Evolution as a Constraint on Theories of Syntax: The Case against Minimalism

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Declaration

I hereby declare that this thesis is of my own composition, and that it contains no material previously submitted for the award of any other degree. The work reported in this thesis has been executed by myself, except where due acknowledgement is made in the text.

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Abstract

This thesis investigates the evolutionary plausibility of the Minimalist Program. Is such a theory of language reasonable given the assumption that the human linguistic capacity has been subject to the usual forces and processes of evolution? More generally, this thesis is a comment on the manner in which theories of language can and should be constrained. What are the constraints that must be taken into account when constructing a theory of language? These questions are addressed by applying evidence gathered in evolutionary biology to data from linguistics.

The development of generative syntactic theorising in the late 20th century has led to a much redesigned conception of the human language faculty. The driving question - 'why is language the way it is?' - has prompted assumptions of simplicity, perfection, optimality, and economy for language; a minimal system operating in an economic fashion to fit into the larger cognitive architecture in a perfect manner. Studies in evolutionary linguistics, on the other hand, have been keen to demonstrate that language is complex, redundant, and adaptive, Pinker & Bloom's (1990) seminal paper being perhaps the prime example of this. The question is whether these opposing views can be married in any way.

Interdisciplinary evidence is brought to bear on this problem, demonstrating that any reconciliation is impossible. Evolutionary biology shows that perfection, simplicity, and economy do not arise in typically evolving systems, yet the Minimalist Program attaches these characteristics to language. It shows that evolvable systems exhibit degeneracy, modularity, and robustness, yet the Minimalist Program must rule these features out for language. It shows that evolution exhibits a trend towards complexity, yet the Minimalist Program excludes such a depiction of language.

By determining where language falls in each of these three cases, the choice between the opposing positions of gradual adaptive evolution and the Minimalist Program is resolved. Language is shown to be imperfect, uneconomic, and non-optimal, and hence a typical biological system. Language is shown to exhibit the key features of evolvability, and hence accords with the usual pressures and constraints of evolution. Language is shown to be both complex and adaptive, and hence amenable to a gradual adaptive evolutionary account.

In addition, the uniqueness of the pivotal property of language according to one minimalist evolutionary account – recursion – is examined, its place as just one of a collection of properties which make language special illustrating that language is significantly more complex and sophisticated than the Minimalist Program allows. Finally, significant flaws in the details of minimalist theories themselves – including extraneous operations, and unmotivated and stipulative features – are uncovered, further signalling that the perfection, simplicity, and economy that minimalism advocates is not a valid characterisation of language.

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CHAPTER 1

Introduction

1.1 Language and Evolution

Language is a defining characteristic of what it is to be human. One of the most fundamental questions that the field of linguistics must therefore try to answer is why language is an ability specific to our species. Attempts to provide such an answer have focussed on investigating a number of peculiarities of language, best thought of as posing the following highly interconnected questions: (1) how do human children acquire language in a relatively rapid and effortless manner based on typically sparse input? (2) what are the idiosyncratic linguistic features that are found in all human languages? (3) what knowledge must the language user have? (4) how is language dealt with in the human brain?

Question (1) asks about the nature of coming to be a language user. What does the child bring to the task of acquiring his first language? Must he have prior knowledge that is specifically linguistic? Is such prior knowledge innately encoded? The second question deals with language universals. There are very many different languages spoken across the world, yet they appear to conform to certain common rules or guidelines. What are these commonalities, and more importantly, why are these features, and not some others, universal? Question (3) asks about the internal state of a mature language user's mind. What does the language user have to know about both his specific language, and language generally, in order to have successful communicative interactions? The fourth question inquires into the nature of the human brain. Are there specific areas in the brain dedicated to linguistic tasks? How is the processing of language carried out by these areas? What is different in the human mind, and are these differences directly responsible for language? Can language itself change the way we think?

None of these issues can stand alone; answers to one set of questions impact on, and are impacted by, the others. Universal characteristics of language may be so because they are aspects that make it more easily acquirable. The universals of language, in turn, will form the basis of the knowledge that the language user must have in his mind in order to successfully put language to use. The manner in which the brain processes language may shed light on the prior knowledge brought to the acquisition task; if the brain deals with language in a very different way to other cognitive functions, this may suggest that domain-specific knowledge is required by the child. Knowing what must be innate will help to answer the question of how the human mind differs from that of other species. Characterising what the language user must know about his specific language, and what he must know about language in general, can aid answering the question of what the child's prior knowledge must consist of. Many other associations hold between the central questions.

Recently, a further question has been added to this list. This takes the following form: (5) how has language arisen in the evolution of *Homo sapiens*? This question asks what happened in the evolution of humans, from the last common ancestor we share with our closest ape relatives (some 5 to 10 million years ago) through the successive hominid species, that gave us language. In other words, what events in our evolutionary history resulted in our ability to communicate in a way very different to that of other species? Question (5) must thus, in its broadest sense, attend to issues in genetics and archaeology. A problem, however, arises through the lack of both genetic and archaeological evidence in answering this question. While the field of genetics has made huge leaps in understanding in the last decades, the empirical data in the case of language is still relatively sparse[1]. In the case of the archaeological record, the story is even worse. Language leaves no fossils; even the anatomical indicators of the ability to vocalise do not all fossilise (and where they do, the human case is not as unique as one might imagine)[2]. Consequently, the language evolutionist appears to face an uphill struggle.

[1]See section 4.7.1 for discussion of just one piece of such evidence.

[2]And, of course, we must recognise that vocalisation does not necessarily entail human language abilities.

One way to ease the language evolutionist's seemingly impossible task is to appeal to evidence that is available; that is, to call upon the knowledge gained in tackling the issues of (1) through (4) above. Other sub-disciplines within the field of linguistics offer to the evolutionary linguist a set of data which can direct his particular enquiry. For example, neurolinguistics offers evidence of the neural patterns relevant to language; comparative evidence can then be used to identify those patterns which are uniquely human. Psycholinguistics offers evidence of the behaviour of language users in both production and perception; such behaviours may signal underlying evolutionary pressures to which language responded. Studies in linguistic universals taken from the sub-disciplines of phonetics and phonology, morphology, syntax, and semantics offer evidence of the types of language that are both possible and actual; this distribution in the space of possibilities must have an evolutionary basis. Studies both in developmental linguistics, and on pidgins and creoles, offer evidence of more underdeveloped forms of language; such data may inform our theories of what earlier, more primitive stages of language looked like. The field of language evolution thus clearly highlights the value of interdisciplinary research.

The issues to be addressed in this thesis fall squarely within question (5), yet the approach taken here will not attempt to answer question (5) by using evidence from other linguistic disciplines. Instead, it will use evidence from studies in evolution to cast a critical light on linguistic theory. As the preceding paragraph noted, cross-fertilisation of evidence and ideas is crucial. In linguistics, as in any scientific endeavour, it is important to consider the effect that findings from outside the discipline have on one's theory. While a grand unified theory of language is still a very long way off, by combining knowledge from different fields we can at least begin to narrow down the possibilities. Just as neurolinguistics, psycholinguistics, or semantic theory can inform our theories of how language evolved, so too can evolutionary biology inform our theories of how language is.

1.2 Studies in Syntactic Theory

A number of sub-disciplines within linguistics are prone to isolation from other fields, and hence lack the inter-disciplinarity that is appropriate in the study of language. Syntactic theory is one such area. Typically, syntactic frameworks rely to a large extent on theory-internal argumentation, predicated on a legacy of assumptions accepted without verification against new evidence garnered in other domains. In order to narrow down the range of possible theories of syntax, we must look at them through an alternative lens. That is, we must scrutinise syntactic theory not simply as a theory which accounts for the syntactic data, but as a theory which is, at once, consistent with the syntactic data and with the evidence from other fields (whether that be psychology, biology, or sociology). In other words, does the particular theory of syntax allow for language to be acquired, allow for language to be processed, allow for language to have evolved, allow for language to be used?

This is a considerable enterprise, given (i) the number of differing syntactic frameworks that are currently available for analysis, and (ii) the number of possible alternative lenses that we might consider the theory through[3]. There are thus two decisions that will determine the direction the current investigation will take. The first of these has already been stated - evolutionary biology will provide the alternative viewpoint on syntactic theory, the evidence against which syntactic theory will be judged to be viable or not. The second decision concerns the particular syntactic theory to be judged. The choice taken is the Minimalist Program (henceforth MP). This choice can be justified both by the MP's standing as a dominant framework under the rubric of *modern syntactic theory*, and also by the fact that the MP makes a number of strong predictions which necessarily invite evolutionary assessment.

Before we can even begin to address these predictions, a brief survey of the backdrop against which the MP stands is in order. The MP is a generative theory of language, assuming a nativist position with respect to the language user's knowledge. The next two sections will spell out what it means for a theory of language to be nativist and generative. A summary of the conditions that syntactic theory in general, and the MP in particular, place on language will then

[3]As noted above, we are a long way from being able to simultaneously consider the compatibility of a theory of syntax with all other domains that impinge on language.

follow.

1.2.1 Nativism versus Empiricism

The question of what the child brings to the task of acquiring his native language can be given a nativist or an empiricist answer. This question is essentially just one realisation of the nature versus nurture question that bears on very many aspects of human cognition. The nativist reply would assert that the language learner is born endowed with a genetically pre-determined body of linguistic knowledge which assists him in the not straightforward task ahead of him. The empiricist reply, in contrast, would place the burden of explanation on experience; the language learner is exposed to an environment filled with stimuli which provide enough information to allow him to determine the structure of his native language.

Linguistic nativism, first clearly articulated by Chomsky in the 1960's (Chomsky 1965b), owes its debt to the early philosophy of Plato's *Meno*, where it is suggested that the paradox of inquiry[4] can be solved if learning is reconstrued as simply recollecting that which we knew in a former existence[5]. What has come to be known as the logical problem of language acquisition - the question of how a complex language can be acquired based on input which is limited and degenerate - forms the basis of the case for linguistic nativism. The proposal is that the human brain is pre-wired to include an innate language faculty - a language-specific domain. By making use of a Universal Grammar (henceforth UG) - a genetically pre-specified body of knowledge about human language - the human language faculty permits the child to have the capability of acquiring a human language despite insufficient input.

Linguistic empiricism, on the other hand, owes its debt to John Locke (Locke 1689), who argued that there are no innate ideas or knowledge, only minds that are capable of undertaking a variety of tasks, of which learning, and more specifically, language learning is one. The strongest version of empiricism will state that the mind is at birth a *tabula rasa*, a blank slate onto which experience writes itself. Language acquisition is then simply a case of statistical learning, where the child employs domain-general learning processes used in the acquisition of

[4]The paradox of inquiry asks how one can inquire into something one knows nothing about *(Meno:80d)*.

[5]As the title of Chomsky's 1965 book suggests, Descartes too held that knowledge is innate, his argument being that it is inscribed in the mind by God.

many other cognitive abilities. A recent defense of empiricism (Sampson 2005) cites creativity as the reason for rejecting nativism. That is, if we are entirely preprogrammed, with all knowledge and ideas lying dormant, just waiting to be aroused, humans cannot be the creative beings that history has shown us to be.

The problem with Sampson's suggestion is that it is based on the strongest nativist claim possible. Just as the furthest extreme at the empiricist end of the spectrum - that we are born with nothing in our minds - is untenable, so too is the furthest extreme at the nativist end - that we are born with all knowledge that we might ever need (and more) already intact. Nativism and empiricism are not two components of a strict dichotomy, but rather two ends of a scale of possibilities. Empiricism can be made more amenable to the nativist by, for example, assuming that the mechanisms used in learning language from experience are not domain-general but domain-specific; in other words, although knowledge of language is not innate, language-specific learning processes are. Similarly, nativism can be made more amenable to the empiricist by reducing the contents of UG; allowing certain linguistic knowledge to be derived from general cognitive intelligence leaves us with less innate machinery for genetics to account for.

The MP is a nativist theory in a strong sense. It assumes a genetically predetermined language faculty, and a UG. Yet the MP differs from its predecessor nativist theories in reducing the amount of innate knowledge[6]. As chapter 2 will detail, the MP envisions a very different system of language, in which the innate machinery required to account for the linguistic evidence is smaller, more atomic, and more economic than previously assumed.

1.2.2 What is a Generative Grammar?

Section 2.2 will delve into the history of generative grammar in some detail. At this point, a number of basic observations will suffice to situate the MP in syntactic theory generally.

Generative grammar dates from the end of the 1950's, and is associated primarily with two of Chomsky's early publications (Chomsky (1957), Chomsky (1975b)). A *generative* theory began as one which assumes that the possible sentences of a language are generated from a set of grammatical rules (a generative

[6]At least this is how the situation appears; chapter 6 will show the truth to be somewhat different.

grammar). Viewing language in this way promotes the notion of creativity; language is creative because the underlying grammar consists of rules which permit the language user to produce (and understand) infinitely many novel combinations of lexical items. Generative theories of language thus rely heavily on syntax as the driving force of the innovation; they are what have come to be known in some parts as *syntactocentric* theories (Jackendoff 1998). The nativist doctrine is an intrinsic part of a generative theory; generativism assumes that the framework for grammar forms part of the newborn's genetic endowment.

The MP is a generative theory of language because (i) it places syntax at the core, relegating non-syntactic aspects of the system to peripheral components (see section 6.7), (ii) it understands the possible utterances of a language to be generated from a grammar (although in more recent times, the underlying set of rules has been replaced by three underlying operations applied to lexical items (see section 2.4)), and (iii) it judges the underlying machinery to be innately encoded.

1.2.3 What Syntactic Theory Tells us about the Language Faculty

The question then is what we know about the language faculty from what syntactic theory says. In other words, what constraints on a unified theory of the system of language do theories of syntax in general, and the MP specifically, impose?

Language is typically thought of as a two-way relation holding between a signal (be it spoken, signed, or written) and a meaning. The first thing that syntactic theory tells us is that the grammatical structure of language is the mediator between signal and meaning. The MP, as a generative, syntactocentric theory, imposes the more specific condition that the syntax actually creates this relation; the grammatical architecture works to construct a mapping between phonology and semantics. Syntactic theory furthermore tells us that the language faculty must incorporate a means for permitting an unlimited repertoire of utterances - a productive system of some sort. A generative theory, and hence the MP, on top of this tells us that the productive system in question is coded in our genes, and pre-wired into our brains from birth. Thus, a generative theory bids us to focus on I(nternal)-language - the competence or knowledge of language that is in the mind of the individual - rather than E(xternal)-language - the performance of the individual, or language as a property of a community (Chomsky 1986a). The MP additionally dictates that the genetically endowed linguistic component should be the most minimal machinery required to allow its possessor to acquire and use his native language.

This vision of the language faculty raises numerous questions for evolutionary linguistics, of which an initial few are the following. Firstly, why would a process for mapping between signal and meaning have evolved? In other words, assuming prior signals and meanings[7], what evolutionary pressures might have given rise to a systematic means for creating correspondences between them? Secondly, how could the language faculty have come to be innate? That is, what has happened in the evolution of our species that has led to, not simply the emergence of linguistic abilities, but the emergence of the genetic machinery for these abilities? Thirdly, how could a complex capacity come to be represented internally to the mind in a minimal fashion? In other words, what sort of evolutionary processes lead to low structural realisation for high functional effect, and could the language faculty have evolved in this manner?

[7]These too, must have an evolutionary explanation, although investigating this is not the remit of this thesis.

1.3 Studies in Language Evolution

This section of the chapter will introduce the work which has been undertaken in the field of language evolution. This high-level survey of the state of the art in a relatively new sub-discipline of linguistics will reveal the sorts of questions that are being asked and the types of answers that are being suggested. Although the question of how humans have come to have language is not a new one, it is only in recent decades that the knowledge we have amassed from other scientific fields has permitted the type of careful and credible argument whose lack the 1866 ban of the Société Linguistique de Paris mitigated against.

1.3.1 A Taxonomy of Theories

The following sub-sections will characterise evolutionary accounts of human language as being classifiable along multiple dimensions. The central tenets and principal motivations of each class of theory will be outlined, and supplemented with examples of the particular types of argument advanced. Importantly, it is not necessary that the different classes of account are mutually exclusive. It is perfectly possible that while certain aspects of language have one explanation, other aspects have followed an alternative evolutionary route. The question of which particular features have evolved in which manner is outwith the scope of this thesis however.

1.3.1.1 Adaptationist Theories

Adaptationist approaches to the evolution of language stress the importance of the typical Darwinian evolutionary scenario. That is, natural selection plays a fundamental role in this class of theories; it is the central (and in some cases, only) process posited as the means for evolving the human language faculty. The principle tenet of an adaptationist theory of language is this: the system of human language has emerged as the result of a pressure to fulfil a functional requirement. The adaptationist account of the human language faculty thus assumes that language has emerged in order to solve a problem set by the environment.

Intrinsic to these accounts are the notions of fitness - language makes the individual more fit; more able to deal with the problems posed by his environment - and evolutionary pressures - the particular problems faced by the individual in his environment that language can solve. The traditional (if the relative youth of the field does not rule out such terms) adaptationist account proposes that fitness and evolutionary pressures are related to communication; fitness is to be measured in terms of the ability of an individual to communicate with others he encounters, and the problems posed by the environment which led to the emergence of language were such things as escaping predators, and finding food. Having an ability to communicate would allow for information about the whereabouts of both of these to be transmitted between individuals more easily and efficiently. The typical adaptationist account of language also assumes that the processes involved were gradual, and the resulting ability built up incrementally. In other words, a succession of specific environmental pressures faced our ancestors, each of which could be answered by adding one more piece to the mosaic that is language.

