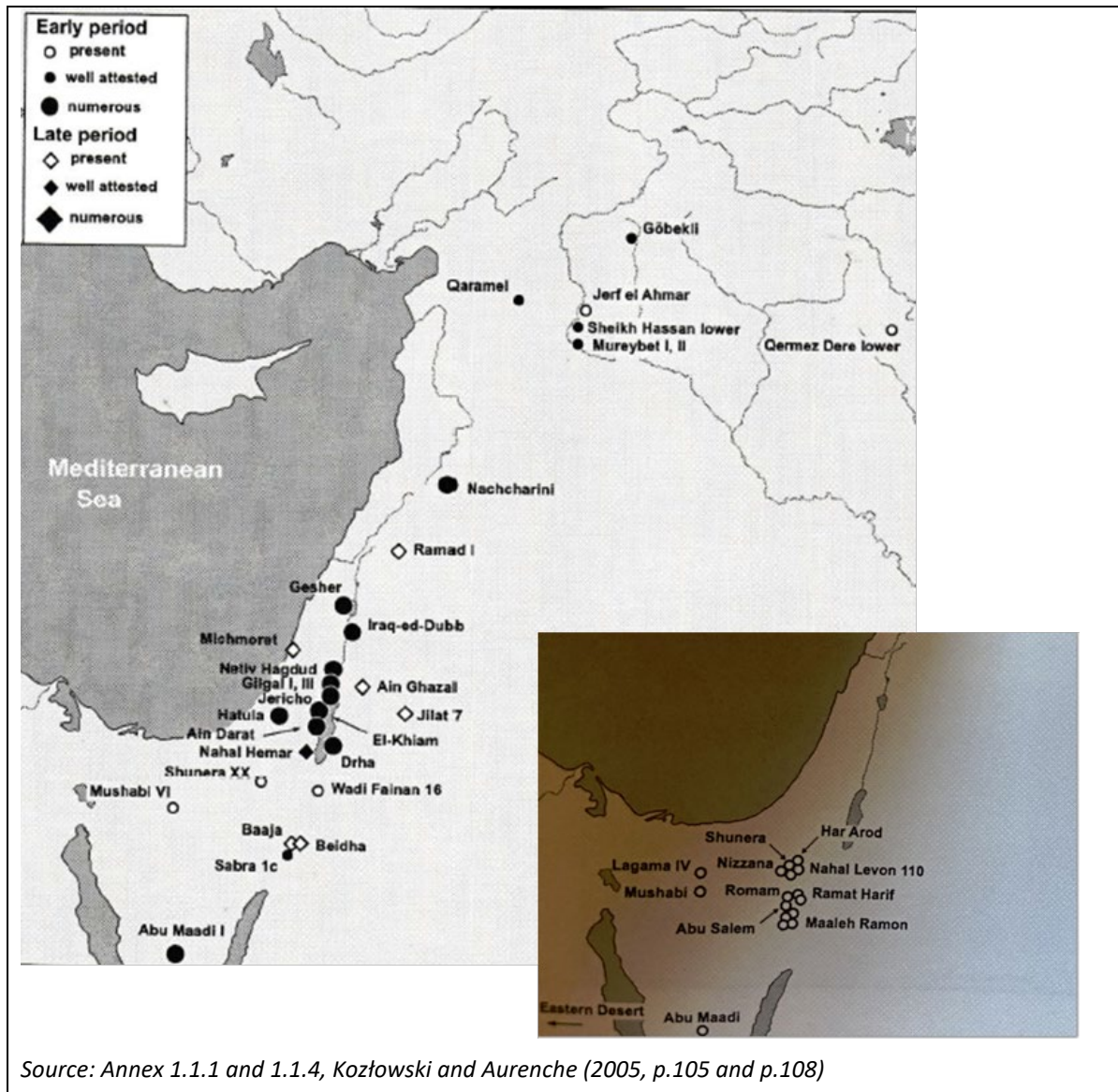
The analysis gave strong support for the origin and spread of the El Khiam point from WF16, although further sites should be incorporated in the analysis to support or challenge this. The analysis of character state changes between sites showed how more distinct and unusual point characters such as the snap notch and couze only base retouch were amended or developed in the diffusion of the El Khiam from WF16, providing hints of the interaction between sites. The analysis also enabled an exploration of aspects of the social learning environment, social structure and community identity of societies from 10-12,000 years ago. This showed the emergence, right at the cusp of the Epipalaeolithic-Neolithic divide, of a very distinct and communal social environment, with features reminiscent of the Harifian, at WF16, and how there might be a transition over a period of a thousand years or so to something more structured, sedentary and household based at Netiv Hagdud.

The results of the case study provided a further test of the predictions of cultural evolution theories. Theories provide an integrated model of human complexity and an explanation for the origin, variation and persistence of culture. Employing the theories in the case study allowed a productive and compelling interpretation of the evidence, particularly when harnessed to detailed studies of the emergence of Pre Pottery Neolithic A communities and of the case study sites. Cultural evolution theories allow nuanced interpretations of change without undue reliance on function and fitness, and acceptance of the weird and wonderful. Inevitably there are limitations to the theories, for example, in failing to capture the role of individual drive, feeling and creativity in cultural evolution. However, within the idea of culture and evolution as models of complexity, culture can be reasonably be said to evolve.

Appendices

Appendix 1: Distribution of El Kham and Harif points

The large map shows the distribution of El Kham points and the insert shows the distribution of Harif points, which are concentrated in the Negev.



Note: Early and late period refers to before and after c. 10,000 BP. WF16 (Wadi Fainan 16) indicated as El Kham only 'present' which understates the position because the date of the map is before much of the excavation at WF16 was undertaken.

Appendix 2: Comparison of morphological and retouch attributes for WF16a and b samples

Character	WF16a		WF16b		WF16 combined	
Sample size/%	n=20	%	n=29	%	n=49	%
Base shape	Straight 13 Concave 5 Irregular 2	65% 25%	Straight 20 Concave 6 Irregular 2 Convex 1	69% 21%	Straight 33 Concave 11 Irregular 4 Convex 1	67% 22%
Base retouch	Direct 10 Only couze 6 Bifacial 3 Inverse 1	50% 30% 15%	Only couze 19 Direct 4 Inverse 4 Bifacial 2	65% 14% 14%	Only couze 25 Direct 14 Bifacial 5 Inverse 5	51% 29% 10% 10%
Tip delineation	Convergent 18 Shouldered 2	90%	Convergent 22 Hooked 5 Shouldered 2	76% 17%	Convergent 40 Hooked 5 Shouldered 4	82% 10%
Tip retouch	Inverse 19 Alternate 1	95%	Inverse 21 Direct 6 Alternate? 1 No retouch 1	72% 21%	Inverse 40 Direct 6 Alternate 2 No retouch 1	82% 12%
Notch type	Snap 12 Retouch 8	60% 40%	Snap 29	100%	Snap 41 Retouch 8	84% 16%
Notch retouch	Bifacial 16 Inverse 2 Alternate 1 Direct 1	80% 10%	Bifacial 20 Inverse 6 Alternate? 3 (One side bifacial the other direct/inverse)	69% 21%	Bifacial 36 Inverse 8 Alternate 4 Direct 1	73% 16%

Note: these point attribute types are introduced at Section 5.6.

Appendix 3: Multivariate analysis of point metrics test statistics

Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.999	30228.672	5.000	115.000	.000
	Wilks' Lambda	.001	30228.672	5.000	115.000	.000
	Hotelling's Trace	1314.290	30228.672	5.000	115.000	.000
	Roy's Largest Root	1314.290	30228.672	5.000	115.000	.000
No	Pillai's Trace	.231	3.025	10.000	232.000	.001
	Wilks' Lambda	.772	3.169	10.000	230.000	.001
	Hotelling's Trace	.290	3.312	10.000	228.000	.000
	Roy's Largest Root	.276	6.396	5.000	116.000	.000

Note: Test statistics show that the groups (sites) differ significantly on a combination of the metrics (Sig. or p-value <0.05)

Appendix 4: Normality tests and boxplots of El Kham point metrics

Table 1: Normality tests for five metrics of WF16 sample (n=64)

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Length	.070	64	.200 [*]	.990	64	.905
Width	.123	64	.017	.972	64	.147
Thickness	.182	64	.000	.913	64	.000
L/W ratio	.051	64	.200 [*]	.991	64	.919
T/L ratio	.148	64	.001	.892	64	.000

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 2: Normality tests for five metrics of Dhra' sample (n=32)

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Length	.098	32	.200 [*]	.945	32	.105
Width	.088	32	.200 [*]	.974	32	.615
Thickness	.120	32	.200 [*]	.943	32	.091
L/W ratio	.104	32	.200 [*]	.980	32	.812
T/L ratio	.165	32	.026	.890	32	.003

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 3: Normality tests for five metrics of Netiv Hagdud sample (n=25)

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Length	.139	25	.200 [*]	.928	25	.080
Width	.123	25	.200 [*]	.965	25	.528
Thickness	.119	25	.200 [*]	.962	25	.456
L/W	.193	25	.017	.866	25	.004
T/L	.110	25	.200 [*]	.966	25	.541

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Appendix 4 (continued)

Table 4: Boxplot showing distribution of point length by site

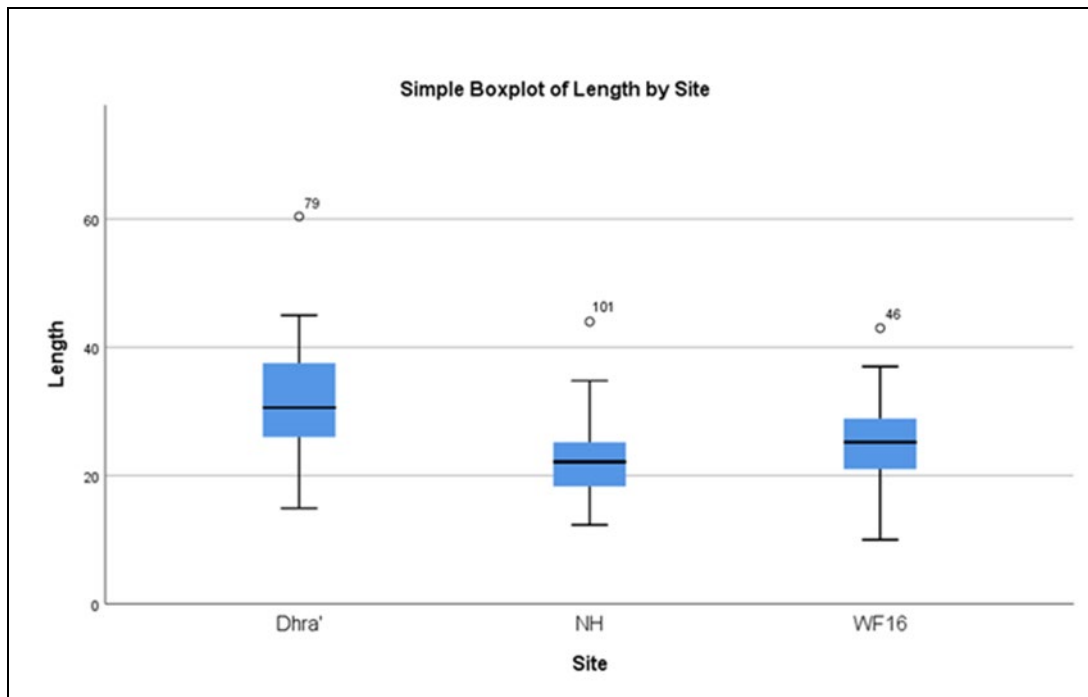
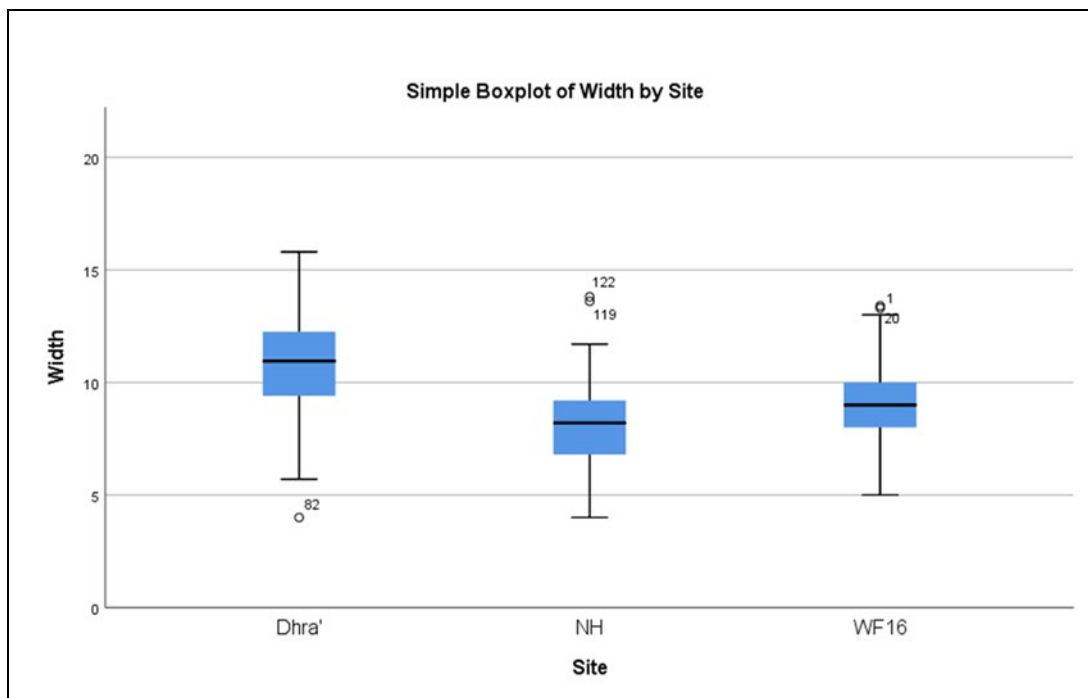
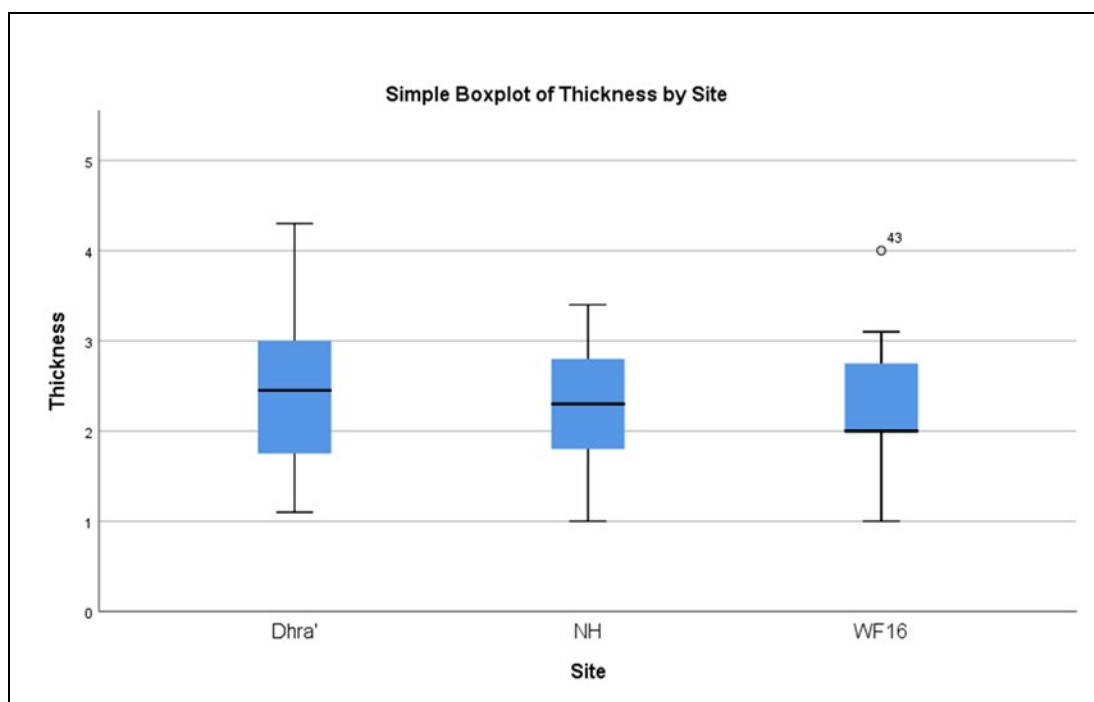