Pinker & Bloom (1990) offer the prototypical adaptationist account following the above outline. For them, the human language faculty is the result of changes in the biology of our ancestors, driven by the day-to-day situations they found themselves in, allowing them to communicate complex propositions through a serial channel. Jackendoff (2002) presents an account with a similar basis, although somewhat more worked out in the details. Although these represent the more classical adaptationist theory, a sub-class of these theories with a very different focus has, in recent years, become ever more popular in the field (Deacon (1997) Kirby (1999), Brighton *et al.* (2005)). These accounts place their main emphasis not on biological, but on cultural evolutionary processes. That is, in its transmission from one generation of users to the next, language itself (rather than the language user) adapts to answer environmental pressures. In this case, fitness and evolutionary pressures are spoken of in terms of the ability of language to be acquired or to be used. The actual structure of language is thus explained as best answering the problems of learning and expressivity faced by the human acquirer[8]. The natures of these two types of adaptationist theory entail two different views of the innateness question considered above. While biological adaptationist accounts sit on the nativist end of the spectrum, those favouring cultural processes require less innate machinery to be posited.

[8]In this thesis I will use the terms *fitness* and *adaptation* in the biological sense. This does not mean that biological and cultural adaptation are mutually exclusive. For example, features of language that make its transmission between generations easier are likely to also improve the biological fitness of language users.

1.3.1.2 *Exaptationist Theories*

While adaptationist theories stress a direct relation between environmental factors and the first emergence of particular features of the human communication system, exaptationist theories stress an alternative approach for evolution to take. Exaptation (Gould & Vrba 1982) refers to the process whereby some trait of an organism is re-appropriated by evolution to answer a new pressure posed by the environment. Thus, in the same way that the feathered wings of birds may have emerged first for reasons of insulation, and only later took on the role of enabling flight *(ibid)*, language, in the exaptationist's case, would be best understood as the result of employing resources which were already available, having evolved through either adaptationist or non-adaptationist means for some other purpose, in a new way to solve new puzzles facing our ancestors.

The exaptationist view of the evolution of the human language faculty does not rule out adaptation as an evolutionary process *per se*; it merely says that in the case of language, any adaptation is restricted to the prior evolution of the resources which were later co-opted for language, and to the later more minor shaping and tuning of the language faculty. Exaptationist theories also say nothing about graduality. While it is possible to advance that the re-appropriation of genetic material to the new function may have taken place in one simple step, an equally available hypothesis to the exaptationist is that this process was gradual, involving numerous intermediary steps.

The details of the theories in this class are worked out in very different ways. The commonality is the general type of process involved; the nature of the preadaptation, and the specifics of the transfer of function, are the aspects that can be given different interpretations. So, for example, while Calvin & Bickerton (2000) suggest that social calculus was exapted to give the thematic roles on which sentence structure is based, Lieberman (1985) advances that syntax is a re-appropriation of the neural mechanisms responsible for the type of motor activity required for tool use, locomotion, and speech, and Carstairs-McCarthy (1999) explains syntactic structure as being exapted from something more closely related - phonological structure[9].

[9] See section 5.4.2.1 for some more discussion of this proposal.

1.3.1.3 *Spandrel Theories*

Another type of theory emphasises the sometimes accidental nature of evolution. A spandrel is a structure arising as a by-product of some other architectural configuration. In evolutionary terms, a spandrel is some trait of an organism which emerges not through direct adaptationist or exaptationist means, but rather as a side effect of some other evolutionary development. In the case of language, a spandrel theory would suggest that some development in the evolutionary history of our ancestors had as a consequence the emergence of the human language faculty. That is, language was not the answer to some direct environmental pressure, but was the unforeseen, chance by-product of something perhaps entirely unrelated.

A theory of the evolution of the human language faculty which states that it is a spandrel does not rule out adaptation or exaptation as potential relevant processes. For one, the trait or traits of which language is proposed to be a side effect must have an evolutionary explanation of their own, and this could involve either adaptation or exaptation (or both). Further, as Pinker & Bloom (1990) point out, language is unlikely to be a spandrel that simply emerged, and, without any additional modification, just worked. While a spandrel may give evolution the necessary structure and material to work with, if the spandrel is to have a function of its own[10], adaptation through natural selection is necessary.

As with exaptationist theories, accounts of language as a spandrel do not necessarily fix on one trait which language is a by-product of. However, Gould's (1987) belief that it is the evolution of the human brain that is responsible is the most usual choice. Chomsky (1975b:59), too, reiterates this view: "[w]e know very little about what happens when 10^{10} neurons are crammed into something the size of a basketball...It would be a serious error to suppose that all properties...can be 'explained' in terms of natural selection".

1.3.1.4 *Saltational Theories*

A slightly different dimension on which to segregate the different types of theories of the evolution of language is the question of graduality. That is, did language evolve over a short or long time period; was its emergence drawn out and piecemeal or at once and abrupt? A saltational evolutionary account assumes

[10]As opposed to true, unmodified spandrels, such as the red colour of blood, which fulfil no function (Pinker & Bloom 1990).

the latter case; a phenotypic trait emerges in the evolutionary development of an organism all in one go, the result of just one genetic mutation. If the trait that emerges is at all complex, as is the case for language, a saltational theory must assume not just a mutation, but a macromutation - a mutation involving the concurrent change of a number of characteristics; that is, a small genotypic change which produces a large phenotypic change.

Saltation is not an alternative to the spandrel or the exaptationist account; the emergence of a spandrel or the re-appropriation of prior material may be sudden in nature. Indeed, even an adaptation does not necessarily have to be gradual, although this is the usual assumption. A saltational account fits well with the minimalist style of argument for language, as a more minimal, more economical language faculty leaves less for evolution to have to explain, a single genetic mutation looking more reasonable as a consequence. In fact, as section 4.7 will discuss in detail, the saltational account is really the only possibility that is left open under a minimalist view of the language faculty. There, it will be reasoned that saltation is a precarious path to take when the trait in question is as complex as language.

1.3.1.5 Non-Biological Theories

The preceding classes of theories all have belong in the domain of biology. In chapters 3 and 4, an alternative possibility will be discussed. Here, I will outline the idea just briefly. Theories which belong in the domain of physics suggest that language is the result of forces such as gravity, temperature, or geometry. The class of non-biological theories includes theories of language as a self-organising system. Self-organisation states that factors internal to a system can be responsible for its evolution; a system becomes more ordered simply as a result of the dynamics of that system.

Examples of self-organising systems have been proposed not just in physics, but also in areas such as mathematics (Wolfram 1982) and biology (Ball 1999). In the context of the evolution of human language, two proposals which fit into this class of theory use computational models. De Boer's (2001) model shows how self-organisation in a population of language users results in vowel systems that are optimal for communication, and Oudeyer's (2006) model shows how an organised system of vocalisations can emerge spontaneously.

1.3.1.6 Other Questions Asked

We have now seen a number of ways in which we can break down the space of theories of the evolution of the human language faculty. Although the question of what evolutionary processes are involved is a crucial one, a number of other questions are central to the work carried out in the discipline. One such question concerns the precursors of language. That is, if language evolved in a gradual manner from some previous forms of rudimentary communication, what were these? Were they gestural, as suggested by Corballis (2003), or vocal, as Lieberman (1984) proposes?

A second question is that of the preadaptations for language. In other words, if language is the result of adaptationist processes, what needed to be in place before that adaptation could take place? The suggestions of Hurford (2003) and Jackendoff's (2002) include a capacity for basic symbolic reference, an ability to vocalise or gesture manually, a facility for conceptualisation and manipulating concepts and propositions, and an ability to cooperate with others, and to understand the behaviour of others.

A third question relates to the environmental pressures to which language is the answer. If communication is the primary use to which the human language faculty is put, then what were the factors that placed communication at such a high level of necessity for our ancestors that they evolved a means of doing so? Dessalles (1998) proposes that language is a means for advertising oneself, and thus acquiring a higher status within one's community. In a later paper (Dessalles 2000), he augments his hypothesis with a further driving force - the individual who achieves higher status through successful communication will be seen by other members of the community to be a good political partner. As human societies, like those of our closest relatives, are based on political coalitions, fitness can be directly related to one's linguistic abilities.

1.3.2 What Language Evolution Tells us about the Language Faculty

The preceding sections have introduced just some of the many themes and issues at the heart of recent studies in evolutionary linguistics. The question now is what sort of specifications this field imposes on our understanding of the human language faculty.

If it is taken as read that language evolved in some fashion, evolutionary biology in general provides us with a set of viable and permissible processes from which to choose: language could be the result of adaptation, exaptation, or it could be a spandrel. Evolutionary biology does not demand that the human language faculty be the consequence of just one of these types of processes, but demonstrates that various combinations are also possible. In an even more general sense, evolution is not necessarily biological, but the above processes and concepts could be spoken of in a cultural light. Further complication is possible: language may be the fruit of both biological and cultural labours of a number of sub-types.

Research in the field of evolutionary linguistics points to more particular restrictions on how we must understand the human language faculty to be. For one, it tells us that language is a cognitive capacity, a characteristic feature of the human mental faculty. Consequently, the system must have a delineation that permits it to exist within the cognitive structures of our species. Further, it tells us that language is a uniquely human phenomenon. Comparative studies of communication systems as distinct as birdsong, the dance of the honeybee, the signature whistles of bottlenose dolphins, and even the signing of trained apes confirm human language to be unmatched in other species. Therefore, our account of the system must highlight the aspects which set it apart, attributing to them a structure and evolution which is not compatible with non-human abilities. Finally, the particular processes invoked in our explanation of the evolution of language place additional constraints on our unified theory. Adaptation says there must be a measure of fitness - some way in which language contributes to our ability to survive and reproduce in our particular environment - and an environmental pressure - some problem posed by the environment that language allowed our ancestors to answer. Exaptation says that there must be some prior material that was suitable for re-appropriation to language. The spandrel theory says that there must have been an evolutionary development elsewhere in our cognition which delivered to evolution the basic structure from which language was carved.

1.4 Constraining the Theory of Language

The job of the language evolutionist is to constrain the set of theories of language to those that are plausible evolutionarily. In other words, theories which do not promote a version of the language faculty for which a reasonable evolutionary account can be posited must be rejected. There are in linguistics, as the preceding paragraphs have intimated, numerous ways in which we can constrain theories of language.

(i) *Considerations of Acquirability* – studies in language acquisition (see among others Fletcher & MacWhinney (1995), Ritchie & Bhatia (1999), Bertolo (2001)) provide us with knowledge about how children acquire language. In that children acquire language quickly and easily, with apparently scant input, and in that they cannot acquire just any arbitrary language, a theory of language constrained by acquirability considerations says that the system must be learnable. The generative predecessor to minimalism, Government and Binding (henceforth GB) theory, spoke directly to this concern.

(ii) *Considerations of Neurological Plausibility* – studies in neurolinguistics (see among others Obler & Gjerlow (1999), Pulvermüller (2003)), and of language disorders (see among others Goodglass (1993), Papathanasiou & de Bleser (2003)), provide us with knowledge about how our brains store and deal with language. A theory of language constrained by neurological considerations says that the system must be neurologically plausible; that the features of language can somehow be instantiated in the neural tissues of the brain.

(iii) *Considerations of Cross-Linguistic Variation* – studies in comparative synchronic syntax (see among others Roberts (1997), Ouhalla (1999)) provide us with knowledge about the differences exhibited across languages in their form. A theory of language constrained by considerations of cross-linguistic variation says that the system must be able to have varying end states. Again, GB theory was designed with this concern in mind.

(iv) *Considerations of Diachronic Change* – studies in diachronic syntax (see among others Kroch (2001)) provide us with knowledge about how languages change in their form over time. A theory of language that is constrained in this way says that the system must be non-static. Further, actual instances of language change (such as the tendency of changes to happen gradually following an s-shaped curve (Bailey 1973)) must be predicted by the theory.

(v) *Considerations of Parsability* – studies in psycholinguistics provide us with knowledge about how we assign a structure to a string that we encounter. They inform us about how we deal with such things as ambiguity and garden path sentences (see e.g. Crain & Steedman (1985)). A theory of language which is constrained by such factors says that the system must be parsable; that is, it should conform to parsing models which accord with psycholinguistic facts. The *Aspects* model of transformational grammar (Chomsky (1965a)) was criticised by Peters & Ritchie (1973) for the very reason that it could generate grammars that are not parsable.

(vi) *Considerations of Simplicity and Economy* – this is the way in which the theory of language posited in studies in the minimalist framework is constrained. The MP makes a distinction between the weak and the strong minimalist theses[11]. The former says that the theory must be the most economic in an Occam's razor sense (economy of statement); in essence this is the type of 'minimalism' that is pursued by all scientists. The latter, the crux of the MP, says that the theory must elucidate a system which is itself the simplest and most economic way to do what it has to do (economy of process), which here is to create the mapping between signal and meaning.

This list enumerates just some of the constraints we can impose on our theory of language. It is envisaged that additional constraints will become apparent in the next few years from work currently being undertaken in the field of genetics. In fact, work in this area has already drawn our attention to one gene involved in language – FOXP2[12]. Leaving genetics (and other constraints which will become clearer in time) to one side, and considering the six constraints above alone, it becomes obvious that the final constraint seems to stand out. While the first five undeniably have independent motivation, the sixth seems unmotivated in terms of the central questions of (1) to (5) posed at the beginning of the chapter.

What the language evolutionist is concerned with relates to an additional way of constraining the theory of language; that is, using considerations of evolutionary plausibility. In other words, studies in evolution can be used to provide us

[11]See section 3.3.2 for detailed discussion.

[12]See Gopnik & Crago (1991), Lai *et al.* (2001), Enard *et al.* (2002), and section 4.7.1 for more detailed discussion.

with knowledge about how biological endowments, such as language, evolve. The language evolutionist employs knowledge gained from evolutionary biology to consider issues of timescales, processes, antecedents, fitness measures, and environmental pressures for language, in order to develop a theory which accounts for the fact that language is a biological capacity, and as such must have followed the same types of evolutionary paths which are posited for other biological capacities in our species. Essentially then, a theory of language that is constrained by considerations of evolutionary plausibility says that the system must be evolvable.

Consider once more the list of constraints above. The constraint of evolvability necessarily entails many of the others enumerated, while the constraint of simplicity or economy does not. For example, an evolvable system must be neurologically plausible; an evolutionary explanation must necessarily make reference to the neurological developments in our species that allowed for, and were necessary for, our linguistic developments. Similarly, an evolvable system will have to be parsable if it is to be of any use to its possessors. If a system evolved which could generate unparsable strings, those who possessed the system would not have attained any advantage over those who didn't; in fact it would probably have been more of a disadvantage. However, the one constraint that is not immediately entailed by the evolutionary constraint is that of simplicity and economy.

1.5 Syntactic Theory in the Light of Evolution: The Thesis

And so to the meat of the thesis, the questions that the chapters which follow will address. This research looks at what happens when one tries to reconcile the many different constraining factors that impinge on a theory of the human language faculty. More specifically, it looks at just two constraints from the list above - considerations of simplicity and economy, and considerations of evolvability - examining their interaction with, and impact on, one another. The issue is how compatible minimalism and evolution are; in other words, is the minimalist language faculty evolvable? The answer to this question will involve analysing why the evolutionary constraint does not entail the minimalist constraint in the same way that it does some others. The chapters which follow will develop an argument for interdisciplinarity in linguistic research; a theory of the language faculty which is developed in isolation of other domains will bring us no closer to answering the fundamental question of how language evolved.

Chapter 2 will outline the theory of language known as the Minimalist Program, setting the stage for an analysis of its central themes. In chapter 3, the theme in question is 'language as perfect'; this will be argued against from an evolutionary point of view. Chapter 4 will then continue the evolutionary treatment of minimalist ideas by taking issue with the notion of 'language as simple'; it will be shown that such a view precludes evolvability. In chapter 5, a recent proposal which tallies with the principal tenets of minimalism will be investigated. The claim will be developed that recursion is *not* (contra Hauser *et al.* (2002)) the key characteristic of the human language faculty, once more reiterating the message that a minimalist language faculty lacks evolutionary plausibility. With the general conceptual motivations of minimalism dealt with, chapter 6 will return to the details of specific minimalist syntactic theories, examining their internal cohesion and adherence to the central themes of perfection and economy. Finally, chapter 7 will draw the discussion to a conclusion, and will suggest a number of potential projects which could further develop the arguments and judgements therein.

CHAPTER 2

Modern Syntactic Theory - The State of the Art

2.1 Introduction

The investigation of this thesis will begin with an examination of the current state of play in syntactic theory. As noted in chapter 1, the term 'modern syntactic theory' might be interpreted in a number of ways depending on the particular biases and pre-conceptions that the reader brings. That is, a not insignificant number of frameworks being currently used and developed in the field of theoretical syntax all fall equally under this rubric. However, although brief references to other models will appear from time to time in the chapters which follow, the focus of this study will be just one specific framework - the Minimalist Program.

The purpose of this chapter is to set the stage for the central questions that the thesis will examine. Here, the motivations for, and the workings of, the MP will be scrutinised to a level deep enough to provoke the sorts of questions that the language evolutionist must be concerned with, yet, at the same time, as shallow as must be the case in a thesis where the principle concern is not an exploration of the internal coherence of the framework (although this question will be taken up in chapter 6).

A whistle-stop tour of the history and thematic concerns of generative grammar from its inception to the introduction of minimalist ideas (section 2.2) will be followed in section 2.3 by a comprehensive exploration of what it means for a theory to be 'minimalist'. In other words, I will consider what principles must be followed, what architecture must be assumed, what operations can be permitted, what entities can be licensed, and what questions must be answered in a theory which falls within the MP. Section 2.4 will conclude the chapter by mapping out the four fundamental problems (and many related, more specialised questions) to be investigated in chapters 3 through 6. These are best thought of as expressing the issues which make minimalism interesting from the point of view of the language evolutionist; the questions which the framework throws up when the constraining factor on our view of language is its evolution. Throughout this chapter then, the reader should bear the following thought in mind: are the motivations driving the minimalist syntactician, the methods and apparatus he employs, and the system of language he arrives at, befitting of a evolutionary approach to the human language faculty?