Table 5: Boxplot showing distribution of point width by site



Appendix 4 (continued)

Table 6: Boxplot showing distribution of point thickness by site



Appendix 5: Harifian and other comparator point CVs

Table 1: Coefficient of variation for length, width and L/W for 19 Harifian Assemblages

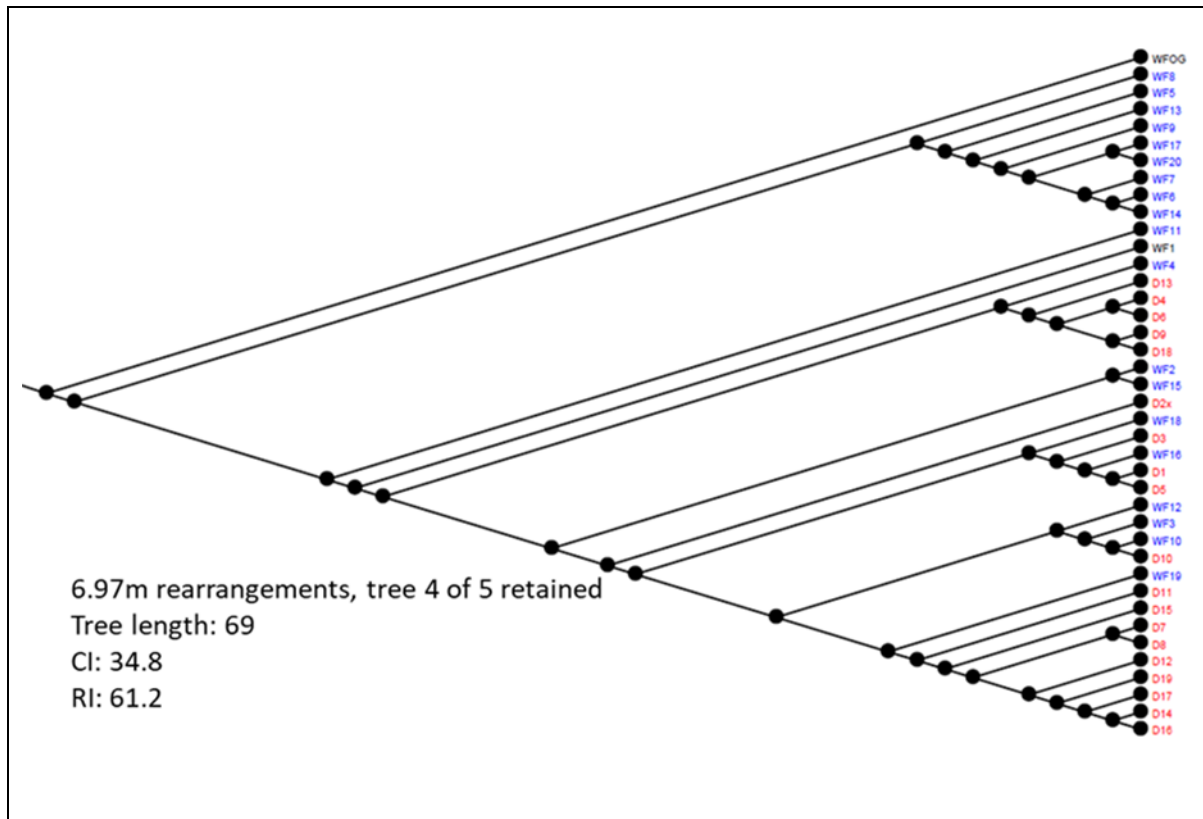
Site	Sample size	Length	Std Deviation	CV	Sample size	Width	Std Deviation	CV	L/W	Std Deviation	CV
Shunera IX	45	19.40	3.10	15.98	51	9.30	1.80	19.35	2.10	0.30	14.29
Shunera XXIV	15	19.40	3.20	16.49	20	10.30	2.30	22.33	2.00	0.20	10.00
Shluhat Romam	12	19.20	2.40	12.50	17	9.00	1.00	11.11	2.10	0.30	14.29
Shluhat Harif K III- 2	17	22.90	4.30	18.78	36	9.80	1.90	19.39	2.40	0.50	20.83
Romam Gxx	32	21.80	3.90	17.89	78	8.70	1.30	14.94	2.50	0.40	16.00
Ramat Harif G VIII- 3/8	33	25.80	3.90	15.12	52	9.80	1.70	17.35	2.70	0.60	22.22
Ramat Harif G VIII- 3/7	183	25.30	4.60	18.18	242	9.60	1.70	17.71	2.70	0.50	18.52
Ramat Harif G VIII- 3/ 2	107	24.60	4.70	19.11	138	9.50	1.50	15.79	2.60	0.50	19.23
Abu Salem Loe 22	45	25.40	5.40	21.26	61	9.10	1.70	18.68	2.90	0.60	20.69
Maaleh Ramon West	9	24.80	2.90	11.69	12	9.80	1.50	15.31	2.40	0.40	16.67
Maaleh Ramon East	28	22.10	4.50	20.36	40	9.80	1.70	17.35	2.30	0.40	17.39
Shunera X	18	22.60	6.00	26.55	23	9.10	1.60	17.58	2.50	0.50	20.00
Shunera VI all	93	23.30	3.90	16.74	117	9.20	1.70	18.48	2.60	0.50	19.23
Shunera VI Loe 1	42	24.00	4.20	17.50	51	9.40	1.30	13.83	2.60	0.50	19.23
Shunera VI Loe 3	29	22.70	3.90	17.18	38	8.90	1.90	21.35	2.70	0.60	22.22
Shunera VI Loe 4	15	23.40	3.70	15.81	19	9.20	2.10	22.83	2.70	0.50	18.52
Nahal Lavan 110	194	23.70	3.90	16.46	194	9.70	1.10	11.34	2.50	0.50	20.00
Mushabi III	56	27.10	3.70	13.65	56	9.80	1.20	12.24	2.80	0.50	17.86
Lagama I V	37	24.60	5.20	21.14	37	8.70	1.70	19.54	3.00	1.00	33.33
Total/mean	1010			17.49				17.18			18.97
Source: Table IX-9, Goring-Morris (1987, p.355). Units in mm.											

Note: Taking out smaller sample sizes, or only including the assemblages seen as contemporary or overlapping with WF15 (Finlayson et al., 2011) i.e. Ramat Harif, Abu Salem Loe and Maaleh Ramon East, does not make a significant difference to average CVs.

Table 2: Coefficient of variation for long diagonal, short diagonal and thickness for nine Scandinavian Assemblages

Site	Sample size	CV long diagonal	CV short diagonal	CV thickness
Tågerup	30	19.40	13.42	19.77
Blak	30	12.59	19.05	N/A
Kongemose	30	15.30	12.14	14.05
Månedale	30	10.93	16.13	19.49
Stationsvej 19	30	13.60	13.38	16.91
Segebro	30	14.06	23.95	19.21
Villingebæk	30	18.79	14.40	18.52
SU7	30	17.90	24.12	27.09
Tågerup Ertebelle	30	18.70	20.12	24.43
Total/mean	270	15.70	17.41	19.93
Source: Table 5.10 Edinborough (2005, p.248). Units in mm.				

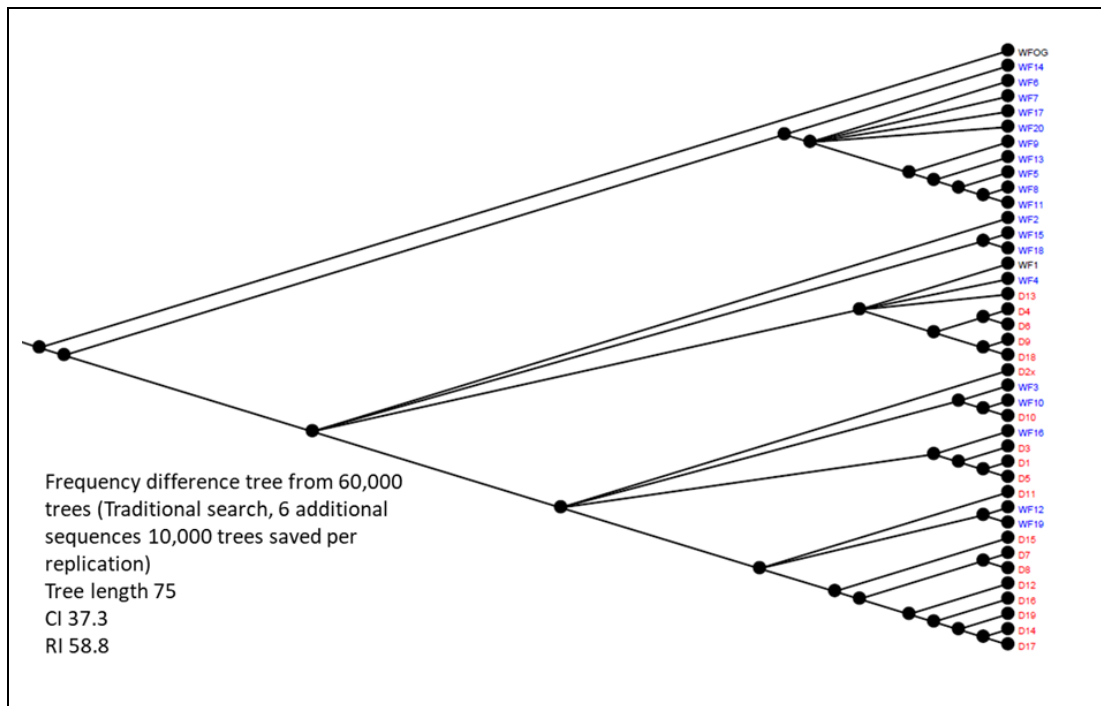
Appendix 6: One of five trees using 'archetype' outgroup for WF16 and Dhra' pair