2.2 A History of Generative Grammar

In order to fully comprehend the motivations and mechanisms of the MP, and to be able to situate it evolutionarily, a brief detour is required to understand the historical directions which have led to its conception. A passing glance through the central themes of linguistic theorising from the beginning of the last century onwards clarifies both the nature of the intellectual climate that welcomed generativism as a revolutionary direction, as well as the fundamental insights that generative grammarians have retained from their predecessors.

Within generativism itself, a historical perspective discloses the course of exploration that led to the issues that are currently central in the thinking of minimalists. To take just one example, there appears to have been a general trend in generativism from rule-based theories to principle-based theories, the MP being a culmination, and also a generalisation, of the principles conceived of during the Government and Binding period.

2.2.1 Pre-Generativism

In modern terms, we might reasonably place the beginnings of the study of linguistics somewhere at the end of the 18th century, or the beginning of the 19th, with the emergence of comparative and historical linguistics (see Campbell (2001) for background discussion). At this time, linguists were mostly concerned with descriptive explorations of the similarities between the lexical items of different languages. Early comparative and historical work had a religious bent, with most frameworks assuming Hebrew as the mother language from which all others were descended (Robins 1990). Later work focused on the Indo-European languages; well-known illustrative findings of this period are Grimm's and Verner's laws (see Lehmann (1967)), which emphasised the significance of sound correspondences in establishing historical relations between languages.

In the early 20th century, the focus of linguistics shifted from diachronic to synchronic studies. Ferdinand de Saussure is often credited with this change of direction. Saussure's influence on modern linguistics deserves far more space than can be afforded to it here; however, two aspects of his work (Saussure 1916) are especially important for the current discussion: synchrony and structure. That is, Saussure put emphasis on studying the form of language at a particular time, with reference neither to its meaning, nor its historical context.

Structuralism continued under the influences of such figures as Sapir in the U. S. and Meillet and Jakobson in Europe[1]. As a founding member of the Prague School in the 1920's, Jakobson's impact can still be felt in today's linguistic theories. His work on markedness, and on implicational universals are just two examples of where modern linguistics has benefitted from his wisdom (Campbell 2001). Between the 1930's and 1950's, structuralism was the predominant approach to the study of language, and it was during this time that Leonard Bloomfield's (1930) American structuralism was to propel linguistics to the level of an autonomous scientific endeavour. Bloomfield's belief was that language should and could be studied independently of both meaning and culture. This position has been echoed by Chomsky since his earliest writings, and in the 1950's and 1960's became one of the central themes of the emerging school of generativism.

2.2.2 *Early Generativism - LSLT and Syntactic Structures*

The Bloomfieldian tradition was influenced by behaviourism. That is, it was believed that only objectively observed behaviour could form the set of data that was to be analysed. Language was viewed as a system that was learned by the child through a set of stimulus-response associations; language was seen as a behaviour, in other words. Thus, for example, Bloomfield held that during acquisition children receive reinforcement from adults on correct and appropriate productions that they do not receive when they make errors.

Chomsky's (1959) review of Skinner's *Verbal Behavior* (Skinner 1957) put an almost immediate halt to the behaviourist paradigm in psychology and linguistics. He argued there that behaviourism cannot explain the facts of language acquisition given the following: (i) that children acquire language so rapidly, (ii) that the input they receive during acquisition is often degenerate, (iii) that children often receive no feedback from adults during acquisition, (iv) that when they do receive correction from adults, it doesn't seem to affect the path of acquisition, (v) that language abilities and acquisition are independent of other cognitive abilities and acquisitions, (vi) that all children, independent of culture or intelligence, acquire language in the same way and within the same timeframe.

Chomsky's nativism strongly opposed the behaviourism of Skinner and Bloomfield. For him, linguistic behaviour was to be understood not as a response to

[1]Jakobson also worked in the U. S., emigrating there in 1942.

particular stimuli, but as a system of rules whose acquisition is driven by specialised linguistic knowledge which is internal to the human brain, and which exists there from birth. In other words, Chomsky stressed nature rather than nurture. What Chomsky did value in Bloomfield was his belief in linguistics as an autonomous science. Indeed, Chomsky was to take this position even further; his aim was to investigate language at the rigorous level that physics is studied. As we will see over the following chapters, this aim is incontrovertibly discernable in his recent work.

Chomsky's *The Logical Structure of Linguistic Theory* (henceforth *LSLT*), written in the mid 1950's but not published until two decades later (Chomsky 1975a), broke with the descriptivist trend in American linguistics at the time by promoting explanation over pure description. That is, the aim for explanatory adequacy – an account of how the linguistic knowledge of a speaker comes to be represented in the mind – displaced the aim for descriptive adequacy – an account simply of the possible expressions of the language – that had previously dominated the field. Although it has been argued (see e.g. Shapiro (1973)) that generative ideas are to be observed in earlier work, it is not controversial to pinpoint *LSLT* and (the later written, but earlier published) *Syntactic Structures* (Chomsky 1957) as the birth of Generative Grammar as we now know it.

Generativism was innovative in stressing the creativity of language; the fact that any speaker of any language has the capacity to produce and understand infinitely many novel utterances. This ability was judged to be predicated on the recursive capacities of syntax. Unlike the preceding work in the Bloomfieldian tradition which had a strong focus on phonological structure, generativism placed syntax at the centre of language, claiming that universals were to be found in this domain too. These universals were argued to form the core of Universal Grammar (UG) - the innate knowledge possessed by each and every speaker/hearer allowing him to produce and understand the infinity of well-formed expressions allowed by his language.

This revolutionary approach to linguistic theorising is known as Generative Grammar as it aimed to demonstrate how a set of phrase structure rules (a grammar) could generate all and only the well-formed sentences of a particular language. The speaker/hearer was assumed to possess innately the requisite language-specific knowledge (UG) to permit acquisition of such a grammar, thus explaining his complex abilities. The generative linguist's method of analysis was to use his own linguistic knowledge in judging the acceptability of utterances, in order to refine the rules of the grammar. Like Saussure's concentration on *langue* rather than *parole*, Chomsky's generativism is focused on the competence[2] rather than the performance of a speaker.

In summary, the central tenets and principal innovations of generativism can be boiled down to the following:

- Mentalism - a belief in an innate Universal Grammar - a template to which the grammar of any language conforms[3]; nature, not nurture, as paramount.
- Creativity - the hypothesis that language is open-ended and infinite.
- Syntax - the positing of syntactic universals, and syntax at the heart of linguistic creativity.
- Autonomy - of both linguistics as a science, and syntax as a system within language.
- Explanation - rather than simple descriptivism.
- Competence - the internal knowledge of the individual, rather than the external data, as primary.
- Introspection - the use of this internal knowledge by the linguist in judging well-formedness of linguistic expressions.

2.2.3 From Standard Theory to Government and Binding

The theory developed during the first decade of generativism is generally known as the Standard Theory (ST). Under the ST, the syntactic component of the grammar (semantic and phonological components were also posited, but will not be considered here) was elaborated to contain not simply a lexicon and a set of phrase structure rules, but also a set of transformational rules. It was shown that a syntax comprising phrase structure rules alone was inadequate to generate all the well-formed sentences of a language, given the enormous complexity that it would entail. For example, Chomsky (1957) illustrated how one transformational rule in addition to one phrase structure rule was sufficient to generate

[2] Note, however, that *langue* and competence are not interchangeable terms. The former relates to a possession of the society, the latter a possession of the individual.

[3] See Jackendoff (2002) chapter 4 for a detailed explication of what exactly Universal Grammar is.

any case of the highly complex verbal auxiliary system in English, while a phrase structure grammar would have required individual rules for each possible combination of auxiliaries[4].

The passive is another example of a transformational rule which demonstrated that a transformational grammar could more elegantly generate a language's acceptable sentences. Context free phrase structure rules introduced lexical items (e.g. $V_t \rightarrow$ hit, kick, open, ...), and generated the underlying string (e.g. S $\rightarrow$ NP + VP). Transformational rules were then applied which modified the underlying string to give the well-formed final sentence. Thus, a passive sentence was generated by applying phrase structure rules which gave the corresponding active sentence, and then modifying this underlying structure by means of the passive transformational rule. The advantage of such a system was that active and passive sentences had one and the same underlying structure, generated by one and the same phrase structure rule; a phrase structure grammar would need to posit two separate rules, and would thus not in any way account for the association between active and passive counterparts.

With *Aspects of the Theory of Syntax* (henceforth *Aspects*) (Chomsky 1965a) came the introduction of the terms *Deep Structure* and *Surface Structure* for the underlying and final structures of the sentence respectively. It was also in this work that Chomsky moved recursion from the transformational component to the phrase structure component. That is, the open-endedness of language made possible through recursive structures was instantiated not by allowing transformations to be embedded within each other as in previous versions of the theory, but by allowing phrase structure rules themselves to be recursive. For example, the rule $NP \rightarrow NP\ N$ or a combination of the rules $S \rightarrow NP + VP$ and $VP \rightarrow V + S$ would generate recursive structures at the underlying Deep Structure level.

Chomsky's work during the period for the ten years or so after the publication of *Aspects* has come to be known as the Extended Standard Theory (EST) or the Revised Extended Standard Theory (REST). It was during this time that mainstream generativism suffered its first challenge. The development of the theory had led to a level of Deep Structure which was highly abstract; so much so that some believed it should not be considered a level of representation different from the semantic level of representation. These beliefs crystallised into the

[4]See Newmeyer (1986) for details.

alternative school of Generative Semantics[5].

As Generative Semantics rose in popularity, the EST underwent a number of key changes. Restrictions on the application of transformations were posited as the focus shifted from positing a descriptively powerful grammar to limiting that power. Ross's (1967) dissertation on island constraints led the way to the trace theory of movement. Chomsky (1973) outlined the hypothesis that the application of movement transformational rules would result in a trace being left behind in the underlying position from which movement took place. The trace and the element moved were then argued to form a chain, and this chain could block certain other transformations, accounting for numerous theretofore problematic empirical cases. The further introduction into the theory of empty categories, of which a trace was argued to be one kind, permitted additional explanatory coverage.

Generativism has always been concerned with applying generalisations and abstractions wherever possible. From the 1970's onwards, a great deal of generalisation can be observed in the work of Chomsky and his generative colleagues. One of the most important abstractions of this period was the rejection of numerous different movement transformations (e.g. passive, equi-deletion, subject-to-object raising, dative shift, etc.) in preference for one all-encompassing rule - Move-α. This one general rule, in combination with a number of constraints on movement, such as those imposed by trace theory, had the explanatory capacity to deal with the same amount of data in a more elegant manner. A further important abstraction was the introduction of X-bar theory (Chomsky 1970) - a generic architectural pattern to which all phrase types conformed.

With the number of rules reduced greatly, the theory began to move in the direction of conditions which held more generally. That is, constraints imposed restrictions not on individual rules, but on levels of representation, and later on entire derivations (e.g. the theta criterion and the projection principle). In 1979, Chomsky's Pisa lectures (published in 1981 as (Chomsky 1981)) signalled the beginnings of a new period in generativism. With Government and Binding theory, the concern was focused in different areas. Specifically, the two questions of import at this time were the nature of language acquisition in the child, and the nature of variation across different languages. By introducing the Principles and

[5]Some representative publications of this school include the following: Lakoff (1971), McCawley (1968a), McCawley (1968c), McCawley (1968b).

Parameters model, Chomsky set the stage for the most successful time generativism has seen, when vast numbers of researchers[6] in both Europe and the U. S. would solve a plethora of empirical problems by hammering out a system based on the core principles of modularity and economy of explanation.

The key insight of GB was that the syntactic component is modularly organised. That is, modules such as Theta Theory, Case Theory, Binding Theory, Bounding Theory, Movement Theory, X-bar Theory, and Control Theory were assumed to each have their own responsibilities, effects of the entire system resulting from crucial interactions between the individual modules[7]. Furthermore, to answer questions of acquirability and variation, the model was divided into principles and parameters, each module presumably encompassing some of each.

Principles were deemed to be universal (e.g. the requirement in all languages that sentences have some type of subject), with parameters being variable across languages (e.g. the order of words in a phrase or sentence). Universal principles were additionally proposed to be innate, forming the UG that gives the child the headstart required in order to be able to acquire language so rapidly and easily despite inadequate input. Parameters, on the other hand, were hypothesised to be set during acquisition. That is, environmental triggers in the form of the linguistic data the child hears around him would set the parameter switches in one direction or another. Again, the proposed process had the advantage of reducing the workload of the acquiring child, and also explained how any child could be born into any linguistic community (no matter what its nationality or what the language of its parents) and successfully acquire the ambient language.

By this time, Chomskyan generativism had succeeded in eliminating rule-based in favour of principle-based theories. Indeed, this can be seen as one of the central themes of the history of generative grammar. A second such theme, also evident by the GB period, is the development of theories with greater empirical coverage coupled with more economical explanation. The Principles and

[6]The very fact that there were many more practicing generativists at this time gave rise to the possibility of a number of alternative generative theories emerging. Two such alternatives which continue to be pursued today are Generalised Phrase Structure Grammar (GSPG) - which in recent years has developed into Head-driven Phrase Structure Grammar (HPSG) (see Pollard & Sag (1994)) and Lexical Functional Grammar (LFG) (see Bresnan (2001)). However, as we are concerned with building up the history behind the MP, and it is the successor to GB, we will not consider these alternatives to any extent here.

[7]See section 3.2.5 for an illustration of this interaction.

Parameters model permitted data in very many languages to be accounted for systematically and efficiently.

2.2.4 *The Beginnings of Minimalism*

The current direction that generativism is taking is once more very different from its predecessors. The start of the MP is usually associated with the publication of Chomsky's (1995b) book of the same title. However, generative thinking had begun to take a turn towards the issues of minimalism somewhat earlier in the 1990's (see Chomsky (1991a), Chomsky (1991b), Chomsky (1993)), and although the program is highly novel in many ways, the principal concerns of the MP had been gaining momentum in generativist theorising during its previous incarnations.

The central motivating factor of economy had reached a peak of importance by the beginnings of minimalism such that this consideration alone turned the architecture of the syntactic component of the grammar almost on its head. As Culicover (1999:138) puts it: "[s]uch a perspective...explicitly rules out precisely the major theoretical achievements of the past. All of them." In the following section of this chapter, it will be shown how economy considerations have fashioned in recent years a more lexicalist, less modular, and barer theory of syntax, and the implications of this remodelling on the questions of historical import to generativists will be investigated.

2.3 Minimalism - A Program for Syntactic Theorising

With the history of minimalism now outlined, this section can turn to the framework itself. Here, consideration of some general conceptual and methodological issues, such as the motivations for the program of research, and the ways it might answer generative questions, will be followed by a (relatively high-level) examination of the ins and outs of the architecture itself.

2.3.1 Program versus Theory

Minimalist theorists are very keen to point out wherever possible that minimalism is not one specific hypothesis of how language works, but is rather a fashion of theorising; it is a program, not a theory. This position is reflected directly in the title of one of Chomsky's first minimalist papers: *A Minimalist Program for Linguistic Theory* (Chomsky 1993); the MP is thus seen as one possible framework within which more minimal, pared down theories of language can be formulated. As Lasnik expresses it: "[m]inimalism is as yet still just an 'approach', a conjecture about how language works ('perfectly') and a general program for exploring and developing the conjecture" (Lasnik 2002b:436).

The approach then, is at the same time an expansion and a specialisation of themes that first surfaced within preceding generative frameworks. The approach is epitomised by a desire to minimise the forms of representations and the lengths of derivations, and by a desire to motivate this minimisation by showing that "...there is some sense in which extra conditions or outside conditions are driving linguistic development - and in fact the form of the initial state as well - to be in some sense perfect, kind of like a snowflake is perfect" (Chomsky 2004:150). Chomsky (2004) surmises that the approach of minimalism allows linguists to now put aside *what* questions - what is language? - and ask instead *why* questions - why is language the way it is?

So, while general minimalist suppositions (such as the economy of the system) hold in all particular variations of the framework, the specific details are subject to modification and development. In terms of the questions being asked in this thesis, the theory versus program issue suggests that we should derive neither criticisms nor commendations from the minutiae of any one version of minimalism, as minor developments may lead to significant changes in such aspects, thus throwing out any implicated evolutionary arguments. However, it will become clear over the next chapters that the points raised in this study are not of this type; it is the higher level conceptual and methodological reasoning of the MP that is in question when the framework is applied to evolutionary concerns[8].

2.3.2 *Motivations*

The historical background to the MP examined in section 2.2 has highlighted certain of the motivating factors leading to the new direction. In this section, three particular motivations will be examined in detail: the economy considerations that have been pursued since the earliest times in modern generative grammar[9], the lexicalist bent that has been developing since the reactions to generative semantics, and finally, the questions of innateness and acquisition that have been central to the generative enterprise since its beginnings in the late 1950's.

2.3.2.1 *Economy Considerations*

Broekhuis & Dekkers (2000) talk of the "...extreme reduction of the descriptive apparatus..." that minimalist theories entail. This reduction is forced by the perhaps strongest motivation of the framework - economy considerations. In the MP, economy has been applied to every level of representation, every principle, every structure, leading to a type of bareness never seen before in generativism. As will be seen in chapter 3, economy is equated with perfection, a characteristic which, it is surmised, might reasonably be attributed to the narrow language faculty. If the narrow language faculty is to carry out its job - mapping between sound and meaning - in a perfect manner, it should have no surplus architectural components, nor should it have excess computational complexity.