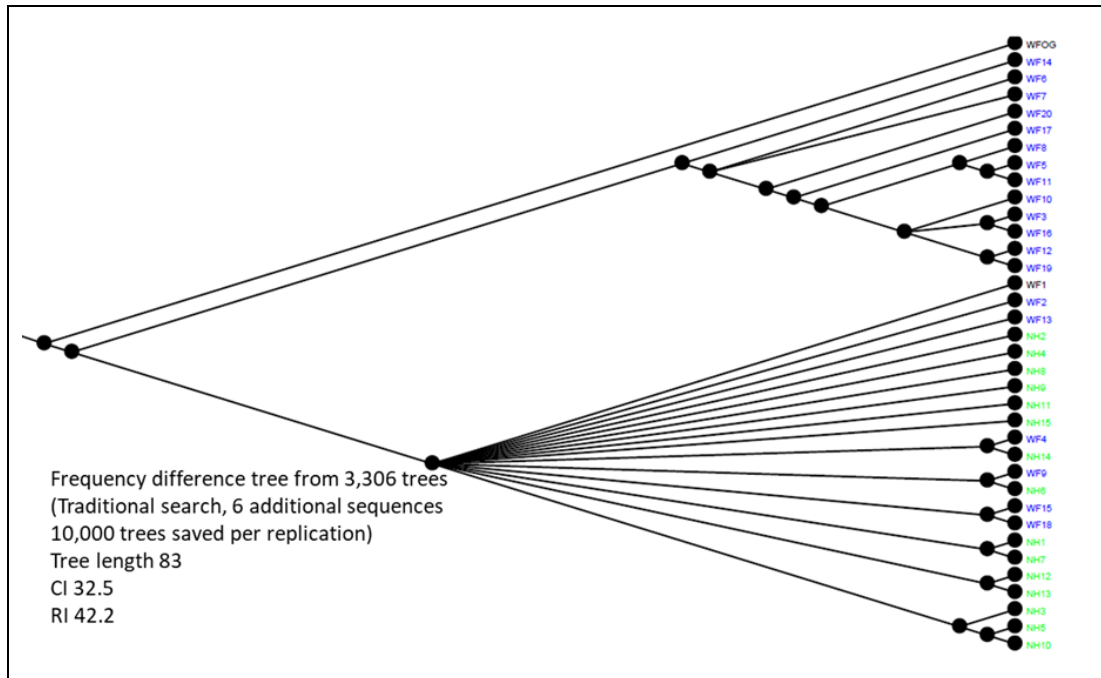
Note: This is one of five trees relating to the WF16 to Dhra' pairing where the outgroup was the typical or 'archetypal' WF16 string (Table 6.5) and the 'New Technology' search tool applied. The patterning is similar to that shown in Figure 7.5a. The majority rule consensus of these five trees is shown in Appendix 13.

Appendix 7: Phylogenetic trees using the neutral outgroup

WF16 and Dhra' pair



WF16 and Netiv Hagdud pair

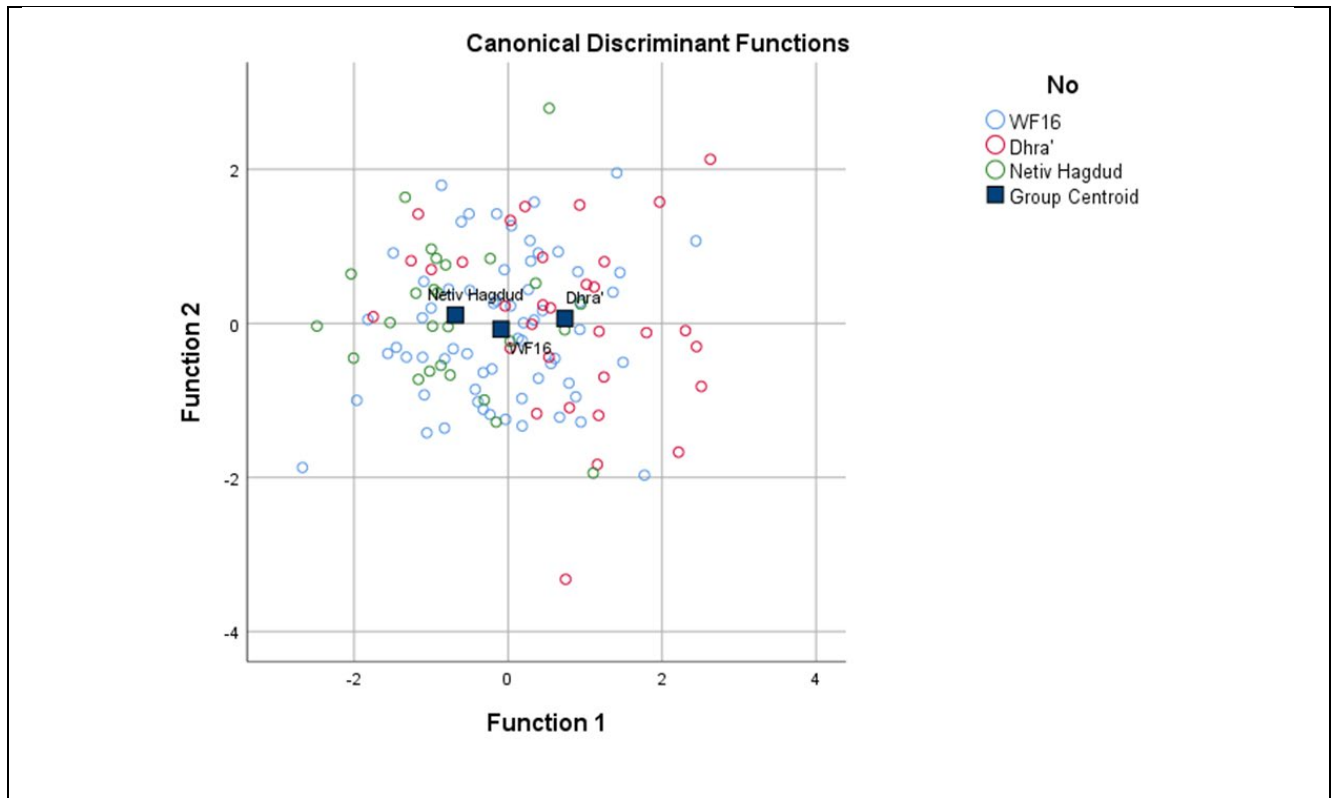


Note: These are both produced using the neutral outgroup (Table 6.5). They produce similar results to the equivalent Figures for the WF16 Dhra' pairing (top, Figure 7.5a) and the WF16 Netiv Hagdud pairing (bottom, Figure 7.5c).

Appendix 8: The process and steps for creating matrices of taxa and character for analysis

Step	Process
1	From Smith (2005) data spreadsheet take only El Khiam points and strip out incomplete, unretouched, and those with no notch data, leaving 40 points, 20 each from WF16 and Dhra'. Add 15 Netiv Hagdud points characterised from drawings in Nadel (1997).
2	Create discrete character table tab , and using VLOOKUP, create matrix tab.
3	Calculate length width ratio, and convert the 2 metric characters into discrete ones using character system.
4	Using CONCATENATE to create string for each point from the matrix into a cell.
5	Using a pivot table, identify any duplicates. There was only one (called Dx2 in analysis) giving 64 taxa.
6	Add hypothetical outgroup taxa WFOG giving 65 taxa in total.
7	Create matrix in Mesquite, and export as a TNT file.
8	Undertake various traditional and New Technology searches in TNT with different parameters and different outgroup choices, and create consensus trees where appropriate. For traditional searches the maximum tree memory of 60,000, and the trade-off between the number of additional sequences (replications) and the trees saved per replication (typically 6 and 10,000 respectively), was explored to ensure consistent results.
9	Export data, including trees, as Nexus file for analysis of CI and RI and re-presentation in Mesquite.

Appendix 9: Results of discriminant analysis using only length, width and thickness

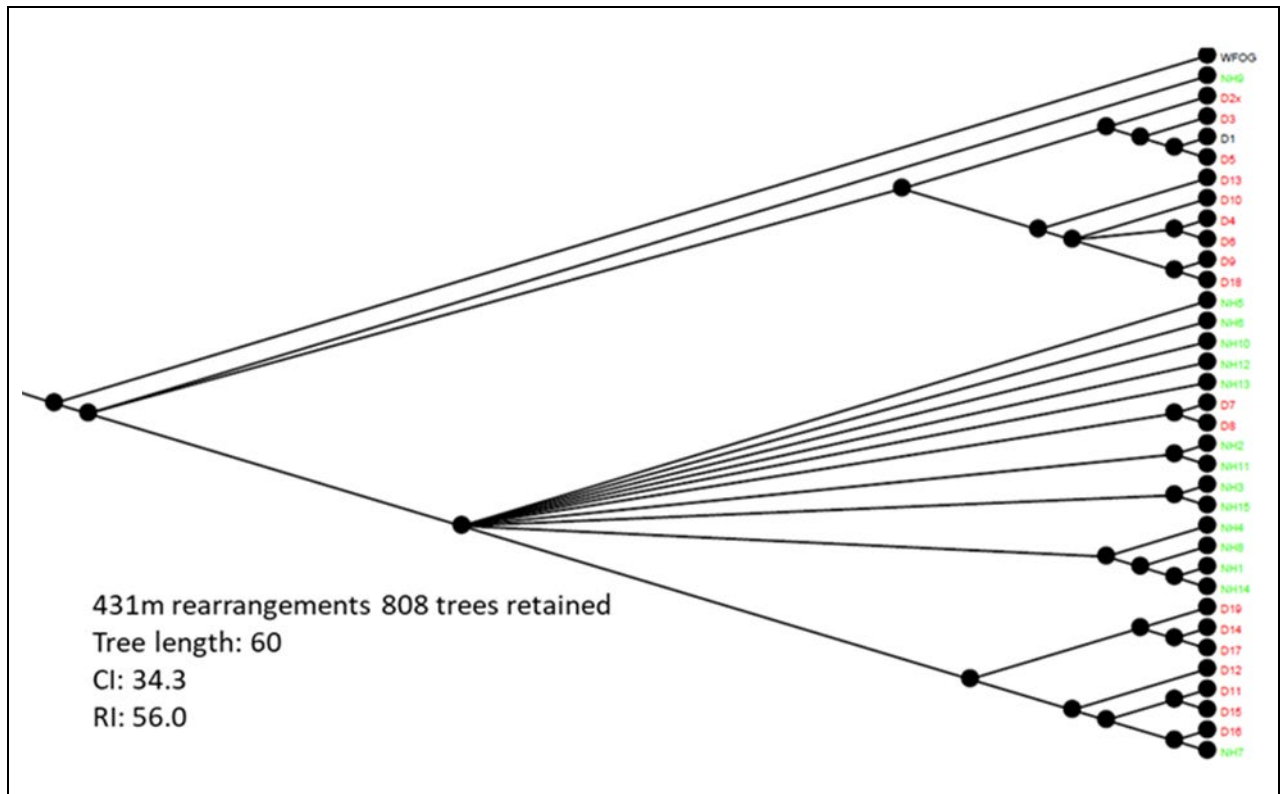


Statistics: Box's M sig. 0.421, Wilks' Lambda sig. 0.000, 57.4% of cases were correctly classified. Multi-collinearity statistics in table below show good to acceptable levels of Tolerance (>0.4 no concern) and Variance Inflation Factor (VIF) (<5 being acceptable is a common threshold).

Collinearity Statistics

Tolerance	VIF
.793	1.261
.831	1.204
.943	1.060

Appendix 10: Majority rule consensus tree for Dhra' and Netiv Hagdud pair



Note: This is the same analysis as the tree shown in Figure 7.5c and shows a similar pattern, but the majority rule as opposed to frequency consensus reduces the CI and RI a little and creates a less well resolved tree particularly in the central section shown by the radiating branches for Netiv Hagdud points.

Appendix 11: Phylogenetic trees produced with the two metrical characters removed

Figure 1: WF16 and Dhra' pairing

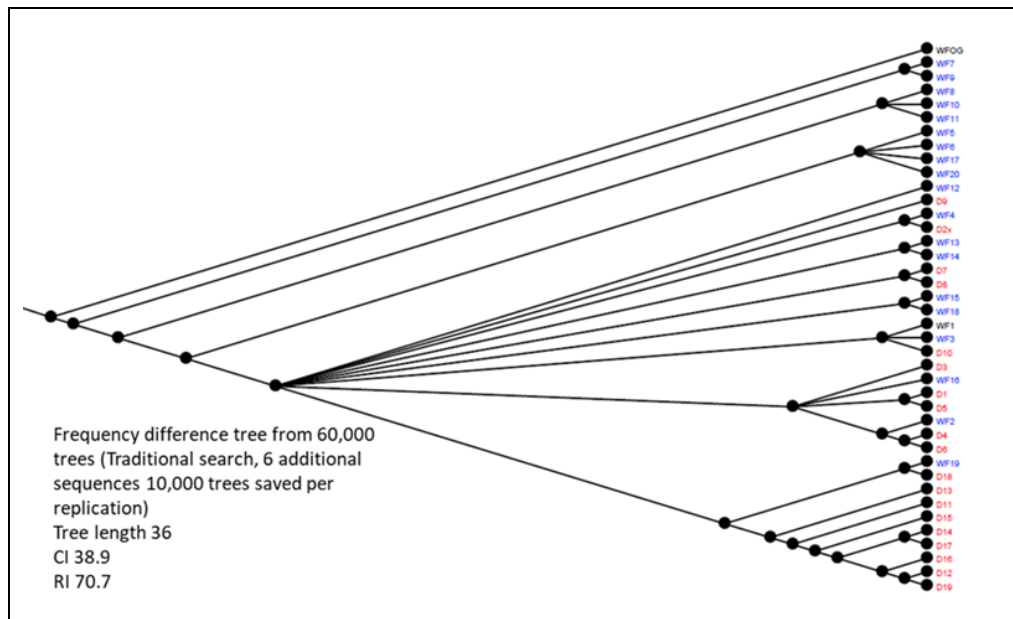
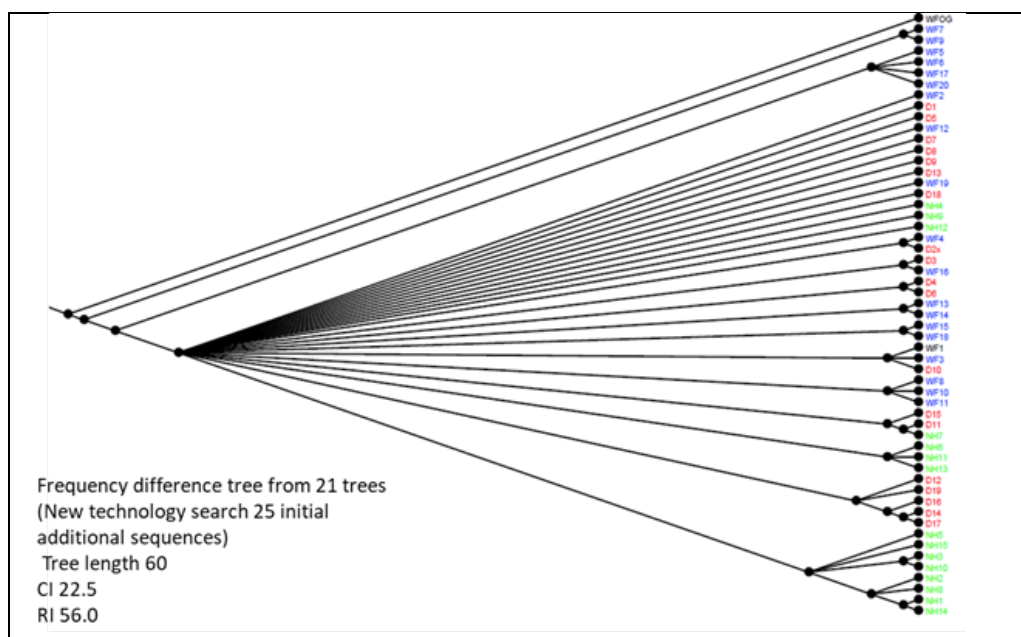


Figure 2: Three site analysis



Note: Fewer characters should simplify the analysis and it does reduce tree lengths and improve CI and RI for the Traditional search results (top), but the maximum number of trees in memory (60,000) was reached. In the bottom New Technology search result the RI seem low given it is the consensus of only a small number of trees (21) with a particularly unresolved patch of radiating Dhra', Netiv Hagdud and WF16 points. In both cases the results are broadly similar to the results with metrical characters (Figure 7.5a for top and 7.6 for bottom) although individual points move around a bit. The metrical characters add some resolution depth particularly to the Dhra' v Netiv Hagdud patterning. Potentially this is because these two are furthest away from each other on the purely metrical comparison (Figure 7.3).

Appendix 12: Matrices used in experimental phylogenetic analysis

Matrix 1 - used to create Figure 6.9a

```

Saved data and trees (Nexus format) to file C:\Users\Jon\Documents\
nstates 8 ;
xread 'Data saved from TNT'
6 13
&[num]
WF1          241223
WF2          211222
WF3          241223
WF4          141213
D1           111214
D2           112113
D3           131313
D4           212113
NH1          211113
NH2          212111
NH3          211113
NH4          132111
WFOG         251225

```

Matrix 2 – used to create Figure 6.9b

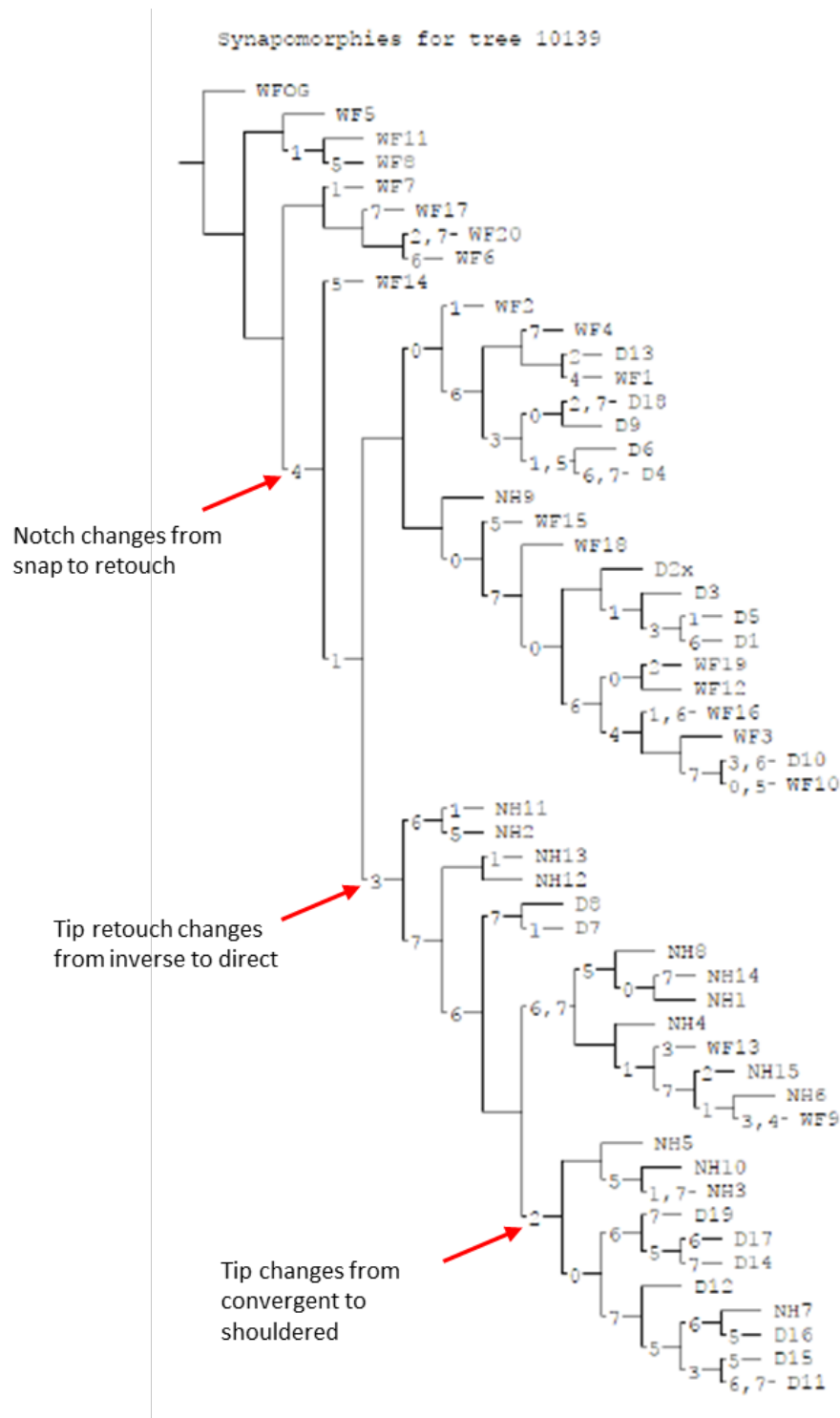
```

xread 'Data saved from TNT'
6 13
&[num]
WF1          211223
WF2          141213
WF3          241223
WF4          241222
D1           132113
D2           212113
D3           111214
D4           111313
NH1          142111
NH2          211111
NH3          211113
NH4          211113
WFOG         251225

```

Appendix 13: Phylogenetic trees showing character synapomorphies

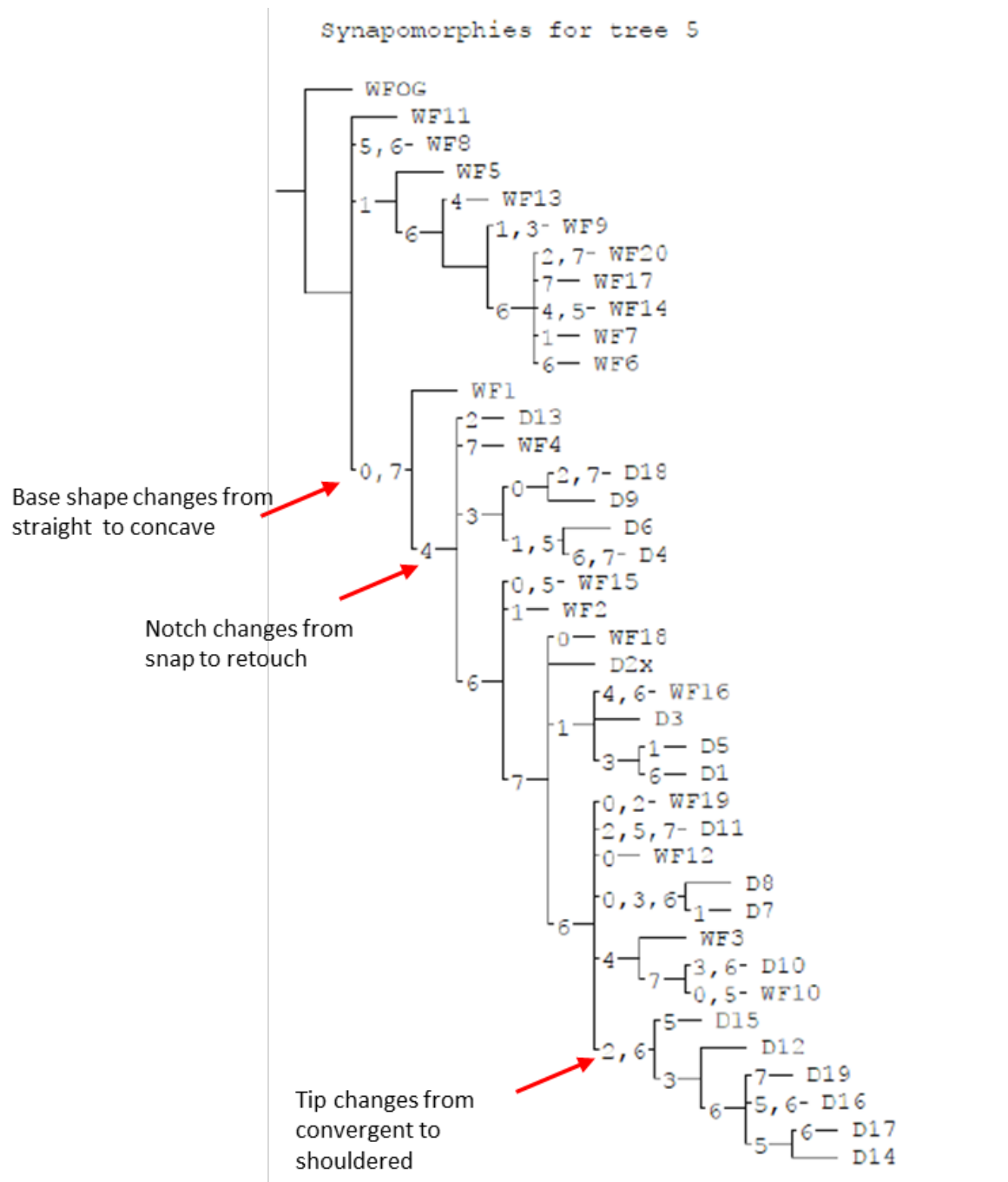
Figure 1



Note: One of the 10,144 trees (tree 10,139) making the consensus tree shown in Figure 7.6 of all three sites (3.8bn rearrangements, tree length: 89). Tree shown has CI of 27.0 and RI of 63.0. Complex reversions and the influence of the metrical characters is shown throughout.