The narrow language faculty is defined as a computational system whose job is to create a mapping between sound and meaning. The systems of sound (phonology) and meaning (semantics) themselves are assumed not to interact directly[10] as their representational means are incompatible; the computational narrow syntax thus bridges them. In doing so, the system will obviously have to interface with the systems of phonology and semantics, and these will impose

[8]Although chapter 6 will examine the details of one line of minimalist reasoning, this will not form the core of the evolutionary argument, but will merely add reinforcement to the claims of chapters 3 through 5.

[9]See e.g. Chomsky & Halle (1968) on evaluation procedures for grammars.

[10]Although, there are clearly cases where there is such a direct interaction, e.g. the intonation patterns of focussed constituents. Such cases prove difficult for the MP; a syntactic [focus] feature must be posited to uphold the mapping character of the computational component, yet this feature typically has no real function.

certain conditions and restrictions on the computational system. Known alternatively as *interface conditions* or *bare output conditions*, these are posited to be the only constraints that allow the narrow syntactic component to deviate from perfection; in other words, these are the only demands that the computational system *must* meet. Thus, economy in the system should fall out directly from its having only these two external forces to contend with.

Economy is instantiated by removing levels of representation that, given these assumptions, no longer have any motivation, by reducing the number of modules the system is composed of to just one, by collapsing multiple generative cycles into one, and by limiting the application of operations by means of least effort restrictions. A more detailed review of these economy measures is reserved for section 2.3.3.1 below; for now, we can summarise by characterising the emergence of minimalist theorising as the catapulting of the long-standing background concern of economy to the foreground.

2.3.2.2 Lexicalism

A more minor and clearly more subtle motivation that can be attached to the MP is the drive towards a more lexicalist theory of language. As section 2.2 already outlined, the early stages of generative grammar were concerned with developing a rule-based system, with different transformations posited to account for almost every different construction the empirical data offered. The rise of Generative Semantics in the mid 1960's, however, was countered by the traditional generativists by a system which granted more weight to the lexicon while reducing the power of transformations. Chomsky's (1970) *Remarks on Nominalization* argued that category alterations that had previously been assumed to be the result of a transformational rule (e.g. the rule changing the verb *give* into its nominal counterpart *gift*) should be analysed instead as two separate entries in the lexicon[11].

Other work in this vein included the refutation of rules which transformed full noun phrases into their pronoun counterparts (Jackendoff (1972), Dougherty (1969)), and the proposal that word-formation rules should be completely eliminated in favour of a lexicon with fully specified entries (Jackendoff 1975). These advances resulted in a system comprising a leaner set of transformational rules,

[11]Or perhaps one entry with alternating paths for nominal, verbal, adjectival (etc.) counterparts.

augmented with a fuller lexicon, and a more complex phrase structure component.

In *Aspects*, Chomsky further developed the trend towards lexicalism by highlighting the lexicon as the repository of irregularity in language. Minimalism follows in this lexicalisttradition (somewhat pushed to one side in the GB era), hypothesising that it is features of lexical items, specified in their entries in the lexicon, that drive derivations, and further that these features are the locus of parameterisation, allowing the theory to account for cross-linguistic variation. The particular details of these lexical features, and their impact on the derivation, will be examined in section 2.3.4.1 below.

2.3.2.3 Generative Questions

The two questions that have been central to generative grammar since Chomsky first drew attention to them in the late 1950's continue to drive minimalist theorising, albeit in a slightly less direct and forceful way than, for example, in GB times. I will now offer just a few words by way of commentary on how the MP proposes to maintain their priority.

The issue of first language acquisition, which asks how it is that children seem to be able to acquire their mother tongue in a rapid and effortless manner, is once more, under minimalism, given a nativist answer. There has been no change to the generative assumption of an innate faculty, or organ, which bestows certain universal knowledge of language on the acquiring infant, permitting the acquisition procedure to consist merely of a fixing of parameters, based on environmental input. What the MP specifically has to offer to the innateness question is its pared down architecture. That is, positing innate universal language knowledge becomes less controversial if what is posited as existing internally at birth is much reduced[12].

There is, however, a problematic matter for the acquisition issue that follows from a different minimalist assumption. Minimalism proposes that the lexicon is the only part of the system in which non-universal features are to be found. What

[12]Of course, what is innate are the genes which code for the linguistic capacity, not the details of the grammar themselves; assuming the latter is confusing two separate levels of description. However, it is the expectation that it may be a reasonable heuristic that a less complex language faculty will be coded by a less complex genotype that has fueled certain optimism that minimalism offers a more reasonable nativist position. As section 4.4 will discuss briefly, we are quite a way from being able to verify this heuristic.

this then says is that the acquisition process need involve the child learning only the properties of lexical items, the rest of the universal architecture being innate. However, as will be examined in more detail in chapter 6, the properties which lexical items are assumed to encompass under the minimalist view are ample in number, and wide-ranging in type. So, although the reduced architecture of the rest of the system makes for a more reasonable innateness claim, the extensiveness of the lexical properties brings us back to the initial question of how the child can come to learn the vast amount of linguistic information that he does in such a short space of time with such little effort.

The universality of all but the lexicon brings us neatly to the second big generative question - how do we account for cross-linguistic variation? Minimalism forces all such variation into the lexicon, so that different features on lexical items in different languages would force different operations to apply. For example, under the framework proposed in Chomsky (2001), the difference between languages like English, in which a wh-phrase must move to the specifier position of the CP in wh-questions such as (1), and Japanese type languages in which the wh-phrase remains *in situ* in such constructions, as in (2), is explained in terms of a parameterised [EPP] feature. The English type languages' head of CP is marked with an [EPP] feature, meaning that movement upwards is necessary, while the head of CP in Japanese and similar languages is not, thus blocking movement (see section 2.3.4 below for further explanation of [EPP] features, and the movement operation they induce).

(1) **What** did John buy?
(2) John-wa nani-o kaimasita **ka**?
John-TOP what-ACC buy Q
'What did John buy'?

Restricting parametric variation to the domain of the lexicon has the advantage of answering the imperfection question that such variation is argued to pose (Chomsky 2001:2). That is, variation across languages is an imperfection in the system; a perfect system should reasonably only have one implementation, hence one possible language. However, as with other imperfections (see section 2.3.4 below, and chapter 3), parametric variation may be an answer to some problem imposed by an outside system, hence unavoidable. Nevertheless, if such variation is restricted, the imperfection is diminished.

Thus, minimalist theories allow for the principal generative position with respect to innateness and cross-linguistic variation to be maintained without any significant revisions.

2.3.3 (Virtual) Conceptual Necessity

We now know that the MP aims to reduce the computational apparatus of language. In section 2.3.2.1 above we briefly noted some ways in which the system achieves this reduction by obeying certain economy considerations. The expression *(virtual) conceptual necessity* recurs frequently in minimalist writing in discussions of this simplicity and reduction in the system. It is often noted that only few operations and few constraints are 'virtually conceptually necessary' features of the language faculty. While nowhere is there elaboration of what exactly the phrase is supposed to denote, it is often used interchangeably with the word 'inevitable', leading the reader to suppose that conceptual necessity refers to only that which *must* exist in the system; nothing superfluous. As Aoun *et al.* (2001:400) put it in relation to the Copy operation: "...Copy is similarly conceptually necessary, in the sense of following from a very uncontroversial design feature of Universal Grammar." Thus, conceptual necessity would seem to bear on those aspects of the narrow language faculty which are fundamental to it.

Turning now to the 'virtual' part of the expression, consensus is far less clear as to the meaning of the word. Postal (2003) assumes that it is a hedge, and this might appear a reasonable interpretation given that it is often omitted or enclosed in parentheses. However, the line from the minimalist camp is that "...certain formal properties of the system may follow from *virtual* conceptual necessity...because there's no *actual* conceptual necessity to assume [minimalist theory]" (Uriagereka 1998:102). Clearly, the features of language which are conceptually necessary will differ depending on the theory of language we are assuming. This thesis will not discuss the merits of choosing between the different sets of conceptually necessary properties posited by different theories; the point here is simply this: the terminology in question clearly identifies the position that the pared down computational system that minimalism advances circumscribes only that which is strictly necessary[13]. I will turn in the following sub-section to a more detailed examination of what minimalists consider to be conceptually

[13]As we will see in chapter 3, the term is also intimately linked to discussions of perfection in language if perfection is understood as correlated with a type of simplicity that holds of the system. Only those aspects of language which are conceptually necessary form the core simple, perfect system.

necessary architectural features.

2.3.3.1 *Elimination of DS and SS and Other Simplifications*

The reductions and minimisations of the MP result in a system that is vastly different in many respects to the earlier generative GB system of language. I will now examine the most important reductions leading to a system that consists of only the conceptually necessary components.

Levels of representation have been whittled down to just two. The argument is that if we are dealing with relating or mapping between sound and meaning, only levels of representation relevant to sound and to meaning should be required in the architecture. Thus, levels such as Deep Structure and Surface Structure, which were theory-internal, and more specifically syntax-internal, should be eliminated. The levels we are left with are LF (Logical Form - the meaning level of representation), and PF (Phonological Form - the sound level of representation). These levels of representation are understood to provide information taken from the narrow syntactic component to the external systems of meaning and sound via interfaces (the conceptual-intentional (CI) and the articulatory-phonetic (AP) interface respectively)[14]. The MP further supposes that there are no interactions between PF and LF, or the corresponding AP and CI interfaces; all relations between the two are mediated in the narrow syntax through the derivation. Moreover, constraints which were previously proposed to hold at the now defunct levels of representation have been dismissed, or moved to a level that still exists (e.g. binding conditions now hold at LF instead of SS (Hornstein *et al.* 2005)).

The minimalist architecture is depicted in early minimalist literature using the following diagram:

[14] Note that while it is usual to assume that LF and PF feed the CI and AP interfaces, and are thus separate to them (Chomsky (1995b), Cornilescu (2004)), some equate the levels of representation LF and PF with the CI and AP interfaces (van de Koot 1996). While there is no significant difference between these alternatives for the investigation here, I will assume the former as more representative of minimalist theorising.

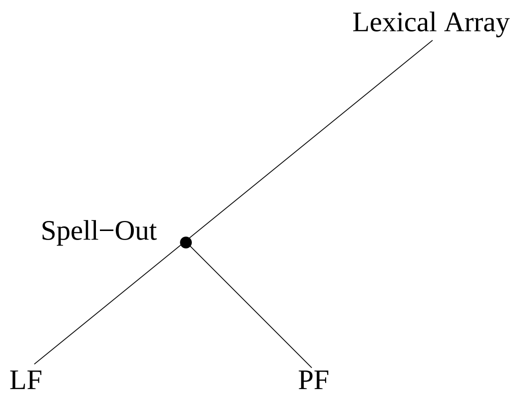


Figure 2.1: Minimalist architecture

The derivation begins with the selection of lexical items, and their creation into a lexical array or numeration (see section 2.3.4.1). These lexical items are then combined, or merged, together repeatedly to form an utterance (see section 2.3.4.2). The derivation proceeds in this manner until it reaches the point of Spell-Out. This is understood to be the stage at which the derivation splits to send meaning information to LF and sound information to PF. All items from the lexical array must have been merged at the point of Spell-Out. Then, one path transmits the expression as it then stands to PF for phonological interpretation, and the other transmits the expression to LF for meaning interpretation.

Operations take place on all three paths. As mentioned, the operation Merge applies on the first path. Movement operations also apply during the derivation (see section 2.3.4.4), and these can apply on any of the three paths. However, any operations that occur on the path from Spell-Out to LF cannot affect the phonological form of the utterance; that is, the way in which the utterance will be articulated cannot be altered by any operations happening on the LF path. This means that movement operations that happen here are *covert* (as opposed to the *overt* operations that apply on the path to Spell-Out). Covert operations are assumed in this framework to be responsible for quantifier raising processes, for example. Movement operations on the path from Spell-Out to PF may rearrange the ordering of lexical items, but only if this does not have any affect on the semantics of the utterance. In the same way that the phonological interface cannot access what is on the path to LF, the semantic interface cannot access that which is on the PF path.

Once the derivation reaches PF and LF, interpretation by these components takes place. If interpretation at both interfaces is successful, the derivation is said to converge. Should there be any reason that the utterance cannot be interpreted by either interface, the derivation is said to crash. A derivation will crash, for example, if phonological information remains at LF, or semantic information at PF, or if syntactic information remains at either (see section 2.3.4.3 for how this is avoided).

Later versions of minimalism do not conform to the diagram in figure 2.1. In section 2.3.4.5 the cyclic phase-driven derivation will be examined in detail; however, some initial observations will be made at this point. Spell-Out has become cyclic, meaning that it occurs not once, but many times in the course of a derivation. The derivation advances in steps, or phases, at each of which only a sub-set of the lexical array is visible. At the end of each phase, Spell-Out applies, sending chunks of the utterance at a time to LF and PF. Thus, there is no distinction between operations that apply before and after Spell-Out on the derivation to LF; no covert versus overt operations. The only distinction that still holds is between operations that occur between Spell-Out and PF and those that occur between selection of the lexical array and LF. The introduction of derivation by phase into the framework highlights locality-type economy considerations (see e.g. Chomsky (2002a) for discussion); that is, the computation involved in deriving an utterance should be bounded in the amount of input it deals with at any one time. Other locality-type constraints that this later version of minimalism imposes are look-ahead restrictions, and search space restrictions. Thus, it should not be possible to determine what will happen at later points of the derivation, and on this basis, choose whether an operation will apply or not; rather, operations must be executed immediately, opening the derivation up to possible later crashes. Similarly, as will be seen in section 2.3.4.5, the domain in which a search for matching features can be carried out is strictly limited.

Operations, too, have been cut back in the MP. The three main operations which remain are Merge (see section 2.3.4.2), Agree (see section 2.3.4.3), and Move (see section 2.3.4.4). A fourth, operation, Copy, appears in certain but not all versions of the program. Furthermore, operations cannot apply optionally[15], but apply only when forced by the requirement to check features (see section 2.3.4.3).

[15]Apart perhaps from in the phonological component (the path from Spell-Out to PF). This path of the derivation is typically not granted much space in the literature, and thus will not be discussed further here.

Economy considerations are clearly observable in numerous other simplifications too. Simpler operations apply in preference to more complex ones. For example, Move will not apply where simple Agree would suffice, as Move is interpreted as consisting of Agree plus Merge. Move will apply only where Agree cannot do the job required; in other words, where an [EPP] feature needs checking (see sections 2.3.4.3 and 2.3.4.4). Less economic derivations are therefore advanced to be blocked by more economical ones, whether that means Agree rather than Move, or moving a shorter rather than a longer distance, or some other opposition. A further simplification of this type comes in the form of the Inclusiveness Condition. This states that nothing can be added in the course of a derivation; that is, only those features and properties which obtain in the lexical array determined at the beginning of the derivation may be used throughout the phases of the derivation.

A reduction of a different type is illustrated by the shift from stipulation to consequence of phrase structure theory. While in GB theory, phrase structure theory was just one of a number of architectural modules specifically postulated, it is claimed that the central operation of the MP - Merge - forces the basic phrase structure required to fall out directly. In other words, simply by merging two lexical items together to form a unit, and later merging another item or unit with that first unit produces the bare structure that minimalism posits, without any special or additional conditions. The bare structure that minimalist theories advocate implies further simplification. Phrasal categories no longer exist; these are considered surplus to requirements given that they have neither semantic nor phonological import. Further, category features such as N or D similarly mean nothing to the CI or AP interfaces, so are dispensed with (in later versions).

To sum up, then, eliminations and reductions have been applied to every aspect of the architecture; levels of representation, operations, syntactic constraints, search space, phrasal categories and categorial features, derivational paths. Although not every simplification investigated fully or simply alluded to in the literature of the past decade or more has been detailed here, the central concept should be more than clear - the architecture should reduce to the bare minimum required to fit between the semantic and phonological systems, and the derivation should follow a course which is computationally restricted in both its use of operations, and the domains in which it can apply them.

2.3.4 *The Derivation*

Now that the conceptual motivations of the program have been outlined, the architectural facts require deeper investigation. In this section, I will examine the general architecture supposed by minimalist theories, as well as the specific operations that are proposed to drive the derivation of utterances within this architecture. Necessarily, due to restrictions of space, and the fact that an exposition of the architectural details of the MP is not the primary goal of this thesis, much detail will be omitted in the sub-sections which follow. Certain assumptions of background comprehension will be made; where the facts are considered radically difficult, more in-depth annotation will be offered, and references supplied. It is also important to remember that as minimalism is an over-arching program, its various specific theories are constantly evolving. Significant changes that have unfolded over various versions of minimalism will be noted on several occasions below. However, this also means that in certain cases, the most up to date version of some particular fact or position may not be reflected in the explanation given; such cases, however, should not impinge on the general comments and issues raised in section 2.4, and in the chapters which follow. Similarly, any cases in which terminological short-cuts have been taken are not crucial to the themes of this enquiry, and have been taken to ease comprehension given the brief treatment of complex data. To be clear, in what follows I take three main works to be representative of two stages of minimalist theorising. Chomsky's 1995 book (Chomsky 1995b) underlies the earlier version[16], and two later papers (Chomsky (2001), Chomsky (2002a)) a later version, of the architectural details.

2.3.4.1 *The Lexical Array and Feature Inventories*

The lexicon plays a considerable role in minimalist theories. It is the centre of all cross-linguistic variation, and it further supplies the lexical features which drive the derivation. For every utterance, a subset of all lexical items available in the particular language is selected to form a lexical array[17]. The lexical array is formed only once, and can be accessed only in the narrow syntactic component (the derivation to LF); once a syntactic object has been sent to LF and PF, the lexical array is no longer visible. As the derivation proceeds, items are inserted from the lexical array throughout, rather than in one go, as was the case in previous

[16] I will also refer to Adger (2003) as representative of earlier minimalist thinking; it is from here that more detailed exposition not given in Chomsky (1995b) is taken.