Appendix 13 (continued)

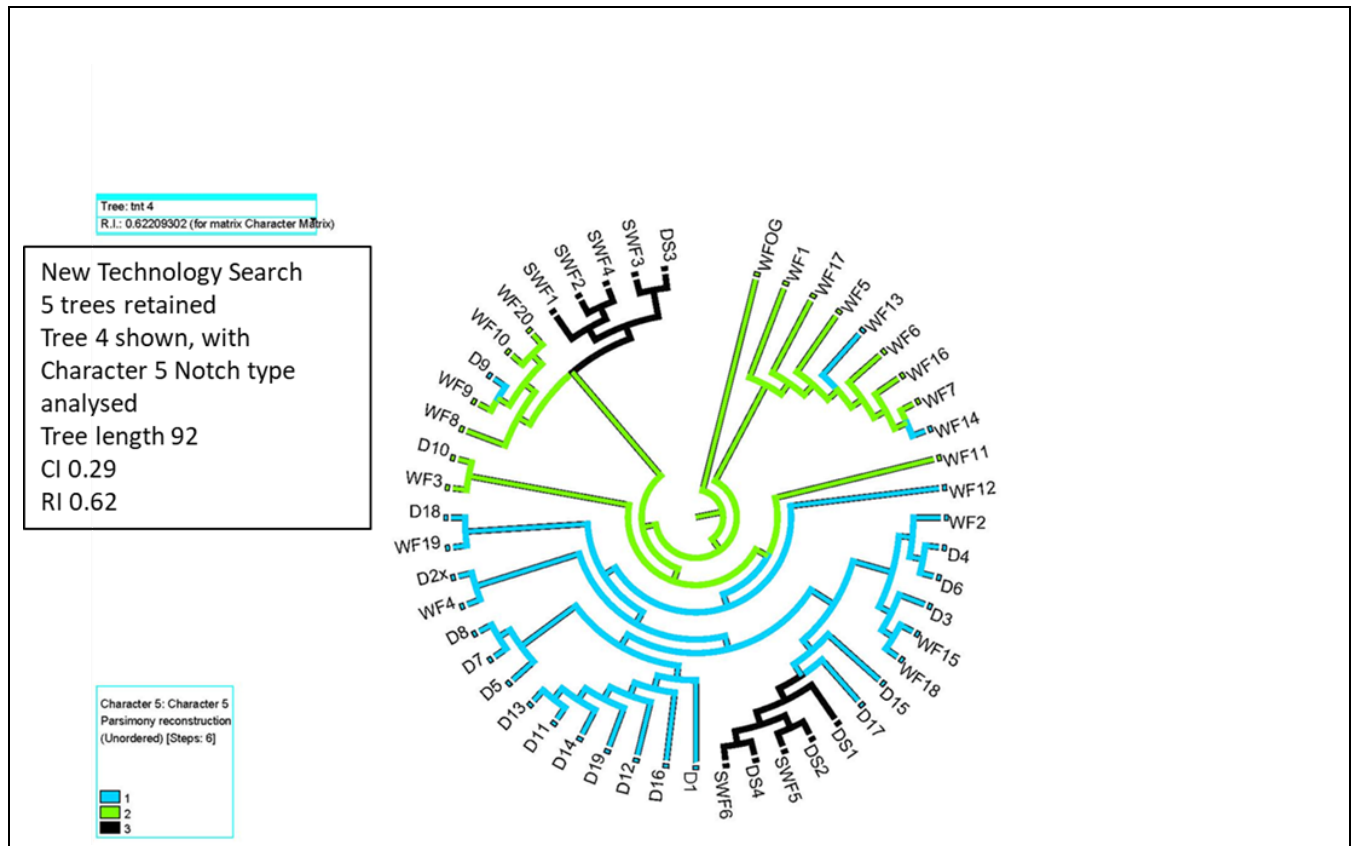
Figure 2



Note: This is a majority rule consensus tree of five (tree 5 is actually 6 counting from 0 as in TNT), showing the WF16 to Dhra' pairing. The outgroup was the typical or 'archetypal' WF16 string (Table 6.5) and the 'New Technology' search tool applied. 6.97m rearrangements were tried and 5 trees retained with a tree length of 69. The consensus tree shown has CI of 32.9 and RI of 57.8. In this example there are again complex reversions and the tip retouch from inverse to direct ('3') is not as clear cut as in Figure 7.8 and it is more ambiguous as to whether it is before or after the tip change from concave to shouldered ('2').

Appendix 14: Salibiya point analysis

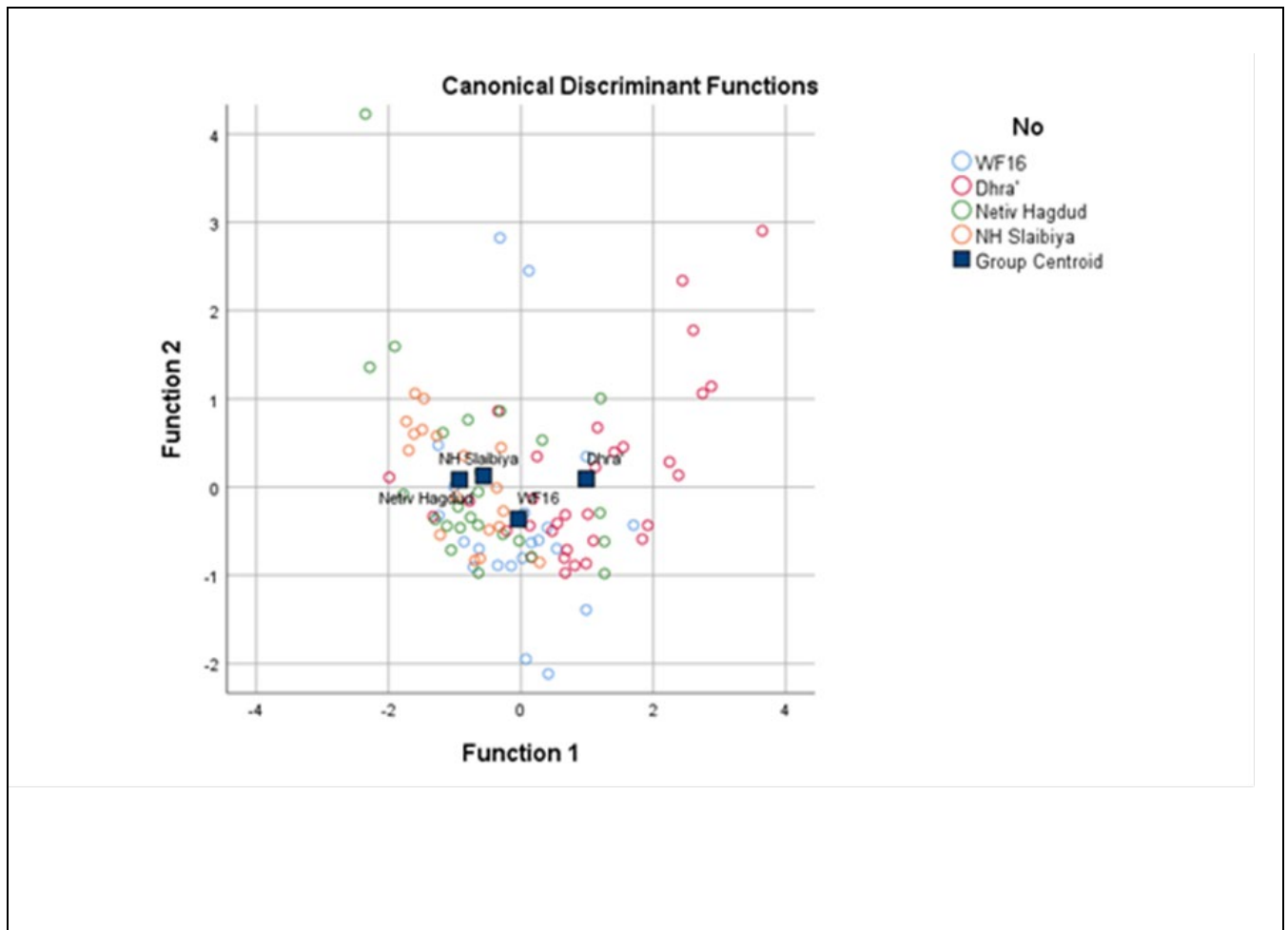
Figure 1: Tree showing distribution of WF16 and Dhra' Salibiya points



Note: Tree shows coding for Character 5, notch type. Black coded points 'other' represent Salibiya points (SWF = Salibiya points from WF16 and DS = ones from Dhra'). Despite coding for the two notch characters in an identical way, and differently to all the other points, the Salibiya points tend to cluster by their site origin because of the first 4 characters such as base shape. The patterning is quite messy, and Tree 4 is one of the clearest, but it illustrates the point.

Appendix 14 (continued)

Figure 2: Results of discriminant analysis including Netiv Hagdud Salibiya points



Note: Analysis shows discrimination between sites treating Salibiya points from Netiv Hagdud (NH Salibiya) as a separate site. Length, width, thickness, L/W and T/L used, size adjusted by the geometric mean. The results show that the NH Salibiya points group closely with their El Kham equivalents. Discriminant analysis of Salibiya points from WF16 and Dhra' did not show the equivalent grouping as they were very small samples with a high variation in metrical attributes. Statistics: Wilks' Lambda sig. 0.000, 55.6% of NH Salibiya cases actually classified as Netiv Hagdud ones.

References

- Acerbi, A. and Mesoudi, A. (2015) 'If we are all cultural Darwinians what's the fuss about? Clarifying recent disagreements in the field of cultural evolution', *Biology & philosophy*, 30(4), pp.481-503.
- Andersson, C., Törnberg, A., Törnberg, P., Davidson, I., Hovers, E., Belfer-Cohen, A., Kohler, T.A., Laubichler, M.D., O'Brien, M.J., Lycett, S.J. and Read, D.W. (2014) 'An evolutionary developmental approach to cultural evolution', *Current Anthropology*, 55(2), pp.154-174.
- Asma, S.T. and Gabriel, R. (2019) *The Emotional Mind: the affective roots of culture and cognition*. Cambridge, MA: Harvard University Press.
- Barkai, R. (2011) 'PPNA Stone and Flint Axes as Cultural Markers: Technological, Functional, and Symbolic Aspects', in Healey, E., Campbell, S. and O. Maeda, O. (eds.) *The State of the Stone: Terminologies, Continuities and Contexts in Near Eastern Lithics. Studies in Early Near Eastern Production, Subsistence, and Environment* 13. Berlin: ex oriente, pp. 443–448.
- Barnard, A. (2000) *History and Theory in Anthropology*. Cambridge: Cambridge University Press.
- Barton, C.M. (1997) 'Stone tools, style, and social identity: an evolutionary perspective on the archaeological record', *Archeological Papers of the American Anthropological Association*, 7(1), pp.141-156.
- Bar-Yosef, O., (1987) 'Direct and indirect evidence for hafting in the Epi-Palaeolithic and Neolithic of the Southern Levant', in La Main et l'Outil. Manches et emmanchements préhistoriques, Table Ronde C.N.R.S. Lyon: Maison de l'Orient et de la Méditerranée, pp. 155-164.
- Bar-Yosef, O. and Gopher, A. (1997) 'The excavations of Netiv Hagdud: stratigraphy and architectural remains', in Bar-Yosef, O. and Gopher, A. (eds.) *An Early Neolithic Village in the Jordan Valley Part I: The Archaeology of Netiv Hagdud*. Cambridge, MA: Peabody Museum of Archaeology and Ethnology Harvard University, pp.41-69.
- Belfer-Cohen, A. and Goring-Morris, A.N. (2010) 'The Initial Neolithic in the Near East: Why It Is So Difficult to Deal With the PPNA', *Journal of the Israel Prehistoric Society*, 40, pp.1-18.
- Belfer-Cohen, A. and Goring-Morris, A.N. (2011) 'Becoming farmers: the inside story', *Current Anthropology*, 52(S4), pp.S209-S220.
- Belfer-Cohen, A. and Goring-Morris, A.N., (2014) 'North and South–variable trajectories of the Neolithic in the Levant', in Bar-Yosef, O., Finlayson, B. and Makarewicz, C (eds.) *Settlement, Survey, and Stone: Essays on Near Eastern Prehistory in Honor of Gary Rollefson*. Berlin: Ex oriente, pp.61-71.
- Belfer-Cohen, A. and Goring-Morris, N. (2017) 'Moving around' and the evolution of corporate identities in the late Epipalaeolithic Natufian of the Levant', in M. Benz, H.-GK Gebel, and T. Watkins (eds.), *Neolithic Corporate Identities, Studies in Early Near Eastern Production, Subsistence, and Environment*, 20. Berlin: Ex oriente, pp.81-90.
- Bentley, R.A., Hahn, M.W. and Shennan, S.J. (2004) 'Random drift and culture change', *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 271(1547), pp.1443-1450.
- Bentley, R. A. and Maschner, H. D. (2007) 'Complexity Theory' in Bentley, R.A., Maschner, H.D. and Chippindale, C. (eds.) *Handbook of Archaeological Theories*. Lanham: AltaMira Press, pp.245-270.

- Bettinger, R.L. and Eerkens, J., (1999) 'Point typologies, cultural transmission, and the spread of bow-and-arrow technology in the prehistoric Great Basin', *American antiquity*, 64(2), pp.231-242.
- Birch-Chapman, S. (2017) *Estimating population parameters of early villages in the Pre-Pottery Neolithic central and southern Levant*. Doctoral dissertation, Bournemouth University.
- Bourdieu, P. (1977) *Outline of a theory of practice*. New York: Cambridge University Press.
- Boyd, R. and Richerson, P.J. (1985) *Culture and the evolutionary process*. Chicago: University of Chicago Press.
- Boyd, R. and Richerson, P.J. (2009) 'Culture and the evolution of human cooperation', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1533), pp.3281-3288.
- Boyd, R. and Richerson, P.J. (2010) 'Transmission coupling mechanisms: cultural group selection', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1559), pp.3787-3795.
- Boyd, R. and Silk, J. B. (2015) *How humans evolved*. 7th edn. New York: W. W. Norton.
- Boyd, R., Borgerhoff-Mulder, M., Durham, W.H. and Richerson, P.J. (1997) 'Are cultural phylogenies possible', *Human by nature: Between biology and the social sciences*, pp.355-386.
- Boyd, R., Richerson, P.J. and Henrich, J. (2011) 'The cultural niche: Why social learning is essential for human adaptation', *Proceedings of the National Academy of Sciences*, 108(Supplement 2), pp.10918-10925.
- Boyd, R., Richerson, P.J. and Henrich, J. (2013) 'The cultural evolution of technology: facts and theories', *Cultural evolution: society, technology, language, and religion*, 12, pp.119-142.
- Buchanan, B. and Collard, M. (2007) 'Investigating the peopling of North America through cladistic analyses of Early Paleoindian projectile points', *Journal of Anthropological Archaeology*, 26(3), pp.366-393.
- Cardillo, M. and Alberti, J. (2015) 'The evolution of projectile points and technical systems: A case from Northern Patagonian coast (Argentina)', *Journal of Archaeological Science: Reports*, 2, pp.612-623.
- Cartolano, M. (2016) *Diverse Evolutionary Paths: a comparative analysis of changes in demography and modes of cooperation across the forager-farmer transition in Southwest Asia*. MSc thesis. Oxford Brookes University.
- Cavalli-Sforza, L.L. and Feldman, M.W. (1981) *Cultural transmission and evolution: A quantitative approach*. Princeton: Princeton University Press.
- Cheshier, J. and Kelly, R.L. (2006) 'Projectile point shape and durability: the effect of thickness: length', *American Antiquity*, 71(2), pp.353-363.
- Chudek, M. and Henrich, J. (2011) 'Culture–gene coevolution, norm-psychology and the emergence of human prosociality', *Trends in cognitive sciences*, 15(5), pp.218-226.
- Clark, G.A. and Barton, C.M. (1997) 'Rediscovering Darwin', *Archeological Papers of the American Anthropological Association*, 7(1), pp.309-319.
- Clarke, D. (1973) 'Archaeology: the loss of innocence', *Antiquity*, 47(185), pp.6-18.

- Clarke, D. (1978) *Analytical Archaeology*. 2nd edn. New York: Columbia University Press.
- Cochrane, E.E. (2001) 'Style, function, and systematic empiricism: The conflation of process and pattern', in Hurt, T. D. and Rakita, G. F. M. (eds.) *Style and Function: Conceptual Issues in Evolutionary Archaeology*. Westport, Connecticut: Bergin and Garvey, pp.183-202.
- Cochrane, E.E. (2009) 'Evolutionary explanation and the record of interest', in Shennan, S. (ed.) *Pattern and Process in Cultural Evolution*. Oakland: University of California Press, pp.113-132.
- Cohen, A.P. (1985) *The Symbolic Construction of Community*. Abingdon: Routledge.
- Collar, A., Coward, F., Brughmans, T. and Mills, B.J. (2015) 'Networks in archaeology: phenomena, abstraction, representation', *Journal of Archaeological Method and Theory*, 22(1), pp.1-32.
- Collard, M., Shennan, S.J. and Tehrani, J.J. (2006) 'Branching, blending, and the evolution of cultural similarities and differences among human populations', *Evolution and Human Behavior*, 27(3), pp.169-184.
- Collier, Z. (In prep.). *Spatial analysis of chipped stone assemblages from WF16 southern Jordan: implications for Early Neolithic Social Organisation*. Ongoing PhD thesis Oxford Brookes University, UK.
- Coward, F. (2010) 'Small worlds, material culture and ancient Near Eastern social networks', in Dunbar, R., Gamble, C., and Gowlett, J. (eds.) *Social Brain, Distributed Mind*. Oxford: Oxford University Press, pp.449-79.
- Creanza, N., Kolodny, O. and Feldman, M.W. (2017) 'Cultural evolutionary theory: How culture evolves and why it matters', *Proceedings of the National Academy of Sciences*, 114(30), pp.7782-7789.
- Dag, D., Groman-Yaroslavski, I., Gopher, A. and Goring-Morris, A.N. (2010) 'The Gilgal I lithic assemblage', in Bar-Yosef, O., Goring-Morris, A.N. and Gopher, A. (eds.) *Gilgal - Early Neolithic Occupations in the Lower Jordan Valley: The Excavations of Tamar Noy*, Oxford, Oxbow, pp.39-82.
- Darwin, C. (1859) *The Origin of Species*. Philadelphia: University of Pennsylvania Press, 2006. Original edition 1859.
- Deacon, T. W. (1997) *The Symbolic Species: The Co -evolution of Language and the Brain*. New York: W. W. Norton & Company.
- De Beauvoir, S. (1948) *The ethics of ambiguity*. Secaucus: Citadel Press.
- Dunbar, R. I. M. (1998) 'The social brain hypothesis', *Evolutionary Anthropology*, 6, pp.178-190.
- Dunbar, R.I.M. (2003) 'The social brain: mind, language, and society in evolutionary perspective', *Annual review of Anthropology*, 32(1), pp.163-181.
- Dunbar, R.I.M. and Shultz, S. (2017) 'Why are there so many explanations for primate brain evolution?' *Philosophical Transactions of the Royal Society B: Biological Sciences*, 372(1727), p.20160244.
- Dunnell, R.C. (1980) 'Evolutionary theory and archaeology', in M. B. Schiffer (ed.) *Advances in archaeological method and theory Vol 3*. New York: Academic Press, pp. 35-99.

- Edinburgh, K.S.A. (2004) *Evolution of bow-arrow technology*. Doctoral dissertation. University of London.
- Edwards, P.C., Meadows, J., Sayej, G. and Westaway, M. (2004) 'From the PPNA to the PPNB: new views from the Southern Levant after excavations at Zahrat adh-Dhra'2 in Jordan', *Paléorient*, pp.21-60.
- Eerkens, J.W. and Bettinger, R.L. (2001) 'Techniques for assessing standardization in artifact assemblages: can we scale material variability?' *American Antiquity*, 66(3), pp.493-504.
- Eerkens, J. W. and Bettinger, R. L. (2008) 'Cultural transmission and the analysis of stylistic and functional variation', *Transmission and Archaeology: Issues and Case-Studies*, pp. 21-38.
- Eerkens, J.W. and Lipo, C.P. (2005) 'Cultural transmission, copying errors, and the generation of variation in material culture and the archaeological record', *Journal of Anthropological Archaeology*, 24(4), pp.316-334.
- Eerkens, J.W. and Lipo, C.P. (2007) 'Cultural transmission theory and the archaeological record: providing context to understanding variation and temporal changes in material culture', *Journal of Archaeological Research*, 15(3), pp.239-274.
- Enquist, M., Ghirlanda, S. and Eriksson, K. (2011) 'Modelling the evolution and diversity of cumulative culture', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1563), pp.412-423.
- Eriksen, T.H. (2004) *What is anthropology?* London: Pluto Press.
- Finlayson, B. and Makarewicz, C. (2017) 'The construction of community in the early Neolithic of Southern Jordan', in M. Benz, H.-GK Gebel, and T. Watkins (eds.) *Neolithic Corporate Identities, Studies in Early Near Eastern Production, Subsistence, and Environment*, 20. Berlin: Ex oriente, pp.91-106.
- Field, A. (2018) *Discovering statistics using IBM SPSS statistics*. 5th edn. London: Sage Publications.
- Finlayson, B., Kuijt, I., Arpin, T., Chesson, M., Dennis, S., Goodale, N., Kadowaki, S., Maher, L., Smith, S., Schurr, M. and McKay, J. (2003) 'Dhra', excavation project, 2002 interim report', *Levant*, 35(1), pp.1-38.
- Finlayson, B., Mithen, S. and Smith, S., (2011) 'On the edge: Southern Levantine Epipalaeolithic–Neolithic chronological succession', *Levant*, 43(2), pp.127-138.
- Foley, R. A., and Lahr, M. M. (2011) 'The evolution of the diversity of cultures', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1567), pp. 1080-1089.
- Fracchia, J. and Lewontin, R.C. (1999) 'Does culture evolve?' *History and theory*, 38(4), pp.52-78.
- Fuentes, A. (2006) 'Evolution is important but it is not simple: Defining cultural traits and incorporating complex evolutionary theory', *Behavioral and Brain Sciences* 29(4), pp.354-355.
- Fuentes, A. (2016) 'The extended evolutionary synthesis, ethnography, and the human niche: Toward an integrated anthropology', *Current Anthropology*, 57(S13), pp.S13-S26.
- Gamble, C., Gowlett, J. and Dunbar, R. (2011) 'The social brain and the shape of the Palaeolithic', *Cambridge Archaeological Journal*, 21(1), pp.115-136.

- Garvey, R. (2018) 'Current and potential roles of archaeology in the development of cultural evolutionary theory', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 373(1743), p.20170057.
- Goloboff, P.A., Farris, J.S. and Nixon, K.C. (2008) 'TNT, a free program for phylogenetic analysis', *Cladistics*, 24(5), pp.1-13.
- Goodale, N.B., Kuijt, I., and Finlayson, B. (2007) 'Chipped stone variability: an overview of the PPNA lithic assemblage from Dhra ', Jordan', In *Technical Systems and Near Eastern PPN Communities. Proceedings of the 5th international Workshop. Antibes: Éditions APDCA*, pp.63-74.
- Goodale, N., Otis, H., Andrefsky Jr, W., Kuijt, I., Finlayson, B. and Bart, K. (2010) 'Sickle blade life-history and the transition to agriculture: an early Neolithic case study from Southwest Asia', *Journal of Archaeological Science*, 37(6), pp.1192-1201.
- Gopher, A., (1989) 'Neolithic arrowheads of the Levant: results and implications of a seriation analysis', *Paléorient*, 15(1), pp.43-56.
- Gopher, A. (1997) 'Ground stone tools and other stone objects', in Bar-Yosef, O. and Gopher, A. (eds.) *An Early Neolithic Village in the Jordan Valley Part I: The Archaeology of Netiv Hagdud*. Cambridge, MA: Peabody Museum of Archaeology and Ethnology Harvard University, pp.152-176.
- Gould, S.J. and Lewontin, R.C., (1979) 'The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptationist programme', *Proceedings of the Royal Society of London. Series B. Biological Sciences*, 205(1161), pp.581-598.
- Goring-Morris, A.N. (1987) *At the Edge: Terminal Pleistocene Hunter-Gatherers in the Negev and Sinai*. Oxford: British Archaeological Reports International Series 361.
- Goring-Morris, A.N., (1991) 'The Harifian of the southern Levant', in O. Bar-Yosef and F. R. Valla (eds), *The Natufian Culture in the Levant*. Ann Arbor, MI: International Monographs in Prehistory, pp.173-216.
- Goring-Morris, N. and Belfer-Cohen, A. (2001) 'The symbolic realms of utilitarian material culture: the role of lithics', in Caneva, I. (ed.) *Beyond tools. Redefining PPN Lithic assemblages of the Levant*. University of Venice: Ex oriente, pp.257-271.
- Goring-Morris, A.N. and Belfer-Cohen, A. (2011) 'Neolithization processes in the Levant: the outer envelope', *Current Anthropology*, 52(S4), pp.S195-S208.
- Goring-Morris, N. and Belfer-Cohen, A. (2016) 'The appearance of the Neolithic in the Levant: Sudden? Gradual? And Where From?' in Yalçın, Ünsal (ed.) *Anatolian Metal VII. Der An-schnitt*. Zeitschrift für Kunst und Kultur im Bergbau, Beiheft 31, Bochum 2016, pp.185-198.
- Gray, R.D., Greenhill, S.J. and Ross, R.M. (2007) 'The pleasures and perils of Darwinizing culture (with phylogenies)', *Biological Theory*, 2(4), pp.360-375.
- Griffiths, P.E. and Gray, R.D. (1994) 'Developmental systems and evolutionary explanation', *The Journal of philosophy*, 91(6), pp.277-304.
- Griffiths, P.E. and Gray, R.D. (2003) 'Darwinism and Developmental Systems' in Oyama, S., Griffiths, P.E. and Gray, R.D. (eds.) *Cycles of contingency: Developmental systems and evolution*. Cambridge, Massachusetts: MIT Press, pp.195-218.

Grove, M. (2016) 'Population density, mobility, and cultural transmission', *Journal of Archaeological Science*, 74, pp.75-84.

Grove, M., & Dunbar, R. I. M. (2015) 'Local objects, distant symbols: fission-fusion social systems and the evolution of human cognition', in Coward, F., Hosfield, R., Pope, M. and Wenban-Smith, F. (eds.) *Settlement, Society and Cognition in Human Evolution: Landscapes in Mind*. Cambridge: Cambridge University Press, pp. 15-30.

Handley, C. and Mathew, S. (2020) 'Human large-scale cooperation as a product of competition between cultural groups', *Nature communications*, 11(1), pp.1-9.

Harvey, D. (2000) 'Cosmopolitanism and the banality of geographical evils', *Public culture*, 12(2), pp.529-564.

Hemsley, S., (2008) *The implications of early village architectures: the sensuous geographies and social experience of the Near Eastern PPNA and PPNB built environments*. Doctoral dissertation, University of Liverpool.

Henrich, J. (2001) 'Cultural transmission and the diffusion of innovations: Adoption dynamics indicate that biased cultural transmission is the predominate force in behavioral change', *American Anthropologist*, 103(4), pp.992-1013.