[17] Note that the lexical array is known as a Numeration if any of the items in the array are selected more than once. In this case, the Numeration will be a set of pairs $< l$, n$>$ where l is a lexical item, and n is the number of times it appears in the lexical array (Chomsky 2002a).

generative theories.

Lexical items enter the derivation with three types of features already specified. Semantic features are required at the level of LF, and provide information related to the meaning of the lexical item, for example the feature [artifact]. Phonological features are required at the level of PF, and provide information related to the form of the lexical item, for example the feature [begins with vowel]. Formal features are required in the course of the derivation from the lexical array to LF. Formal features include Case features, tense features, person, number, and gender features (the latter three collectively referred to as ϕ-features), and more besides.

An important property in the discussion of formal features is interpretability. It is postulated that a formal feature is either [+interpretable] or [-interpretable] (uninterpretable). This property refers to whether the feature can be interpreted at the interface level of LF. Interpretable formal features differ from purely semantic features in that the latter hold no syntactic information whatsoever. The interpretable formal feature can be thought of as a type of bridge between the syntactic component and the semantic component. An example of such a feature is [number] on nominals. Clearly, such a feature is required in the narrow syntactic component, as syntactic number relations hold between nouns and verbs. However, it is just as clear that the [number] feature should be required in the semantic component of the grammar, in that it is important to distinguish singular and plural nominals at the levels of meaning; *man* means something different to *men*, for example. As with [number], the other ϕ-features of nominals are also considered interpretable, while all the ϕ-features of verbs are uninterpretable (there is no sense in which the [number] or [person] properties of a verb are meaningful in the same way they are for a noun). Case features contrast significantly in only existing on nominals, and always being uninterpretable.

A further type of formal feature which will be relevant in the discussions of the operations of the system is what is termed in the literature the [EPP] feature. The name derives from the Extended Projection Principle of GB theory, which states that a predicate must have a subject. The [EPP] feature is always uninterpretable, and is found, not on nominals, but on inflectional and tense heads only. In the MP, the [EPP] feature has a central role: it motivates movement (see section 2.3.4.4), thus fulfilling the requirement of certain heads to have a filled specifier position.

What is essential about uninterpretable formal features is that they must not remain once the derivation arrives at LF and PF, as these features cannot be interpreted here. They must therefore be somehow removed in the course of the derivation by means of a checking process. This will be outlined in section 2.3.4.3.

2.3.4.2 Merge

The operation Merge is at the centre of the derivation of utterances in the MP. It is a binary concatenation operation, taking as input either single lexical items, or units of previously combined lexical items. Its output is a unit consisting of lexical items structured in a hierarchical manner. One of the two items merged - the target - projects to form the label of the unit. Thus merging α and β will give either (3a) or (3b):

(3) a. α (α β)   b. β (α β)

The item that is projected to label the unit is, by definition, the head (Hornstein *et al.* 2005).

The choice of what items can merge together is not open, but is dependent on particular features they possess. The features which permit merge are thus equivalent to selectional restrictions. A sample derivation of the simple expression *The dog chased the cat* will illustrate how the operation works. This derivation is based on the model of Adger (2003). At a basic level, it illustrates the process; however, there are a number of drawbacks with such a model. The features which drive the merges are here thought of as holding at a categorial level, i.e. a noun can merge with an adjective or with a verb as these have nominal features, but an adjective cannot merge with an adverb as the latter does not have features of the former category, nor the former of the latter category[18].

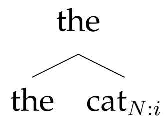
[18]Morphological merging resulting in compounds (e.g. *stirfry*, a verb-verb compound), indicates that particular lexical items show idiosyncratic restrictions which features at the categorial level may not capture. This difficulty notwithstanding, Adger's model will suffice for the current purposes (and, of course, no model will be problem-free).

We begin with the lexical array (a numeration in this case, as one item, *the*, is selected twice), the unordered subset of the lexicon containing the items *dog*, *chased*, *the*, and *cat*. The first step is to select a lexical item from the numeration. Let's begin with *chased*. As a verb, *chased* is specified with, among other features, a categorial [V] feature. This is an interpretable feature so does not need to be removed in the course of the derivation. *chased* is also specified as having two uninterpretable [N] features, indicating that it is a two-place predicate, and must merge with two nouns[19].

(4) chased$_{V:i,N:u,N:u}$

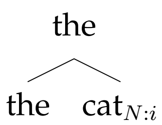
The second step is to insert the complement of the verb – *the cat*. This is done in two sub-steps: firstly, we need to merge the two lexical items *the* and *cat*, and then we need to merge the combined unit with the verb. The lexical item *cat* is specified with an interpretable categorial [N] feature, and an uninterpretable [D] feature. Its [D] feature is satisfied by the [D] feature of the determiner *the*.

(5) cat$_{N:i,D:u}$ + the$_{D:i}$ $\rightarrow$

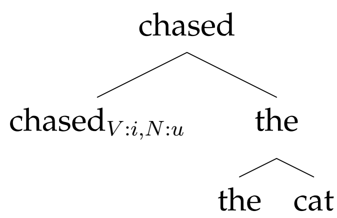


The noun *cat* still has its interpretable [N] feature intact. This can check against one of the two uninterpretable [N] features on the verb *chased*. So, we merge the verb and the unit formed previously.

(6)



\+ chased$_{V:i,N:u,N:u}$ $\rightarrow$

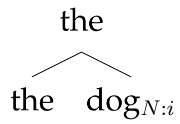


The third and final step again needs to be broken down into two sub-steps: the first merges the remaining noun and determiner, the second merges the newly formed unit with the verb. The lexical item *dog*, as another noun, is specified with an interpretable categorial [N] feature, and an uninterpretable [D] feature. The

[19]In the following diagrams, categorial features are marked on lexical items with a subscript. Following Adger (2003), *:i* indicates an interpretable feature, while *:u* indicates an uninterpretable one. Furthermore, once features have been checked and eliminated, they are removed from the diagram.

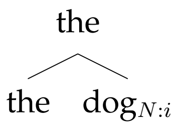
[D] feature is checked by merging *dog* with *the* to form the DP *the dog*.

(7) $\text{dog}_{N:i,D:u}$ + $\text{the}_{D:i}$ →



Merging *the dog* with the previously formed unit *chased the cat* allows us to check off the remaining uninterpretable [N] feature on the verb. At this stage all the uninterpretable formal features have been checked off and removed, so the derivation is complete.

(8)



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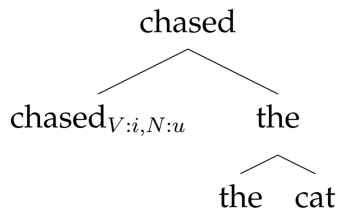

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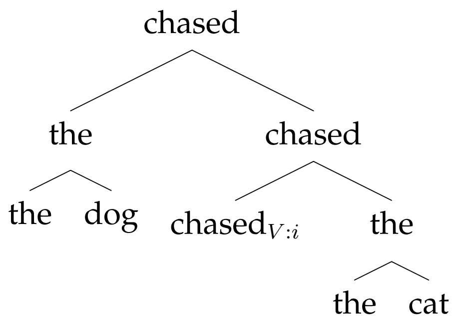


This categorial-feature model follows a version of minimalism prior to the removal of such features. In more recent work in the minimalist framework, the exact manner in which Merge is limited by features on lexical items is somewhat unclear. Although later versions would leave ϕ-features to drive certain merges, other merges appear to lack the requisite driving force[20]. One possible way forward would be to assume that in the latter case, nothing in the narrow syntactic component blocks random merges, but that these are later ruled out by interpretation difficulties in the semantic component. This is obviously not a satisfactory dichotomy to uphold, however, and it would moreover introduce additional complexity in the semantic component.

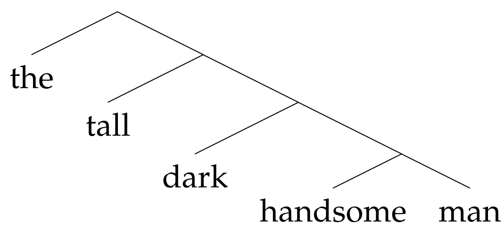
[20]For example, [person] and [number] features on verbs and nouns (uninterpretable on the former, interpretable on the latter) would allow these types of lexical items to merge, yet there are no corresponding features which match on prepositions and nouns, allowing construction of a PP.

Theories of Distributed Morphology (see e.g. Halle & Marantz (1993), Halle & Marantz (1994), Marantz (1997), Barner & Bale (2002)) offer a further alternative. The proposal is that lexical items should be underspecified for category, the lexicon consisting instead of generic roots which can undertake nominal or verbal (or other) work depending on the functional environment they occur in. For example, the root *jump* can be inserted in an extended projection of tense and agreement, and function as a verb, or can be inserted into a DP projection and function as a noun. This scenario is not without its problems either (see e.g. Panagiotidis (2005)). However, as a detailed investigation of the current answers to the question of how to restrict Merge would take us too far from the pertinent questions of the thesis, these issues will not be explored further here; the outline of Merge according to early minimalism provides sufficient characterisation for current purposes.

Simply assuming the operation of Merge is enough, minimalists claim, to give a number of properties and relations that previous generative theories would have had to stipulate separately. For example, it is argued that recursion - a key property of natural language, to be examined in detail in chapter 5 - falls out from the operation of Merge; applying Merge over and over, the output of one cycle of Merge becomes the input to the next. Thus, Merge is the operation which implements recursion (see section 5.3.2.1 for more on this). Merge is also argued to yield a number of relations which feature as crucial configurational patterns in the computational component (e.g. c-command - see Chomsky (2002a)).

The manner in which Merge operates also means that the Specifier-Head relation no longer has the special status which it was granted in GB theory. For example, to form the NP *the tall dark handsome man*, a number of merges take place. First, *man* and *handsome* are merged - this is termed first Merge. Then *dark* is merged to the resulting unit - second Merge. Then, *tall* is merged to this unit - third Merge. Finally *the* is merged to this unit - fourth Merge. As Hornstein *et al.* (2005:193) put it "...a head may project as many times as it has specifications to be met." The structure in (9) is the result:

(9)



Thus, application of Merge in such a fashion gives what are essentially multiple Specifiers, rejecting the possibility of Specifier-Head as a structural relation with special status.

A final point to note in this section is the difference between Merge and Pure Merge (Chomsky (1995b), Chomsky (2002a)), a distinction which will appear again in section 2.3.4.4. When the Merge operation is applied in isolation from any other operations, it is more specifically referred to in the literature as Pure Merge (the cases seen thus far in this section are then instances of Pure Merge). In contrast, when the Merge operation is applied as part of the composite operation Move, it is known simply as Merge. Move, which comprises Merge plus additional operations, is more costly than Pure Merge, and as a result should apply only when Pure Merge is not computationally sufficient.

2.3.4.3 Feature Checking and Agree

Section 2.3.4.1 stated that uninterpretable formal features must undergo a checking process in order that they can be removed from the derivation before it reaches the interfaces. Checking proceeds under the configuration of Agree. Agree establishes a relation between two lexical items (or more properly, between their features): a probe and a goal. The probe has unvalued uninterpretable ϕ-features which must be deleted. For this to happen, it must find a goal that possesses matching features with which it can check. More specifically, matching features are understood not to be features which match in value (e.g. [+singular] and [+singular]) but simply features which match in dimension (i.e. [$\pm$singular] and [$\pm$singular], or, more simply put [number] and [number]). For example, the probe T(ense)[21] in (10) has an unvalued (hence uninterpretable) [number] feature, while the nominal *a good book* has a [number] feature valued as [singular]:

(10) [...T be read [a good book]]

[21] The hierarchy of projections in the minimalist system is assumed to adhere to the following general pattern: [$_{CP}$ Spec C ...[$_{TP}$ Spec T ... [$_{vP}$ Spec v ... [$_{VP}$ Spec V XP]]]]], where C = complementiser, T = tense, v = a light causative verb, which takes the VP as complement, and adds further semantic information to the VP projection (see Adger (2003) for explanation), V = the main verb, and XP is some complement of the main verb.

Under Agree, the uninterpretable feature of T is given the value [singular], and both the [number] feature of T and of the nominal can be deleted. It is further posited that in order for an element in an Agree relation to be able to remove the uninterpretable features of the matching element, it must have a full set of features. In other words, should α not have a full set of ϕ-features, although an Agree relation can obtain with β, β's features cannot be removed. Illustrations of so-called *defective probe* behaviour in the literature include raising and ECM constructions, and cases where more than one head appears to match a nominal (as in the case of certain Romance constructions where both the tensed verb and the participle agree with the noun) (see Chomsky (2001)). The ECM construction in (11) illustrates the point:

(11) [John T seems [T_def to be happy]].

Here, the lower T is defective in that it lacks a [tense] feature, forcing *John* to raise to the higher clause. Here, *John* can enter an agreement relation with the higher, non-defective T[22].

Economy considerations stipulate that the goal of the probe must be within its local domain, and must be c-commanded by it; that is, the Agree relation may only hold locally. Features may match a probe, but if they belong to a goal that is too distant from it, they cannot Agree with the probe.

Another type of feature which must be removed in the narrow syntactic component is the Case feature. Case is hypothesised to be of a different nature to ϕ-features in that only goals are specified with Case, while probes have no Case feature (valued or unvalued). The Case feature of the goal is unvalued until it enters into an Agree relation with a probe. Via the matching, checking, and removal of the probe and goal's ϕ-features, the Case feature is valued and removed too. The value given to the Case feature depends on the probe in question; for example, a T probe values the goal's Case feature as [nominative], a v probe as [accusative]. Furthermore, the Case feature fulfils another role in the derivation; as with uninterpretable ϕ-features, the Case feature is instrumental in marking the goal to which it belongs as *active*. A goal must be not only local, but also

[22]It is, however, unclear as to *why* lacking a tense feature leads to the probe being defective; there are cases reported of languages in which infinitives show agreement (e.g. Hungarian (Tóth 2000)). The MP appears thus to simply stipulate that this must be the case. I will return in chapter 6 to the issue of stipulations in the MP.

active, for it to be accessible to a probe.

[EPP] features, too, are uninterpretable, and hence must be removed before the interfaces are reached. This feature may only be removed following movement of the goal to the EPP position of the probe (its Specifier)[23]. Thus, whereas uninterpretable ϕ-features on the probe and the goal, and uninterpretable Case features on the goal, may be removed by simply being in an Agree relation (provided the probe and goal are non-defective), a further operation must take place for the [EPP] feature to delete. This will be the subject of the next section.

In much of his writing, Chomsky refers to uninterpretable features as imperfections, but only apparent ones. That is, he assumes that although uninterpretable features look like something that should not be found in a perfect, economical system, they are the result of external conditions imposed on the narrow language faculty; they are the optimal way of dealing with these conditions, and so are not real imperfections. Further discussion of this issue will follow in the next section, and will be central to the investigations of chapter 3. At this stage, we can summarise the types of uninterpretable formal feature, and their functions in the system, as follows: (i) ϕ-features pick out the probe, and establish the type of goal that the probe must find, (ii) [EPP] features determine that the probe offers a position to which the goal can move, and (iii) Case features activate the goal.

2.3.4.4 Move

As in previous versions of generative syntactic theory, a movement operation is posited for certain derivations. However, unlike earlier theories, minimalism says that movement is not optional, but must be forced in some way. That is, Move can only be licensed as part of the minimalist architecture if it in some way deals with requirements set by outside systems. In fact, movement, in the same way as uninterpretable features, is often referred to as an apparent imperfection of the system.

The mitigation of the imperfection of Move is explained in early versions of the MP in the following manner[24]. Movement allows uninterpretable features which remain in the derivation to be checked and eliminated before the interfaces

[23] [EPP] features can also be removed by merging of an expletive in this position - see section 2.3.4.5.

[24] The details here are limited; section 3.2.4 offers a fuller explanation.

are reached. That is, after all lexical items have been merged together, certain uninterpretable features might remain unchecked. For example, an uninterpretable [wh] feature on the C head has not been checked at the point the derivation has reached in (12):

(12) [$_{CP[wh]}$ [John bought what]]

Moving the wh-phrase from the position in which it is first merged as the object of the verb to the specifier position of CP will allow its interpretable [wh] feature to check the uninterpretable counterpart and remove it.

In later work, the assumption that movement is driven by uninterpretable features has been modified slightly. The introduction of an uninterpretable [EPP] feature means that movement is now proposed to be motivated by the requirement that certain heads have a filled specifier position. In the case of (12) above, it would thus be hypothesised that the C head additionally has such an [EPP] feature, triggering movement of a lexical item which can check the uninterpretable [wh] feature.

In the following section of this chapter, the issues of cyclicity and limited derivation (by means of phases) will be examined. It is as part of this later version of the theory that the [EPP] feature is introduced. Prior to the notion of phases, there was a distinction between operations applying before Spell-Out and those applying after Spell-Out on the path to LF (overt versus covert operations). The overt/covert distinction provided an account for cross-linguistic variation in cases like wh-movement and verb raising. Thus, under this view, the difference between (12) and its Japanese counterpart in (2) derives from the fact that the movement operation which shifts the wh-phrase happens overtly in English, but covertly in Japanese. In order to explain why movements are overt in some languages but covert in others, features took on another dimension - strength. Strong features induce pre-Spell-Out movement, while for weak features post-Spell-Out movement suffices.

Once the pre- versus post-Spell-Out distinction became obliterated in the *Derivation by Phase* era, this account of cross-linguistic variation needed to be revised. In this later version, then, such differences are explained in terms of the existence of an [EPP] feature. So, the C head with an uninterpretable [wh] feature in English-type languages also has an [EPP] feature, while this C head in

Japanese-type languages does not. As the previous section made clear, uninterpretable features can be checked in an Agree relation. Although early minimalism stipulated that Agree could only hold of items in a specifier-head relation, the Agree relation is now proposed to be a possibility at longer distances[25]. Consequently, where there is no [EPP] feature, Agree can hold of the C head and the wh-phrase in its initially merged position, and movement is not required. Only when the probe has an [EPP] feature does movement take place.

There are thus a number of interpretations of the nature of the Move operation, depending on what version of the MP we are considering. In Chomsky (1995b), Move is understood to be simply an internal application of Merge, adding no complexity to the existing architecture. In Chomsky (2002a), Move has been re-interpreted as Merge plus Agree, and in Chomsky (2001), as Merge plus Agree plus an additional pied-piping operation which moves the phonological material of the goal along with the relevant feature. In these latter two cases, movement must be analysed as considerably more complex than Pure Merge or Agree. Thus, in later versions of the MP, Merge and Agree are preferable to Move; Move may not occur where simple Agree will suffice.

A number of simplifications to the architecture are relevant here. Firstly, movement does not leave a trace. Traces would violate the Inclusiveness Condition, being elements added in the course of the derivation not existing at its outset. Instead, movement is postulated to involve copying; a copy of the moved item is left in its initially merged position[26]. Copies, by their very nature, are assumed not to violate the Inclusiveness Condition. A second economy consideration of Move is what has been called the Minimal Link Condition. This states that the link between the new position and the old position of a moved item must be the shortest possible; essentially, this rules out movement of a goal when there is a closer possible goal to the probe.

One type of movement that has not been discussed here is the movement that happens on the PF path of the derivation. The literature has much less to say on this[27]. The assumption seems to be that movement which appears not

[25]Although there are certain restrictions on the distance possible. The following section will make this clear.

[26]In order that this copy is not pronounced, a deletion rule is assumed to operate in the phonological component.

[27]See Poole (1996) for one example of an attempt to unify PF movement with the rest of the system.

to be forced belongs to the PF domain. Here, movement is not driven by the elimination of uninterpretable ϕ- or [EPP] features, but has an optional nature. Such ordering movements as scrambling and focusing are taken to belong to this set of operations (see e.g. Koike (1997), Kidwai (1999)). The sidelining of such movement operations has the effect of complicating the system in two ways. For one, there is a dichotomy that perfection would presumably rather do without; why should there be two types of movement? Secondly, the path to PF is still part of narrow language faculty, and as such, minimalist principles should hold equally here. Optionality strongly goes against the central tenets of minimalism, and its existence in the PF component thus weakens the minimalist argument. We will return to related points in chapter 6.

2.3.4.5 Phases and Cyclicity

The preceding sections have made passing references to the cyclicity/phase versions of the MP; here we will examine in more detail what is germane to this revision of the theory. In *Derivation by Phase* (Chomsky 2001), Chomsky introduces a further simplifying notion to the program - that derivations should be divisible into smaller sections (*phases*), each of these a sub-derivation, if you will.

In each phase only a sub-set of the lexical array is visible to the operations of the system. This is claimed to then account for certain empirical data, such as the existence of structures such as (13)[28]:

(13) There is a possibility that proofs will be discovered.

A problem with such cases in previous versions of minimalism was why they can be derived at all, given that Pure Merge of an expletive (*there*) in the lower subject position would be computationally 'cheaper' than moving the object of the lower verb (*proofs*) to the empty lower subject position. In a derivation advancing phase by phase, it can be hypothesised that at the particular phase in which the empty subject must be filled, movement may occur where there is no expletive available in the sub-set of the lexical array accessible at that point (even if there is an expletive in the entire array). Thus, in (13), it would be assumed that in the phase where the empty subject of the lower clause *will be discovered proofs* requires filling, the expletive *there* was not yet available, thus ruling out (14):

[28]Chomsky's (2002a) (7b).

(14) *Is a possibility that there will be discovered proofs.

Of course, (14) is independently ruled out as the higher clause violates the EPP, not having a subject. Another alternative to (13) would be (15), where the expletive was available to insert into the empty lower subject position, and *proofs* was later moved to satisfy the higher clause's empty subject. The claim would be that cyclicity would rule this case out as the expletive should not have been available to the lower phase:

(15) *Proofs is a possibility that there will be discovered[29].

A phase is defined as being the closest syntactic counterpart to a proposition; consequently, CP and vP are specified as phases (Chomsky 2001). In the same way that lexical items outwith the current phase's sub-set are not available, information about earlier derivational stages is not available either. That is, operations functioning in the current phase do not need to know about operations that applied in earlier derivational phases of the utterance; each phase is independent of the others in this way.

It is further proposed that the point of Spell-Out, which earlier versions of minimalist thinking supposed was a single point in the derivation of an utterance, now occurs at the end of each and every phase. Thus, the derivation is cyclic. At each point of Spell-Out, the relevant chunk of the derivation is sent to PF and LF for phonological and semantic interpretation respectively. Once interpreted, the chunks are assembled together for feeding to the relevant interfaces. This cyclic nature of Spell-Out has the advantage of eliminating the requirement for reconstruction at Spell-Out to differentiate uninterpretable and interpretable features. If, after checking, uninterpretable and interpretable features become indistinguishable (due to removal of feature values as a result of checking), a Spell-Out process happening only much later in the course of the derivation will have to reconstruct in order to obtain the relevant information. If Spell-Out happens at the end of a phase, it is suggested (Chomsky 2001) that such reconstruction will be avoided, as the relevant information can be 'remembered' for this short span.

[29] Again, (15) could also be argued to be independently ruled out, this time because it must involve improper movement.

The Phase Impenetrability Condition is stipulated to ensure that a phase can see what is termed the edge of the previous phase. In this way, the utterance does not become a set of entirely independent derivations, but phases can be linked together appropriately. In other words, phase edges provide a manner of accounting for non-local dependencies; they provide the *escape hatches* required for successive cyclic movement. Specifically, only the head of a phase and its highest specifier (with phonological content (Chomsky 2001)) are omitted from the Spell-Out operation applying at the end of that phase, leaving them visible to the next phase. In (16), this means that the head of phase 1 (Y), and its specifier do not spell out at YP, but are visible to the XP phase (phase 2), and spell out at the end of this phase. In contrast, the complement of Y (ZP) spells out at phase 1 as it is too low down to be visible to the XP phase.

(16) [$_{Phase\ 2^{XP}}$ X...[$_{Phase\ 1^{YP}}$ Spec [Y ZP]]]

Further economy considerations follow. For one, an [EPP] feature that exists on the head of a phase (C or v) must be satisfied within that phase. In other words, an item from the immediate lexical sub-array must be merged, or an element from within the current phase moved. From these assumptions, it is argued that the Minimal Link Condition mentioned in the previous section falls out directly, in that long-distance movements will no longer be possible[30]. Cyclicity also reduces the size of the search space for a probe, as it may only seek a goal within the current phase. Look-ahead is similarly held to be limited to the immediate sub-derivation[31].

The phase view of the derivation is best understood with the following diagram:

[30]There do, however, appear to be cases where the Minimal Link Condition does not follow from phases and cyclicity. One example is the superiority effects seen in the passivisation of double object constructions. The indirect object tends to be promoted to subject position rather than the direct object. However, although the indirect object is higher in the structure (and thus forms a more minimal link), both objects are in the same phase.

[31]It seems that this last argument does not hold, however, in cases of cyclic wh-movement - see section 6.6.

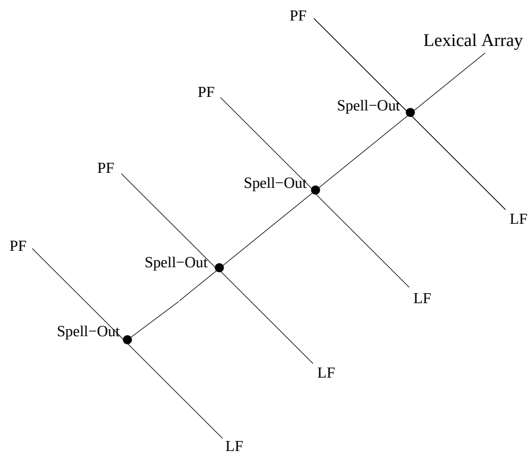


Figure 2.2: Derivation by phase architecture

Thus, there are two parallel cycles: the narrow syntactic cycle to LF, and the phonological cycle to PF.

In conclusion, the previous sections have outlined the growing concerns and reflections of the generative enterprise which led to the formulation of minimalist theories. The particular architectural details which follow from these intuitions were then laid out. What should be clear from the preceding discussion is that minimalism differs significantly from preceding generative theories primarily in its assumption of economy principles regulating operations, and its reduction of the computational apparatus of the language faculty to the bare essentials. In the final section of this chapter, a number of ensuing questions will be posed, setting the scene for the evolutionary exploration of the subsequent chapters.

2.4 Issues for Evolution

The general picture of what the minimalist view of language is has been clearly explicated in the preceding sections. We can turn now to the very high-level question that this thesis is dealing with - how has language evolved? This is a question which has recently received much attention from a number of different scientific communities. But, is this increase in inquiry in any way related to the recent emergence of minimalist theorising?

The answer to this question is no. In fact, the recent growth of studies in the evolution of language is due more to developments in other fields (psychology, computer science, genetics, among others) than to developments in linguistics. Very little work on the evolution of language has much to say about the MP. True, there are some linguists who have offered hypotheses as to how the system they concern themselves with might have evolved - Berwick (Berwick 1998), Chomsky (Hauser *et al.* 2002), and Uriagereka (Piatelli-Palmarini & Uriagereka 2004) are three - but such hypotheses are few, the bulk of the work in evolutionary linguistics coming from outside the field.

The question here then is whether linguistics can add anything to the debate through the insights of the MP. Many questions of an evolutionary nature stem from the architecture, the motivating themes, and the workings of the system outlined above. These will form the subject of the next four chapters, and can be organised into the following four corresponding headings.

2.4.1 Perfection as Fundamental to Minimalism

It is by now obvious that the notion of perfection has a large part to play in minimalist theories of language. Quotations from Chomsky and from Lasnik in the preceding sections are representative of the accepted judgement of those working within the framework. It was alluded to above that perfection in this sense is equated with economy and simplicity in the system. The many puzzles which ensue will be examined in chapter 3. These include such questions as the following:

1. How is perfection to be defined?
2. Is economy equivalent to perfection?
3. Is adaptation equivalent to perfection?
4. What is the nature of imperfection? Is it real or only illusory?

5. Do we find perfection in nature? If so, what is the evolutionary history of such perfection?
6. Is perfection just an ideal, or is it plausible given that language evolved?

2.4.2 *How Evolvable is Minimalism?*

The minimalist language faculty is a system reduced in both its representation and its derivation. The next issue to be addressed is whether a system so reduced has a reasonable evolutionary account. In chapter 4, issues such as the following will be focussed on:

1. How do we measure how simple the language faculty has become?
2. Does evolution necessarily lead to more complex systems, or is simplification equally possible?
3. What type of evolutionary accounts does the MP allow? Are such accounts plausible in a general sense, and more specifically for language?
4. What would a language faculty that evolved look like?

2.4.3 *The Composition of the Narrow Language Faculty*

The MP seeks to describe and explain the narrow language faculty - the aspects of language which are unique to our species, and unique to language; in other words, the MP is concerned with the workings of the syntactic component of language. A recent paper (Hauser *et al.* 2002) sees Chomsky, in collaboration with non-linguists, offering a specific hypothesis about the composition of the narrow language faculty. The suggestion is that the only component of language which is human-specific and language-specific is recursion. Consequently, the assumption must be that only recursion underlies the workings of the narrow language faculty, minimising the system yet further. Chapter 5 will investigate this proposal, asking the following questions:

1. How should we define the narrow language faculty?
2. How should we define recursion?
3. Is recursion a significant component of the narrow language faculty?
4. Is recursion the only component of the narrow language faculty?

2.4.4 *How Minimal is Minimalism?*

Issues of a slightly different nature are the remit of chapter 6. Minimalism aims to show that the language faculty is a simple, economic system. However, it also aims to characterise this system in a simple, economic way[32]. While chapter 5 is concerned with demonstrating that the narrow language faculty itself is pre-theoretically not as simple as the MP supposes, the business of chapter 6 is demonstrating that the minimalist delineation of the system may not be so minimal. The questions to be addressed there include:

1. Are minimalist theories of language themselves simple?
2. Are the complexities of previous generative theories truly gone?
3. Are there hidden complexities in the system?
4. Do the answers to the previous questions tell us anything about the nature of the system of language itself?

[32]See section 3.3.2 for explanation of the difference.

CHAPTER 3

Perfection and Adaptation

3.1 Introduction

This chapter will take up the first of the evolutionary issues posed at the end of chapter 2: the importance of the notion of *perfection* in minimalist theories of language. The concept is particularly interesting from the evolutionary viewpoint for one because perfection appears initially to be consonant with the process of adaptation - reaching towards an ever more optimal solution - and at the same time as it has often been argued that that which arises through the typical processes of evolution is never perfect. The path the investigation here will take is to determine which of these perspectives is on target.

Section 3.2 will firstly work through the place of perfection in minimalist theories, coming to an understanding of what minimalists mean with the claim that 'language is perfect'. Following this, section 3.3 will answer the first evolutionary question of whether perfection can be equated with adaptation. A number of terms are used interchangeably in minimalist discussions of perfection. It will be the remit of section 3.4 to clarify and distinguish these, and to set each of them apart from the concept of adaptation. Section 3.5 will then analyse other natural systems that are the result of evolutionary processes, questioning whether perfection is a reasonable defining characteristic for such systems. Finally, section 3.6 will draw a number of conclusions.

3.2 The Perfection of Language

Theorising in the Generative Enterprise in the last decade has led to a conception of language that is quite substantially altered from previous theories in this tradition. The MP, according to Chomsky, is a framework for considering language from a different viewpoint than that of previous incarnations of generative syntactic theorising, and that is to look at language as a system which is in some way perfect for the job it needs to do: "[T]he Minimalist Program...is...a research program concerned with...determining the answers to...the question "How 'perfect' is language?""(Chomsky 1995b:221)

Let us break this conception down somewhat. Two main issues present themselves for further dissection. Firstly, what is meant by 'perfection'? That is, how can we determine if any system is 'perfect'; what type of properties and features would this entail for the system? Secondly, for what is language 'perfect'? In other words, a system can only be considered perfect in relation to some function it has; as Pinker & Jackendoff (2005:27) put it: "...nothing is "perfect" or "optimal" across the board but only with respect to some desideratum." In the case of language, what function might it fulfil such that it does so in a perfect fashion?

Tackling these issues in reverse order, Chomsky views the system's job as the creation of a mapping between signal and meaning. The term 'language', as used here, is then meant to refer to some computational combinatorial system that achieves the Saussurean mapping through application of the operations discussed in the foregoing chapter (Merge and Move). Thus, the perfect system is not language in its broad interpretation, but rather language in its narrow interpretation; what is referred to by Hauser *et al.* (2002) as FLN – the faculty of language in the narrow sense; in other words, syntax.

Assumptions of perfection in the language faculty require that one embrace this division proposed by Hauser, Chomsky and Fitch. The authors draw a distinction between the faculty of language in the broad sense (FLB), and the faculty of language in the narrow sense (FLN). The former is assumed to include the latter, but also to include the systems that are required for the computational system underlying language to interface with other systems of the mind; that is, the conceptual-intentional system and the articulatory-phonetic system. FLN consists purely of the computational system itself, which the authors believe to be underpinned by one mechanism – the mechanism of recursion. On this division, FLN is the definition of 'language' typically meant by minimalists in discussions of its perfection. FLB is the definition of 'language' that is typically assumed by those outside the fields which investigate our linguistic capacities. Hauser, Chomsky and Fitch assert that FLN is the interesting part of the faculty from an evolutionary point of view. They relegate many of the baroque aspects of language to the broader faculty, arguing that these are the result of forces which are external to the simple computational device.

Crucially then, in considering the minimalist view of perfection in language, we must remember that the object of investigation is restricted to the computational component; the system is perfect in the manner it carries out the computation required to map a phonetic signal to a semantic meaning. As we will see in section 3.2.3 below, this view can only be maintained if any imperfections in language can be accounted for in terms of the broader faculty.

The first question posed above turns out to be far harder to pin down. Although perfection is invoked as a central and leading argument in minimalist theorising, little space is devoted to clarifying precisely what is meant by the term. Even with an idea of what the system is perfect for, it is difficult to know what might constitute a perfect solution to the mapping problem. It appears that perfection in language is equated with economy to a large extent. The MP elevates the role of economy conditions in the computational component. While economy considerations began to surface in later work under the GB framework (see e.g. Chomsky (1991b)), it is the MP that has catapulted such issues to the forefront of the theory. The question "How "perfect" is language?" (Chomsky 1998:118) is then equated with the question "...how "economical" is the design of language?" (*ibid*).

As discussed in chapter 2 above, the MP delineates a system which is more reduced in terms of the principles, operations and constraints applicable to it than earlier generative models. It has a flavour of simplicity that other theories of language lack. The perfection that is spoken of thus seems to arise as a result of two different interpretations of 'economy'. Firstly, there is the economy which corresponds to this flavour of simplicity; that is, the MP assumes that there is less going on in the narrow computational language faculty than other theories do. Secondly, there is the economy of the constraints that make up the system; operations such as Merge and Move are postulated to be moderated by universal conditions of economy, such as the proviso that longer derivations are obviated by shorter ones. It is important to distinguish these two conceptions of the term, as will be further examined and explained in section 3.3.2 below. For now, let us simply note that we should remember not to collapse these into one.