Henrich, J. (2004) 'Demography and cultural evolution: how adaptive cultural processes can produce maladaptive losses: the Tasmanian case', *American antiquity*, pp.197-214.

Henrich, J. (2010) 'The evolution of innovation-enhancing institutions', in O'Brien, M.J. and Shennan, S.J., (eds.) *Innovation in cultural systems. Contributions from evolutionary anthropology*. Cambridge, Massachusetts: MIT Press, pp.99-120.

Henrich, J. (2016) *The secret of our success: how culture is driving human evolution, domesticating our species, and making us smarter*. Princeton: Princeton University Press.

Henrich, J. and Boyd, R. (1998) 'The evolution of conformist transmission and the emergence of between-group differences', *Evolution and human behavior*, 19(4), pp.215-241.

Henrich, J. and McElreath, R. (2003) 'The evolution of cultural evolution', *Evolutionary Anthropology*, 12(3), pp.123-135.

Henrich, J., Boyd, R. and Richerson, P.J. (2008) 'Five misunderstandings about cultural evolution', *Human Nature*, 19(2), pp.119-137.

Henrich, J., Heine, S.J. and Norenzayan, A. (2010) 'The weirdest people in the world?' *Behavioral and brain sciences*, 33(2-3), pp.61-83.

Heyes, C. (2009) 'Evolution, development and intentional control of imitation', *Phil. Trans. R. Soc. B*, 364, pp.2293-2298.

Heyes, C. (2019) 'Précis of cognitive gadgets: The cultural evolution of thinking', *Behavioral and Brain Sciences*, 42, e169: pp.1-58.

Hodder, I. (2017) 'Things and the Slow Neolithic: the Middle Eastern Transformation', *Journal of Archaeological Method and Theory*, 25(1), pp.155-177.

- Hovers, E. (1997) 'The physical environment of Netiv Hagdud', in Bar-Yosef, O. and Gopher, A. (eds.) *An Early Neolithic Village in the Jordan Valley Part I: The Archaeology of Netiv Hagdud*. Cambridge, MA: Peabody Museum of Archaeology and Ethnology Harvard University, pp.1-11.
- Ingold, T. (1990) 'An anthropologist looks at biology', *Man*, pp.208-229.
- Ingold, T. (2007) 'The trouble with 'evolutionary biology'', *Anthropology Today*, 23(2), pp.13-17.
- Jiménez, Á.V. and Mesoudi, A. (2019) 'Prestige-biased social learning: current evidence and outstanding questions', *Palgrave Communications*, 5(1), pp.1-12.
- Jungers, W.L., Falsetti, A.B. and Wall, C.E., (1995) 'Shape, relative size, and size-adjustments in morphometrics', *American Journal of Physical Anthropology*, 38(S21), pp.137-161.
- Killick, D. (2004) 'Social constructionist approaches to the study of technology', *World Archaeology*, 36(4), pp.571-578.
- Kislev, M.E. (1997) 'Early agriculture and paleoecology of Netiv Hagdud', in Bar-Yosef, O. and Gopher, A. (eds.) *An Early Neolithic Village in the Jordan Valley Part I: The Archaeology of Netiv Hagdud*. Cambridge, MA: Peabody Museum of Archaeology and Ethnology Harvard University, pp.209-236.
- Kohler, T.A., Van Buskirk, S. and Ruscavage-Barz, S. (2004) Vessels and villages: evidence for conformist transmission in early village aggregations on the Pajarito Plateau, New Mexico. *Journal of Anthropological Archaeology*, 23(1), pp.100-118.
- Kozłowski, S.K. and Aurenche, O. (2005) *Territories, boundaries and cultures in the Neolithic Near East*. Oxford: Archaeopress.
- Kuijt, I. (2001) 'Lithic inter-assemblage variability and cultural-historical sequences: A consideration of the Pre-Pottery Neolithic A occupation of Dhra', Jordan', *Paléorient*, pp.107-125.
- Kuijt, I. and Finlayson, B. (2009) 'Evidence for food storage and predomestication granaries 11,000 years ago in the Jordan Valley', *Proceedings of the National Academy of Sciences*, 106(27), pp.10966-10970.
- Kuijt, I. and Goring-Morris, N. (2002) 'Foraging, Farming, and Social Complexity in the Pre-Pottery Neolithic of the Southern Levant: A Review and Synthesis', *Journal of World Prehistory*, 16(4), pp.361-440.
- Kuijt, I. and Prentiss, A.M. (2009) 'Niche construction, macroevolution, and the Late Epipaleolithic of the Near East', In Prentiss, A.M., Kuijt, I. and Chatters, J.C. (eds.), *Macroevolution in human prehistory* (p. 235). Springer. *Macroevolution in human prehistory*. New York: Springer, pp.253-271.
- Laland, K.N., (2017) *Darwin's unfinished symphony: how culture made the human mind*. Woodstock: Princeton University Press.
- Laland, K.N. and Brown, G.R. (2011) *Sense and nonsense: Evolutionary perspectives on human behaviour*. 2nd edn. Oxford: Oxford University Press.
- Laland, K.N., Kendal, J.R. and Brown, G.R. (2007) 'The niche construction perspective: Implications for evolution and human behaviour', *Journal of Evolutionary Psychology*, 5(1), pp.51-66.
- Laland, K.N. and O'Brien, M.J. (2010) 'Niche construction theory and archaeology', *Journal of Archaeological Method and Theory*, 17(4), pp.303-322.

- Laland, K.N. and O'Brien, M.J. (2011) 'Cultural niche construction: an introduction', *Biological Theory*, 6(3), pp.191-202.
- Laland, K.N., Odling-Smee, J. and Feldman, M.W., (1999) 'Evolutionary consequences of niche construction and their implications for ecology', *Proceedings of the National Academy of Sciences*, 96(18), pp.10242-10247.
- Laland, K.N., Odling-Smee, J. and Myles, S. (2010) 'How culture shaped the human genome: bringing genetics and the human sciences together', *Nature Reviews Genetics*, 11(2), pp.137-149.
- Laland, K.N., Sterelny, K., Odling-Smee, J., Hoppitt, W. and Uller, T. (2011) Cause and effect in biology revisited: is Mayr's proximate-ultimate dichotomy still useful? *science*, 334(6062), pp.1512-1516.
- Laland, K.N., Uller, T., Feldman, M.W., Sterelny, K., Müller, G.B., Moczek, A., Jablonka, E. and Odling-Smee, J. (2015) 'The extended evolutionary synthesis: its structure, assumptions and predictions', *Proceedings of the Royal Society B: Biological Sciences*, 282(1813), p.20151019.
- Latour, B. (2005) *Reassembling the Social: an introduction to actor-network-theory*. Oxford: Oxford University Press.
- Lemonnier, P. (1986) 'The study of material culture today: toward an anthropology of technical systems', *Journal of anthropological archaeology*, 5(2), pp.147-186.
- Lewens, T. (2012) 'Cultural evolution: integration and skepticism', in Kincaid, H. (ed.) *The Oxford handbook of philosophy and social science*. Oxford: Oxford University Press, pp.458-480.
- Lewontin, R.C. (2000) *The triple helix: Gene, organism, and environment*. Cambridge, MA: Harvard University Press.
- Lipscomb, D. (1998) *Basics of cladistic analysis*. Washington DC: George Washington University.
- Lycett, S.J. (2007) 'Why is there a lack of Mode 3 Levallois technologies in East Asia? A phylogenetic test of the Movius-Schick hypothesis', *Journal of Anthropological Archaeology*, 26(4), pp.541-575.
- Lycett, S.J. (2011) "'Most beautiful and most wonderful": those endless stone tool forms', *Journal of Evolutionary Psychology*, 9(2), pp.143-171.
- Lycett, S.J. (2015) 'Cultural evolutionary approaches to artefact variation over time and space: basis, progress, and prospects', *Journal of Archaeological Science*, 56, pp.21-31.
- Lycett, S.J. (2016) 'The importance of a "quantitative genetic" approach to the evolution of artifact morphological traits', in Mendoza Straffon, L. (ed.) *Cultural Phylogenetics. Concepts and Applications in Archaeology*. Cham: Springer, pp. 179-202.
- Lycett, S.J. and Gowlett, J.A. (2008) 'On questions surrounding the Acheulean 'tradition''. *World Archaeology*, 40(3), pp.295-315.
- Lycett, S.J., von Cramon-Taubadel, N. and Foley, R.A., (2006) 'A crossbeam co-ordinate caliper for the morphometric analysis of lithic nuclei: a description, test and empirical examples of application', *Journal of Archaeological Science*, 33(6), pp.847-861.
- Mace, R. (2014) 'Human behavioral ecology and its evil twin', *Behavioral Ecology*, 25(3), pp.443-449.

- Mace, R. and Jordan, F.M. (2011) 'Macro-evolutionary studies of cultural diversity: A review of empirical studies of cultural transmission and cultural adaptation', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1563), pp.402-411.
- Maher, L., Richter, T. and Stock, J. (2012) 'The Pre-Natufian Epipaleolithic: Long-term Behavioral Trends in the Levant', *Evolutionary Anthropology*, 21(2), pp.69-81.
- Makarewicz, C.A. and Finlayson, B., (2018) 'Constructing community in the Neolithic of southern Jordan: Quotidian practice in communal architecture', *PloS one*, 13(6), p.e0193712.
- Malafouris, L. (2010) 'The brain–artefact interface (BAI): a challenge for archaeology and cultural neuroscience', *Social Cognitive and Affective Neuroscience*, 5(2-3), pp.264-273.
- Mendoza Straffon, L. (2016) 'The applications and challenges of cultural phylogenetics in archaeology: An introduction', in Mendoza Straffon, L. (ed.) *Cultural Phylogenetics. Concepts and Applications in Archaeology*. Cham: Springer, pp. 1-15.
- Mesoudi, A. (2011) *Cultural Evolution: How Darwinian Theory Can Explain Human Culture and Synthesize the Social Sciences*. Chicago: University of Chicago Press.
- Mesoudi, A. (2017) 'Pursuing Darwin's curious parallel: Prospects for a science of cultural evolution', *Proceedings of the National Academy of Sciences*, 114(30), pp.7853-7860.
- Mesoudi, A. and Lycett, S.J. (2009) 'Random copying, frequency-dependent copying and culture change', *Evolution and Human Behavior*, 30(1), pp.41-48.
- Mesoudi, A. and Thornton, A. (2018) 'What is cumulative cultural evolution?' *Proceedings of the Royal Society B: Biological Sciences*, 285(1880), p.20180712.
- Mesoudi, A., Veldhuis, D. and Foley, R.A. (2010) 'Why aren't the social sciences Darwinian? Introduction to a special issue of the Journal of Evolutionary Psychology', *Journal of Evolutionary Psychology*, 8(2), pp.93-104.
- Mesoudi, A., Whiten, A. and Laland, K.N. (2004) 'Perspective: Is human cultural evolution Darwinian? Evidence reviewed from the perspective of The Origin of Species', *Evolution*, 58(1), pp.1-11.
- Mesoudi, A., Whiten, A. and Laland, K.N. (2006) 'Towards a unified science of cultural evolution. *Behavioral and brain sciences*', 29(4), pp.329-347.
- Mithen, S. (1997) 'Cognitive archaeology, evolutionary psychology and cultural transmission, with particular reference to religious ideas', *Archeological Papers of the American Anthropological Association*, 7(1), pp.67-74.
- Mithen, S., Finlayson, B., Maričević, D., Smith, S., Jenkins, E. and Najjar, M. (2019) *WF16: Excavations at an Early Neolithic Settlement in Wadi Faynan, Southern Jordan*. Oxford: Council for British Research in the Levant.
- Miu, E., Gulley, N., Laland, K.N. and Rendell, L. (2020) 'Flexible learning, rather than inveterate innovation or copying, drives cumulative knowledge gain', *Science Advances*, 6(23), p.eaaz0286.
- Muthukrishna, M. and Henrich, J. (2016) 'Innovation in the collective brain', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 371(1690), p.20150192.

- Muthukrishna, M., Doebeli, M., Chudek, M. and Henrich, J. (2018) 'The Cultural Brain Hypothesis: How culture drives brain expansion, sociality, and life history', *PLoS computational biology*, 14(11), p.e1006504.
- Nadel, D. (1997) 'The chipped stone industry of Netiv Hagdud', in Bar-Yosef, O. and Gopher, A. (eds.) *An Early Neolithic Village in the Jordan Valley Part I: The Archaeology of Netiv Hagdud*. Cambridge, MA: Peabody Museum of Archaeology and Ethnology Harvard University, pp.71-149.
- Nadel, D., Bar-Yosef, O. and Gopher, A., (1991) 'Early Neolithic arrowhead types in the southern Levant: A typological suggestion', *Paléorient*, pp.109-119.
- Navarrete, A.F., Reader, S.M., Street, S.E., Whalen, A. and Laland, K.N. (2016) 'The coevolution of innovation and technical intelligence in primates', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 371(1690), p.20150186.
- Neiman, F.D. (1995) 'Stylistic variation in evolutionary perspective: inferences from decorative diversity and interassemblage distance in Illinois Woodland ceramic assemblages', *American Antiquity*, pp.7-36.
- O'Brien, M.J. and Lyman, R.L. (2000) *Applying evolutionary archaeology: A systematic approach*. New York: Kluwer Academic.
- O'Brien, M.J., Boulanger, M.T., Buchanan, B., Collard, M., Lyman, R.L. and Darwent, J. (2014) 'Innovation and cultural transmission in the American Paleolithic: phylogenetic analysis of eastern Paleoindian projectile-point classes', *Journal of Anthropological Archaeology*, 34, pp.100-119.
- O'Brien, M.J., Collard, M., Buchanan, B. and Boulanger, M.T. (2013) 'Trees, thickets, or something in between? Recent theoretical and empirical work in cultural phylogeny', *Israel Journal of Ecology & Evolution*, 59(2), pp.45-61.
- O'Brien, M.J., Darwent, J. and Lyman, R.L. (2001) 'Cladistics is useful for reconstructing archaeological phylogenies: Palaeoindian points from the southeastern United States', *Journal of Archaeological Science*, 28(10), pp.1115-1136.
- O'Brien, M.J., Lyman, R.L. and Leonard, R.D. (1998) 'Basic incompatibilities between evolutionary and behavioral archaeology', *American Antiquity*, pp.485-498.
- Ortner, S.B. (1984) 'Theory in Anthropology since the Sixties', *Comparative studies in society and history*, 26(1), pp.126-166.
- Ortner, S.B. (2005) 'Subjectivity and cultural critique', *Anthropological Theory*, 5(1), pp.31-52.
- Oyama, S., Griffiths, P.E. and Gray, R.D. (2003) 'Introduction: What is Development Systems Theory', in Oyama, S., Griffiths, P.E. and Gray, R.D. (eds.) *Cycles of contingency: Developmental systems and evolution*. Cambridge, Massachusetts: MIT Press, pp.1-11.
- Perry, G. and Mace, R. (2010) 'The lack of acceptance of evolutionary approaches to human behaviour', *Journal of Evolutionary Psychology*, 8(2), pp.105-125.
- Peterson, J. (2010) 'Domesticating gender: Neolithic patterns from the southern Levant', *Journal of Anthropological Archaeology*, 29(3), pp.249-264.
- Pirie, A. (2007) 'The chipped stone', in Finlayson, B. and Mithen, S.J. (eds.) *The Early Prehistory of Wadi Faynan, Southern Jordan: Archaeological Survey of Wadis Faynan, Ghuwayrand al Bustan and*

Evaluation of the Pre-Pottery Neolithic Site of WF16. Oxford: Council for British Archaeology in the Levant/Oxbow Books, pp.227–283.

Powell, A., Shennan, S.J. and Thomas, M.G. (2010) 'Demography and variation in the accumulation of culturally inherited skills', in O'Brien, M.J. and Shennan, S.J., (eds.) *Innovation in cultural systems. Contributions from evolutionary anthropology*. Cambridge, Massachusetts: MIT Press, pp.137-160.

Prentiss A.M., Walsh M.J., Skelton R.R. and Mattes M. (2016) 'Mosaic Evolution in Cultural Frameworks: Skateboard Decks and Projectile Points', in Mendoza Straffon, L. (ed.) *Cultural Phylogenetics. Concepts and Applications in Archaeology*. Cham: Springer, pp. 179-202.

Ragsdale, G. and Foley, R.A. (2018) 'Epigenetics and the Evolution of Human Social Cognition', In Di Paolo, L.D., Di Vincenzo, F. and De Petrillo, F. (eds.) *Evolution of Primate Social Cognition*. Springer. *Evolution of Primate Social Cognition*. Cham: Springer, pp.163-179.

Rapport, N. (2014) *Social and cultural anthropology: The key concepts*. London: Routledge.

Reader, S.M., Hager, Y. and Laland, K.N. (2011) 'The evolution of primate general and cultural intelligence', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1567), pp.1017-1027.

Rendell, L., Boyd, R., Cownden, D., Enquist, M., Eriksson, K., Feldman, M.W., Fogarty, L., Ghirlanda, S., Lillicrap, T. and Laland, K.N. (2010) 'Why copy others? Insights from the social learning strategies tournament', *Science*, 328(5975), pp.208-213.

Richerson, P.J. and Boyd, R. (2005) *Not by genes alone: How culture transformed human evolution*. Chicago: University of Chicago Press.

Richerson, P.J. and Boyd, R. (2008) 'Response to our critics', *Biology & Philosophy*, 23(2), pp.301-315.

Richerson, P., Baldini, R., Bell, A.V., Demps, K., Frost, K., Hillis, V., Mathew, S., Newton, E.K., Naar, N., Newson, L. and Ross, C. (2016) 'Cultural group selection plays an essential role in explaining human cooperation: A sketch of the evidence', *Behavioral and Brain Sciences*, 39, pp.1-68.

Riede, F. (2005) 'Darwin Vs. Bourdieu - Celebrity Deathmatch or Postprocessual Myth? A Prolegomenon for the Reconciliation of Agentive-Interpretative and Ecological-Evolutionary Archaeology', *BAR INTERNATIONAL SERIES*, 1411, pp.45-64.

Riede, F. (2010) 'Why isn't archaeology (more) Darwinian? A historical perspective', *Journal of Evolutionary Psychology*, 8(2), pp.183-204.

Riede, F. (2011) 'Steps towards operationalising an evolutionary archaeological definition of culture', in Roberts, B.W. and Vander Linden, M (eds.) *Investigating archaeological cultures: material culture, variability, and transmission*. New York: Springer, pp. 245-270.

Rollefson, G.O., and Gebel, H. G. K. (2004) 'Towards New Frameworks: Supra-Regional Concepts in Near Eastern Neolithization', *Neo-Lithics* 1/04, pp.21-22.

Rosenberg, D. (2008) 'Serving meals making a home: the PPNA limestone vessel industry of the southern Levant and its importance to the Neolithic revolution', *Paléorient* 34(1), pp.23-32.

Sayej, G. (2007). 'Lithic variability among the PPNA assemblages of the Dead Sea Basin', in *Technical Systems and Near Eastern PPN Communities. Proceedings of the 5th international Workshop*. Antibes: Éditions APDCA, pp.87-102.

- Shea, J.J. (2013) *Stone tools in the Paleolithic and Neolithic Near East: a guide*. Cambridge: Cambridge University Press.
- Shennan, S. (2008) 'Evolution in archaeology', *Annual review of anthropology*, 37, pp.75-91.
- Shennan, S. (2011) 'Descent with modification and the archaeological record', *Philosophical transactions of the royal society B: Biological sciences*, 366(1567), pp.1070-1079.
- Shennan, S.J. and Wilkinson, J.R. (2001) 'Ceramic style change and neutral evolution: a case study from Neolithic Europe', *American Antiquity*, 66(4), pp.577-593.
- Smith, S.J. (2005) *A comparative analysis of the form and function of chipped stone artefacts from Wadi Fayyan 16 and Dhra': implications for the description and interpretations of Early Neolithic chipped stone variability*. Doctoral dissertation. University of Reading.
- Smith, S. J. (2007) 'The form and function of the el Khiam point at Dhra' and WF16: Issues for interpreting chipped stone assemblage variability', in *Technical Systems and Near Eastern PPN Communities. Proceedings of the 5th international Workshop*. Antibes: Éditions APDCA, pp. 75-86.
- Sperber, D. (1996) *Explaining culture: A naturalistic approach*. Cambridge, MA: Cambridge.
- Sperber, D. (2019) 'Instincts or gadgets? Not the debate we should be having', *Behavioral and Brain Sciences*, 42, e169: pp.35-37.
- Sperber, D. and Claidière, N., (2008) 'Defining and explaining culture (comments on Richerson and Boyd, Not by genes alone)', *Biology & Philosophy*, 23(2), pp.283-292.
- Sterelny, K. (2006a) 'The evolution and evolvability of culture', *Mind & language*, 21(2), pp.137-165.
- Sterelny, K. (2006b) 'Mememes revisited', *The British Journal for the Philosophy of Science*, 57(1), pp.145-165.
- Sterelny, K. (2011) 'From hominins to humans: how sapiens became behaviourally modern', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1566), pp.809-822.
- Sterelny, K. (2014) 'Cooperation, culture, and conflict', *The British Journal for the Philosophy of Science*, 67(1), pp.31-58.
- Sterelny, K. and Watkins, T. (2015) 'Neolithization in southwest Asia in a context of niche construction theory', *Cambridge Archaeological Journal*, 25(3), pp.673-691.
- Stout, D. (2018) 'Human brain evolution: History or science', in Schwartz, J.H. (ed.) *Rethinking Human Evolution*. Cambridge MA: MIT Press, pp.297-317.
- Stout, D., Rogers, M.J., Semaw, S. and Jaeggi, A.V. (2019) 'Archaeology and the origins of human cumulative culture: a case study from the earliest Oldowan at Gona, Ethiopia', *Current Anthropology*, 60(3), pp.309-340.
- Tehrani, J.J. and d'Huy, J. (2017) 'Phylogenetics meets folklore: Bioinformatics approaches to the study of international folktales', in Kenna, R., MacCarron, M. and MacCarron, P. (eds.) *Maths Meets Myths: Quantitative Approaches to Ancient Narratives*. Springer International Publishing Switzerland, pp. 91-114.
- Tëmkin, I. and Eldredge, N. (2007) 'Phylogenetics and material cultural evolution', *Current anthropology*, 48(1), pp.146-154.

- Tomasello, M. and Moll, H., (2010) 'the Gap is Social: Human Shared Intentionality and Culture', in Kappeler, P. M. and Silk, J. B. (eds.) *Mind the gap: tracing the origins of human universals*. Berlin and Heidelberg: Springer, pp.331-349.
- Tomasello, M., Carpenter, M., Call, J., Behne, T. and Moll, H. (2005) 'Understanding and sharing intentions: The origins of cultural cognition', *Behavioral and brain sciences*, 28(5), pp.675-691.
- Tostevin, G.B. (2019) 'Content Matters: The Materiality of Cultural Transmission and the Intersection of Paleolithic Archaeology with Cultural Evolutionary Theory', in Love, A.C. and Wimsatt, W. (eds.) *Beyond the Meme: Development and Structure in Cultural Evolution*. Minneapolis: University of Minnesota Press, pp.311-364.
- Tripp, A. (2016) 'A cladistics analysis exploring regional patterning of the anthropomorphic figurines from the Gravettian', in Mendoza Straffon, L. (ed.) *Cultural Phylogenetics. Concepts and Applications in Archaeology*. Cham: Springer, pp. 179-202.
- van Schaik, C.P. and Burkart, J.M. (2011) 'Social learning and evolution: the cultural intelligence hypothesis', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1567), pp.1008-1016.
- van Schaik, C.P., Isler, K. and Burkart, J.M. (2012) 'Explaining brain size variation: from social to cultural brain', *Trends in cognitive sciences*, 16(5), pp.277-284.
- Vaesen, K. and Houkes, W. (2017) 'Complexity and technological evolution: What everybody knows?' *Biology & philosophy*, 32(6), pp.1245-1268.
- Watkins, T. (1992) 'The beginning of the Neolithic: Searching for meaning in material culture change', *Paléorient*, pp.63-75.
- Watkins, T. (2008) 'Supra-regional networks in the Neolithic of Southwest Asia', *Journal of World Prehistory*, 21(2), pp.139-171.
- Watkins, T. (2010) 'New light on Neolithic revolution in south-west Asia', *Antiquity*, 84(325), pp.621-634.
- Wicks, K., Finlayson, B., Maričević, D., Smith, S., Jenkins, E. and Mithen, S. (2016) 'Dating WF16: Exploring the chronology of a Pre-Pottery Neolithic A settlement in the Southern Levant', *Proceedings of the Prehistoric Society*, 82, pp.73–123.
- Wilson, E.O. (1975) *Sociobiology: The New Synthesis*. Cambridge, MA: Harvard University Press.
- Whiten, A. (2011) 'The scope of culture in chimpanzees, humans and ancestral apes', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1567), pp.997-1007.
- Whiten, A. and Erdal, D. (2012) 'The human socio-cognitive niche and its evolutionary origins', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 367(1599), 2119-29.
- Whiten, A., Hinde, R.A., Laland, K.N. and Stringer, C.B. (2011) 'Culture evolves', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1567), pp.938-948.
- Whiten, A., McGuigan, N., Marshall-Pescini, S. and Hopper, L.M. (2009) 'Emulation, imitation, over-imitation and the scope of culture for child and chimpanzee', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1528), pp.2417-2428.

Whiten, A., Spiteri, A., Horner, V., Bonnie, K.E., Lambeth, S.P., Schapiro, S.J. and De Waal, F.B. (2007) 'Transmission of multiple traditions within and between chimpanzee groups', *Current Biology*, 17(12), pp.1038-1043.

Wright, K.I.K. (2014) 'Domestication and inequality? Households, corporate groups and food processing tools at Neolithic Çatalhöyük', *Journal of Anthropological Archaeology*, 33, pp.1-33.

Yellin, J. (1997) 'Miscellaneous finds: the obsidian artifacts from Netiv Hagdud', in Bar-Yosef, O. and Gopher, A. (eds.) *An Early Neolithic Village in the Jordan Valley Part I: The Archaeology of Netiv Hagdud*. Cambridge, MA: Peabody Museum of Archaeology and Ethnology Harvard University, pp.193-196.