This is undoubtedly a large shift in focus in generative grammar. The displacement of interest is explained in the literature as arising out of an optimism of sorts in the field. The era of GB theory and the Principles and Parameters framework was one of huge advancement in generativism. Understanding of language grew vastly, and questions of acquirability, learning, and variation, among others, were considered to have been answered in, if not definitive, certainly non-trivial ways. With this body of knowledge under his belt, the generative linguist felt armed to tackle new questions, and these questions took the form of the MP. That is, the new questions aimed to show that the general intuitions arrived at through previous research were correct, but that the specifics could be recast to unveil a system more concise, and more efficient in its operation than hitherto hypothesised.

The minimalist view of language as a perfect system is interesting from an evolutionary perspective for a number of reasons. It is unclear how a perfect system might arise in the course of evolution, or indeed, how evolution might begin with a non-perfect system and fashion it to become perfect. The perfection of the minimalist language faculty makes it appear unlike other biological systems, which are typically not considered perfect in any sense. The purpose of this chapter is to investigate the evolutionary questions that the minimalist conception of language provokes.

3.2.1 Quotations

It is important to clarify just how central to the minimalist thesis the claim of perfection in language is. This section presents numerous quotations from Chomsky's work over the past decade which appeal to the notion of perfection to greater or lesser extents. The number of such quotations alone should highlight the importance laid at its door.

The quotations below can be divided into three sections: first, are the quotations which make reference to language as a perfect system, second are those quotations which admit to a certain amount of imperfection in this system, and third are those which indicate that the imperfections may only be illusory, being explainable in terms of requirements of the external systems with which the narrow language faculty must interface. In section 3.2.3 below I will consider the outside systems that are referred to in these latter quotes, and what their impact is on the minimalist thesis. In section 3.2.4 the question of imperfections in the system will be explored in greater depth.

3.2.1.1 Perfection of the system

The quotations which refer to the perfection of the narrow language faculty note the historical developments leading to this standpoint, appeal to the plausibility of language being constrained by general conditions of simplicity and elegance, and delineate the perfection as the optimal solution to meeting external conditions:

> "With at least a general picture of what a genuine theory of language might be like, we can contemplate some more principled questions about its nature. In particular, we can ask how 'economical' is the design of language. How 'perfect' is language, to put it more picturesquely?" (Chomsky 1998:118)
>
> "...language is surprisingly 'perfect', in this sense, and...it may not be premature to formulate the issues more carefully and investigate them." (*ibid*:119)
>
> "...language is designed for elegance, not for use, though with features that enable it to be used sufficiently for the purposes of normal life...Typically, biological systems are not like this at all. They are highly redundant, for reasons that have a plausible functional account." (Chomsky 1991a:49)
>
> "...what conditions are imposed on the language faculty by virtue of...(2) general considerations of simplicity, elegance, and economy that have some independent plausibility?" (Chomsky 1995a:385-6)
>
> "There is no strong reason to believe that a biological system should be well-designed in anything like this sense. To the extent that it is, the conclusion is somewhat surprising, therefore interesting." (Chomsky 1998:119)
>
> "The substantive thesis is that language design may really be optimal in some respects, approaching a 'perfect solution' to minimal design

specifications. The conclusion would be surprising, hence interesting if true.” (Chomsky 2002a:93)

“The strongest minimalist thesis would be this:
(2) Language is an optimal solution to legibility conditions.” (*ibid*:96)

“ ...could it be that FL is an optimal solution to interface conditions imposed by the systems of the mind-brain in which it is embedded, the sensorimotor and thought systems?” (Chomsky 2002b:90)

“...the idea that language may be an optimal solution to interface conditions seems a good deal more plausible than it did a few years ago. Insofar as it is true, interesting questions arise about the theory of mind, the design of the brain, and the role of natural law in the evolution of even very complex organs such as the language faculty...” (*ibid*)

“This is the research direction: try to show that the apparent imperfections in fact have some computational function, some optimal computational function.” (*ibid*:118)

3.2.1.2 Imperfections in the system

In observing that there may be imperfections in the system, the areas of phonology, morphology, and the lexicon, and the dislocation operation are drawn on:

“A related imperfection lies in morphological systems, the locus of a substantial part of parametric variation of languages...” (*ibid*:121)

“...there seems to be one dramatic imperfection in language design, at least an apparent one: the ‘displacement’ property that is a pervasive and rather intricate aspect of language.” (*ibid*:123)

“There are some respects in which the strong thesis seems untenable, and we find what appear to be ‘design flaws’ that are not necessary for language-like systems. The most obvious involve the phonological component.” (Chomsky 2002a:117)

“Morphology is a very striking imperfection; at least it is superficially an imperfection. If you were to design a system, you wouldn’t put it in. It’s not the only one though; no formal language, for example, has a phonology, or a pragmatics, and things like dislocation in the sense we all understand...All of these are imperfections, in fact even the fact that there is more than one language is a kind of imperfection." (Chomsky 2002b:109)

3.2.1.3 *Imperfections as satisfying external conditions*

That the imperfections may be only apparent is hinted at through the example of the Agree operation and uninterpretable features, which although seemingly imperfect, may be required in order to implement the displacement operation:

> "One expects 'imperfections' in the morphological-formal features of the lexicon and aspects of language induced by conditions at the AP interface, at least. The essential question is whether, or to what extent, these components of the language faculty are the repository of departures from virtual conceptual necessity, so that the computational system C_{HL} is otherwise not only unique but in some interesting sense optimal." (Chomsky 1995b:9)
>
> "How 'perfect' is language? One expects 'imperfections' in the formal part of the lexicon. The question is whether, or to what extent, this component of the language faculty is the repository of departures from virtual conceptual necessity, so that the computational system C_{HL} is not only unique but optimal." (*ibid*:389)
>
> "Within PHON [the phonological component] there seems to be substantial 'imperfection', including operations beyond those that are required for any language-like system...'Imperfections' in this component of language would not be very surprising: for one reason, because of the relative availability of direct evidence for LAD; for another, because of special properties of sensorimotor systems that access the information in the language and allow the thoughts expressed in it to be externalised." (Chomsky 1998:121)
>
> "If empirical evidence requires mechanisms that are 'imperfections', they call for some independent account: perhaps path-dependent evolutionary history, properties of the brain, or some other source." (Chomsky 2001:2)
>
> "The relation Agree and uninterpretable features are *prima facie* imperfections...both may be part of an optimal solution to minimal design specifications by virtue of their role in establishing the property of displacement." (*ibid*:3)

> "I have raised...the problem of whether the most striking apparent imperfections of narrow syntax...are true imperfections or are reasonable ways of satisfying design conditions..." (*ibid*:139)

> "Narrow syntax also involves devices that are imperfections unless shown to be unreal or to be motivated by design specifications...
> (34) a. Uninterpretable features of lexical items
> b. The 'dislocation' property.
> ...These properties are never built into special-purpose symbolic systems. We might suspect, then, that they have to do with externally imposed legibility conditions." (Chomsky 2002a:119-120)

> "In some sense the system is not well designed for use, at least not perfectly designed for use, but it has to be designed well enough to get by...that raises the question: can we find other conditions such that language is well designed, optimal for those conditions?...It might turn out that it is not optimal for some of the ways in which we want to use it...So, the system is not well designed in many functional respects. But there's a totally separate question: is it well designed with regard to the internal systems with which it must interact?" (Chomsky 2002b:106-108)

3.2.2 Perfection in other Linguistic Frameworks

Interestingly, work in other linguistic frameworks puts little or no emphasis on this aspect of language. Minimalism stands alone in seeing perfection as an appropriate centre around which to pivot its claims. Optimality Theory (henceforth OT) may be the only other linguistic framework which might appear at first blush to highlight this angle.

After a period as a predominantly phonological theory, the domain of syntax has been examined from an optimality theoretic viewpoint. In this formalism, Universal Grammar is equivalent to a mechanism for generating candidate outputs and a set of constraints. Constraints are 'soft' rather than 'hard', in that all constraints can be violated. A hierarchy exists specific to each and every language, which identifies which constraints have priority over others. Constraints may only be violated if in so doing a higher ranked constraint is satisfied. An evaluating mechanism chooses the optimal candidate from a set of alternatives. The optimal candidate is the one that violates the fewest constraints, bearing in mind that a higher-ranked constraint cannot be violated over a lower-ranked one. Although OT stands out as fundamentally different from Chomskyan minimalism, or its predecessors (for one, it is usually considered a non-derivational theory), the optimality of the system it delineates again stems from a type of economy - the smaller the number of constraint violations the better.

Although the very name of the framework hints at perfection of some sort, OT does not imply that language is perfect in the same way that minimalism does. In her discussion of the constraints of OT, Grimshaw (2001) notes that some form of complexity is endured as a result of not being able to satisfy all constraints. 'Complexity' here can be interpreted as the opposite of the 'optimality' that the framework's title suggests[1]. That is, due to the fact that any linguistic expression will never satisfy all the constraints, there will always exist a certain amount of sub-optimality. In OT, competing constraints thus lead to perfection being *impossible* in the system[2].

3.2.3 Outside Systems and Interface Conditions

For minimalists, the perfection of language lies in the fact that the recursive combinatorial system that maps signals to meanings does so in the best possible way. Mapping signals to meanings is understood to involve not simply the computational component itself, the narrow language faculty, but also (at least) two other systems. These are the conceptual-intentional system, which is responsible for interpreting the meaning of the linguistic representation, and the articulatory-phonetic system, which is responsible for articulating the linguistic representation. The perfect mapping is thus assumed to come about through the computational system interacting with these other systems in an optimal manner.

These external systems impose certain conditions on the computational component. That is, the computational component must operate in such a way that it can send information to both of these systems that they can recognise and use. These conditions are variously referred to in the literature as *interface conditions*, *(bare) output conditions*, and *legibility conditions*. A number of questions arise at this point: for one, how does language interface with these systems? Secondly, what does it mean to say that it interfaces with them in the perfect way?

[1]Although see chapter 4 for in-depth discussions and alternative interpretations of complexity.

[2]I will return in section 6.3 to the issue of competing constraints or motivations.

In order that the computational component can send information to these external systems, the information must exist in a format accessible to them. Intermediate stages exist between the narrow language faculty and both of the other systems; these are the interface levels[3]. The interfaces take in the information from the computational component, and send on to the external systems representations that they can read. The features that were discussed in the preceding chapter form the contents of the information passed from the computational component to the interfaces; semantic features for the conceptual-intentional interface, phonological features for the articulatory-phonetic interface.This process can be visualised as in figure 3.1[4]:

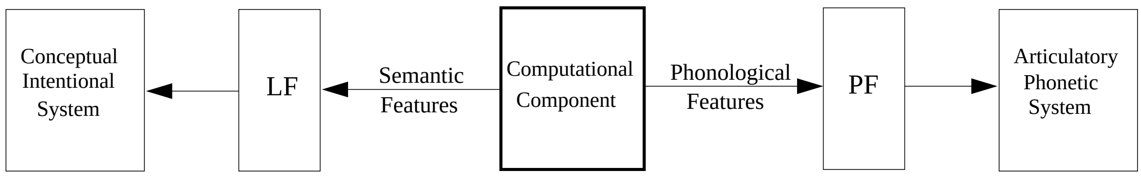


Figure 3.1: Information transfer from the computational component to the external systems

The second of the two questions posed above is that with which the MP concerns itself; the subject of inquiry is the mapping carried out by the computational system, and the guideline employed in this inquiry is to discover the optimal way of carrying it out. The perfection that the system is argued to manifest is apparent in the way in which it meets the requirements set by the systems with which it must interface. What it means for the computational system to do this in the perfect way is what the program of research is working out. As is often cautioned in the literature, the MP is not a theory, but a program of research. Despite this cautionary note, however, it is true to say that those working within this framework assume that optimality and perfection are reasonable and plausible guidelines to use, and the theories that have emerged from the program indicate that the central *a priori* assumptions have been adopted. That is to say, minimalist theories take as given that the computational system interfaces with the external systems in the optimal manner by employing the minimal set of machinery necessary.

[3]As noted in chapter 2, the interface between the computational component and the conceptual-intentional system is fed by Logical Form (LF), while the interface between the computational component and the articulatory-phonetic system is fed by Phonetic Form (PF).

[4]See Jackendoff (1998) for an alternative but not dissimilar view.

3.2.4 *Imperfections in the System*

In the quotations given above, it appears that there is certain elbow room given in respect to the notion of perfection of language. Imperfections are indeed discussed, yet further investigation uncovers caveats surrounding them. In fact, what at first glance might look like a revision of the central theme is actually not. The claim that the narrow language faculty is perfect in its operation is developed by allowing imperfections in the system, but rationalising these as the results of the constraints imposed by the external systems. In other words, as was mentioned in chapter 2, the imperfections are only apparent, not real. This section will survey a number of such imperfections, analysing their source and their interpretation.

Frequent mention is made of imperfections in the phonological component of the grammar. In fact, these aspects of the system are said to be unsurprisingly imperfect, and Chomsky (2002b:118) goes so far as to claim that "...the whole phonological system looks like a huge imperfection, it has every bad property you can think of." The literature, however, makes few inroads into clearly defining what these phonological imperfections are. Pursuing as the subject of inquiry here the prevalent assertions of minimalism, we will thus leave the imperfections of phonology to one side.

Imperfections in the morphological component are afforded more space in the literature. Examples of imperfections in the morphological component are case features, or number features on verbs and adjectives. Specifically, the imperfections assigned to this category are uninterpretable features. Uninterpretable features were discussed in chapter 2; to recap, these are the features that a lexical item is said to possess which must be removed during the course of the derivation as they cannot be interpreted by either interface. Their imperfection stems from this inherent fact: a feature which stipulates that extra work be done (in the form of displacement and checking - see chapter 2) during the derivation strongly opposes the requirement for perfection and simplicity in the system.

A third imperfection is the displacement or Move operation. As chapter 2 showed, a sentence is derived under minimalism through repeated application of the Merge operation; an initial pair of lexical items are merged together, and subsequent items are merged with the initial unit until the sentence is fully derived, or the derivation converges. However, in order to derive sentences such as (1) through (3) below, a further operation - Move - must be introduced into the equation. As an additional operation to what would appear to be the bare minimum (a Merge-only system), Move is an imperfection.

(1) What did John eat?
(2) Mary's apple was eaten by John.
(3) John seems to have eaten Mary's apple.

Now let us turn to the 'apparent' aspect of these imperfections. It is argued that the imperfections cited (among others) are not true imperfections, but exist as a response to the conditions imposed by the external systems; they are there to satisfy design conditions. So, the morphological imperfections and the displacement operation can be accounted for by appealing to requirements of the conceptual-intentional and articulatory-phonetic systems (and the relevant interfaces, LF and PF) in the following way. Language exhibits two types of semantics, what can be referred to as deep and surface semantics. Consider (4) below:

(4) The man punches the boy.

Given such an utterance, we need to make a distinction between the predicate-argument structure and the discourse structure. On the one hand, we want there to be a distinction between agent and patient, and on the other we need to break down the utterance in terms of topic and comment. The former is deep semantics, the latter surface semantics[5]. Deep semantics is usually marked using Case morphology[6]. Surface semantics, however, is generally marked by word order. In other words, two different techniques need to be in place to identify these two separate semantic levels (Chomsky 2002b). While the deep semantics of thematic roles is manifest at the point of merge, the surface level semantics may require that the initial word order be shifted. In English, this is more obvious in cases like (5):

(5) The boy, the man punches.

[5]See also Newmeyer (1992) for discussion of the same basic idea.

[6]Although this is difficult to see in English, a language without rich Case morphology, the German translation of (4) illustrates the point:

De**r**	Mann	schlägt	de**n**	Junge**n**.
The-NOM	man	punches	the-ACC	boy-ACC

In order to achieve the word order which highlights this surface level semantics, displacement must take place in the course of the derivation. Chomsky's claim then, is that the displacement operation is required by the conceptual-intentional system; in dealing with the meaning of the linguistic representation, the conceptual-intentional system uses the word order facts to retrieve the surface semantics and the morphological facts to retrieve the deep semantics. Therefore, displacement is not a real imperfection, it is not a 'departure from virtual conceptual necessity'; it is forced by an external system, and thus only an apparent imperfection[7].

What about the imperfections of uninterpretable features and the Agree operation? Again, Agree appears like an imperfection as it is an additional operation which the system could plausibly do without. Uninterpretable features are imperfect by their very nature. The story that minimalism tells is that both of these imperfections are related intricately to the displacement operation and so they too are only apparent imperfections, demanded (indirectly) by the conceptual-intentional system.

The specifics are as follows. Movement is required in order to get the correct surface semantics, but the displacement operation calls for three things: (i) an element to move (the goal), (ii) an element to attract the moved item (the probe), and (iii) a position to move to. Uninterpretable features give us the machinery to pick out these components. The element which will be moved is identified by an interpretable feature which matches the uninterpretable feature of the probe. The position that the moved element will be merged into is marked by another uninterpretable feature – the EPP feature[8]. Thus, uninterpretable features are requisite inputs which drive the Move operation, the latter necessary for reasons of semantics. In other words, uninterpretable features are not real imperfections either. As for the Agree operation, whether part of a movement operation, or applying at a distance, it is the manner in which uninterpretable features are removed, again a condition imposed by the interfaces, and hence unavoidable.

This account means that all imperfections discussed above have an essential place in the narrow language faculty. None are extraneous, each has a role to

[7]The question of whether displacement is the only possible means by which deep and surface semantics can be distinguished will be questioned in section 6.3.

[8]Further discussion of the nature of this feature will take place in chapter 6.

play, and as such is argued to be vital, and therefore not a true imperfection. Under such an interpretation, the central claim of the MP that the narrow language faculty is perfect in its implementation and its operation can stand.

3.2.5 Atomicity as Perfection - Superiority Effects

In order to clearly illustrate the perfection that is foundational to the MP, it is important to examine particular empirical data and the account that minimalism invokes thereof in contrast with the explanation of other theories. The issue is this: under the minimalist framework, language is reduced in a computational sense – it is highly atomic, and it is difficult to break it down into interacting parts.

Consider wh-movement in English, the phenomenon illustrated in (6). This is normally explained as a question word or phrase appearing in a sentence in a position distinct from where it is interpreted. In other words, although we put question words, e.g. *what*, *who*, *where*, *how*, at the beginning of the sentence in English, the referent of that question word is interpreted as belonging to an action that occurs later in the sentence. In a generative framework, we assume that this discrepancy is the result of movement of the wh-phrase from the position in which it is initially merged into the derivation to a higher position. In (6) the wh-phrase *who* has been moved from the position indicated by *e* (for 'empty category') – the object position of *see*. So, although the question word *who* appears at the start of the sentence, it is interpreted as belonging at the end of the sentence, given the fact that it is the object of the seeing action.

(6) Who$_i$ did John see e$_i$?

The analysis of wh-movement in the minimalist framework provides us with a clear example of how this framework reduces the computational complexity of the derivation. Let us take the more detailed examples in (7) to illustrate this point. The sentences in (7a) and (7b) show what are generally known as Superiority effects. While (7a) is considered completely acceptable, (7b) is deemed less acceptable. The difference between the two sentences is the position from which the highest wh-phrase has moved; it has moved from the subject position of the lower clause in (7a), and from the object position of the lower clause in (7b):

(7) a. Who$_i$ did John persuade e$_i$ to visit who?
b. *Who$_i$ did John persuade who to visit e$_i$?

In order to show how the minimalist analysis of this phenomenon is so atomic, it is necessary to compare the minimalist analysis to another available analysis. For this, I have chosen the typical analysis put forward under GB theory. It is important to note that GB theory was not designed to deal with evolutionary questions any more than the MP was, so the comparison is not assumed to illustrate a better evolutionary account in the earlier Chomskyan methodology; it simply provides a comparison through which the atomicity of the minimalist analysis can be made clearer[9].

In a GB analysis, we need to assume a number of interacting modules and constraints in order to account for the difference in acceptability of (7a) and (7b). We firstly need to assume that the wh-phrase has moved from a lower to a higher position in the sentence. On top of that, we need to assume an abstract level of representation which deals with semantics – the level of LF. It is assumed in the GB framework that at this level of representation all wh-phrases must move to the higher position. The reason that the wh-phrase must move to the higher position is that wh-phrases are operators, and so take scope over some part of the sentence they occur in, and the scope position is assumed to be left-peripheral.

We further assume a component of the grammar which deals with empty categories (traces) – the positions left behind when the wh-phrases (or indeed any type of phrase) move. This component of the grammar is underlain by a rule which assumes the structural relation of government. That is, the Empty Category Principle says that an empty category must be properly governed, where government is understood as a structural relation that holds between two elements in a sentence, and proper government is understood as a more restrictive

[9]In fact, the question of which theory of language is better from an evolutionary point of view could be asked about any theory of language which exists. It is important to note that this thesis is not concerned with a comparative analysis of linguistic theories from an evolutionary standpoint. The argument I would put forward is that we should not take any existing theory and re-model it. There are no extant theories of language that are discernably designed with evolution in mind, and so we should not settle for the best we can find; instead we should aim to create a theory to fit our needs. This point will be further discussed in section 7.3.

type of government reserved for empty categories[10]. Proper government, in turn, entails the assumptions of theta theory and a process of co-indexation.

Turning now to the minimalist analysis of the phenomenon, we again assume movement, this time in order to check features (as was discussed above, and in chapter 2). Here, a formal uninterpretable [wh] feature exists on the higher position (the C position), and a corresponding interpretable [wh] feature exists on the wh-phrase itself. Further, (more recent versions of) minimalism posit an [EPP] feature on the C position. The uninterpretable [EPP] feature on C can be removed by moving the wh-phrase so that it is local to C, and then checking off the matching [wh] features against each other. In addition to this, all we need to assume to account for the difference in acceptability between (7a) and (7b) are economy conditions. (7b) violates an economy condition while (7a) does not. Different versions of minimalism would formulate the analysis here using different economy conditions, but the pertinent point is the same. We can say, for example, that (7b) violates the Shortest Move Constraint, because the wh-element we move is further away from the target than the alternative available one (the one moved in (7a)), or we can say that (7b) violates the Minimal Link Condition, as the link created between the position moved to and the position moved from is not the shortest, or most minimal possible (a shorter link could be created between the position moved to and the object of *persuade* as in (7a))[11].

---

[10] Government is formally defined in the following way:
A governs B iff:
(i) A is an X^o category (i.e. a Noun, Verb, Adjective etc. heading a phrase)
(ii) A c-commands B (where c-command is defined as follows:

A c-commands B iff:
(i) the first branching node in a tree that dominates A also dominates B
(ii) A does not dominate B.)

Proper government can be formally defined as follows:
A properly governs B iff:
(i) A θ-governs B (where θ-government is defined as follows:
A θ-governs B iff A is an X^o category that θ marks B (i.e. that selects B as an argument)) or
(ii) A antecedent-governs B (where antecedent government is defined as follows:

A antecedent-governs B iff:
(i) A and B are co-indexed
(ii) A c-commands B
(iii) A is not separated from B by a barrier)

[11] In a phase based analysis, both the Shortest Move Constraint and the Minimal Link Condition would fall out from the limited visibility at any point in the derivation - see section 2.3.4.5.

Table 3.1 summarises the assumptions required in both the GB and minimalist analyses of superiority effects. The table clearly highlights the fact that the difference between the two analyses stems from the reduction of complexity in the MP[12]. While the minimalist framework posits analyses which involve movement as a result of feature checking, and economy conditions to regulate the movement, the GB analysis requires many more interacting modules to exist in the grammar.

Government and Binding	Minimalist Program
Movement	Feature Checking
LF Movement	Economy Conditions
(Proper) Government	
Empty Category Principle	
Theta Theory	
Co-indexation	

Table 3.1: Requirements for Government and Binding and Minimalist analyses of superiority effects

The perfection of language is thus understood to result from the simple uncluttered way that the system operates. Mapping sound to meaning through the bare essential architectural composition suffices to allow acceptable sentences such as (7a) to be generated, while concurrently excluding unacceptable sentences such as (7b). Minimalism thus constitutes a move towards a theory of language which highlights simplicity and economy rather than complexity and intricateness.

On face value, it might appear at this point that the minimalist analysis of this phenomenon is preferable to the GB analysis, given that it looks like a more parsimonious account; it involves only two modules or processes while the GB analysis involves six. However, our immediate intuition proves to be false when we look deeper. In the MP, all of the considerations which fall outside of issues of economy are simply re-formulated and appear as a complex inventory of features to be checked. In other words, although Theta Theory, or the Empty Category Principle are not conceived of as separate modules in the minimalist system, their effects are still felt through the existence of particular features on lexical items which must be checked in order to complete a derivation. Importantly, the number of features that must be posited in order to account for the

[12]Chapter 4 of the thesis will be concerned with the issue of complexity in the MP.

effects of such ‘hidden’ modules isn’t necessarily in line with Occam’s razor any more than the number of constraints posited in the GB framework. The question of how minimal the MP actually is will be the subject of chapter 6.

3.3 Perfection = Adaptation?

The preceding sections have illustrated the overriding minimalist theme of perfection, or optimality, in the design of language. Initially, this conception of language might seem to fit well with an adaptationist account of the evolution of the system. In the sections that follow, I will show that this is, in fact, decidedly not the case, and that the perfection assumed by minimalists has no place in such a story.

3.3.1 Natural Selection as Optimiser

An adaptationist evolutionary account of any system invokes the explanatory mechanism of natural selection to a greater or lesser extent. In order to penetrate the incompatibility of adaptionist evolutionary accounts of language, and its characterisation under the MP, the concepts of adaptation and natural selection must be clarified. Adaptation "...refers to "design" in life – those properties of living things that enable them to survive and reproduce in nature" (Ridley 1996:5). An adaptive evolutionary account thus involves organisms changing over generations to become better able to deal with the environmental puzzles that are thrown at them. In other words, organisms adapt to become fitter[13]. An organism with superior traits will then thrive in the environment where a less fit organism will fail. Individuals better able to cope with environmental stresses will survive long enough, and will be attractive enough to the opposite sex, to be in a position to produce offspring. The fitness of an individual is correlated with their prolificacy.

Natural selection is a medium for adaptation. It is best thought of not as a mechanism however, but as the result of genetic and environmental forces that act on the organism. In other words, nature selects the traits of the organism which will ensure a greater chance of survival. This selection is based on, and is constrained by, environmental and genetic factors. Environmental forces are those problems and tasks faced by the organism. These can be of differing forms – physical, sociological, psychological, etc. Genetic forces refer to the transmission of genes in reproduction; that is, inheritance and mutation. Traits (whether or not they confer fitness on their host) are coded genetically in the organism, so the evolutionary processes that genes are subject to will accordingly affect the

[13] A more precise definition should state that organisms also adapt to maintain fitness; that is, if changes in the environment would lessen the fitness levels of the organism, it will adapt to maintain its current level.

fitness of the organism by determining and constraining the (level of the) traits that the organism can enjoy.

Gradual adaptation by means of natural selection is often conceived of as a hill-climbing process; the fitness landscape symbolises the space of possible phenotypes that the organism could attain. The highest points in the landscape are the fitter phenotypes, the troughs represent the least fit phenotypes. Gradual adaptation involves traversing the landscape, searching for the highest points, or the more optimal phenotypic instantiations.

Adaptation means looking for the optimal solution to some problem posed by the environment. As Gould & Lewontin (1979:581) put it, natural selection is "...an optimizing agent". The MP suggests that the narrow language faculty is the optimal solution to a particular problem – the problem of creating a mapping between sound and meaning. Thus, it looks as if minimalist syntax may be just one instance of this optimisation, which would mean that the minimalist hypothesis that language is a perfect system is consonant with an adaptationist account of the evolution of the system.

However, this initial conclusion is, in actuality, somewhat premature. Equating the perfection of language that is implicit in minimalist theorising with the optimality of adaptation[14] is a conceptual leap too far. The adaptive process of natural selection involves successive modifications over many generations, each constituting an improvement in the system. The perfection of the MP, however, is not assumed to have arisen in this manner. The difference between the MP's perfection and adaptation's optimality stems from a crucial distinction in the meanings of these two terms. While perfection conjures up an absolute notion, optimality entails points on a gradient scale, each of which can be reached only by overcoming certain limitations. While perfection would only hold of the very highest peak in the fitness landscape, the optimality that adaptation brings about holds of lower peaks too. Alternatively formulated, in a search space containing a global optimum (the highest peak) and many local optima (the lower peaks), natural selection will often stop when it reaches a local optimum. Although this local optimum is not the perfect solution to the problem in question, it is a good enough solution. Adaptive evolutionary processes lead to organisms which are fit enough to deal with their environment, but this does not necessarily mean

[14] In section 3.4 I will examine more closely the use of the term optimality in relation to adaptive evolutionary processes.

that they are the most fit, or most perfect, that they could be.

3.3.2 Economy of Statement versus Economy of Process

A crucial distinction, hinted at in section 3.2 above, needs to be introduced into the discussion at this point, and that is the difference between economy of statement and economy of process. The former derives from Occam's razor – it is the guideline of descriptive parsimony followed by all scientists in pursuing their goals. The latter, in contrast, is parsimony in the functioning of a system; that is, independently of whether or not the description of what a system does is simple, the function itself that the system carries out is the simplest way of achieving its aim. The MP strives towards both economy of statement and economy of process. Minimalism aims to give us a parsimonious description of the language faculty, but also aims to show that the language faculty itself is the most parsimonious, optimal solution to a particular problem.

To clarify, economy of statement in minimalist terms refers to the limited number of principles and operations that the system is hypothesised to consist of; the system is described in parsimonious terms. Economy of process, on the other hand, is seen in the way the derivation is assumed to proceed; by adhering to economy conditions such as Shortest Move and Last Resort, the derivation of any sentence is parsimonious. It is in discussion of this latter concept that the notion of perfection is most pertinent in minimalist writings; nevertheless, it is also assumed (sometimes implicitly) that perfection arises from the minimal characterisation of the system.

An interesting point made by Uriagereka is relevant here. He notes that "...one of the basic premises of the MP..." is "...that language is, in some sense, optimal." Further, "[f]or the neo-Darwinian this might be good news, if the optimality in question were shown to be functional. However, linguistic optimality is not functional at all, but only structural; in fact, functionally the linguistic system is definitely suboptimal – support, instead, for the neo-neo-Darwinian." (Uriagereka 1998:xxxvii). The point Uriagereka makes would hold on the understanding that the function of language is communication. Indeed, from this point of view, there are enormous sub-optimalities in language[15]. However, this is not the minimalist viewpoint. In the MP, the function of the narrow language faculty (that which is argued to be perfect and optimal) is to create a mapping between

[15]See chapter 4 for further discussion.

phonological form and logical, or semantic form. Under this interpretation of function, the minimalist does then argue for both functional and structural optimality (both economy of process and economy of statement).

Perfection in the MP thus arises from two different conceptions of economy. The system is more economical because (1) there are less principles and operations in the system, and (2) the derivations are shorter and more efficient. In the sections which follow, the claim will be made that the perfection of language cannot fit with a gradual adaptationist evolutionary account for the system. The problem in short is this: perfect systems do not emerge in evolution through gradual adaptive processes. Rather, the systems that emerge are compromises, hotchpotched patchworks of parts, good enough to get on with the job at hand, but rarely, if ever, perfect – imperfections, if you will[16]. This claim of incongruity can be applied to both types of economy, but in slightly different ways.

It is important to recognise that economy of statement and economy of process are independent of each other. A system may be very economically described, but may function in a highly inefficient manner. Conversely, a system may operate economically, but our manner of characterising it may be complex and uneconomical. In the literature (see e.g. Chomsky (2002b:97ff)) a distinction is drawn between methodological and substantive minimalism (or the weak and strong minimalist theses), where the former refers to the style of methodology employed in the MP, and the latter refers to the central question the MP wishes to answer[17]. Methodological minimalism causes a problem not just for a strictly gradual adaptationist evolutionary story, but more generally for any evolutionary account. Chapter 4 will discuss the methodological difficulties of the MP in detail; it is enough for now to note that in aiming for an economical description of language, minimalists have failed to take certain data into consideration.

[16]Section 3.5 will address the issue of why systems that evolve in the typical manner are not perfect, giving examples and explanation of how we know that such systems are not perfect.

[17]Methodological and substantive minimalism characterise two different levels of description. Within substantive minimalism, we can see two levels of characterisation too. One is the level at which we talk of the properties of the language faculty and their interaction; the minimalism that arises from the manner in which the language faculty carries out its job (derivational economy). But at a deeper level of description, this minimalism must be the direct result of the manner in which the neurons in our brain that are involved in language work. In the same way that methodological and substantive minimalism were differentiated, it might be the case that at the neural level, language is extremely complex, while at the level of linguistic derivation it appears simple, or *vice versa*. Despite acknowledgement of this distinction, the notion of perfection that will be at issue in this thesis is the higher level of the substantive thesis. It is a question for another day how that minimalism is neurally instantiated.

Among these data are the facts of evolution. Ignoring these facts consequently leads to a conception of language which is evolutionarily awkward.

The dubious conception of language that is arrived at through this methodology is the crux of the substantive thesis. In evolutionary terms, this is not problematic in the general sense that methodological minimalism is; it is problematic only for a gradual adaptationist evolution, for the simple reason mentioned above, that perfect systems do not evolve in this manner. We cannot say that the adaptive process of natural selection aims for economy of process. Consider the role the environment plays in the evolutionary development of an organism, or a system of that organism. The environment can be damaging to an organism; it can cause problems that result in the disabling of the canonical method for carrying out some function. An adaptive organism will overcome this difficulty through degeneracy. A degenerate system will be able to co-opt a non-canonical component to carry out the required function. We can say then, that the degenerate system is robust in the face of environmental damage. A perfect machine, however – one that exhibits economy of process – can have no degeneracy, as it goes against the maxim of simplicity and economy. It is this latter principle that will be subjected to rigorous dispute in the rest of this chapter and the next one. Degeneracy is just one of the properties of systems that evolve in a gradual adaptive fashion that will be shown in section 4.8 to be absent from the minimalist language faculty, and lead to the fundamental incompatibility.

3.4 Perfection versus Optimality versus Economy versus Adaptation

The preceding sections have introduced a certain amount of terminology that is still somewhat ambiguous. Specifically, a number of terms have been bandied about in relation to the central theme of the MP. Is language *perfect*, or is it *optimal*, or indeed is it *economic*? Are these simply different labels for the one concept, or can they be separated? In this section, I will attempt to individuate the three terms *perfection*, *optimality*, and *economy*, and then relate each to the process of adaptation. It will be seen that the minimalist literature tends to collapse these terms in a way that alternative domains do not. Teasing them apart will elicit a greater penetration of the evolutionary contentions that the MP entails.

3.4.1 Perfection versus Optimality

Up to this point, the terms perfect and optimal have been used interchangeably with relation to the minimalist view of the narrow language faculty. The quotations in section 3.2.1 indicate clearly that this alternation originates in the minimalist literature itself. Here, I will suggest a differentiation between these terms, and further, a reason for the minimalist to choose one over the other. I will claim, based on untainted definitions of the two words, that interchangeability of the terms only leads to confusion.

Orzack & Sober (1994) define a phenotype as optimal if it outperforms other phenotypes and results in a higher fitness. While this characterisation is not untrue, it fails somewhat to clearly highlight the difference between optimality and perfection; it misses the crucial point that *a higher fitness* does not necessarily mean *the highest fitness*. Perfection is best understood as something that lacks nothing, that is in no way incomplete, diluted or unpure. A perfect system is one without defects or failures, one that is thoroughly adept for its job. An optimal system, in contrast, is the most favourable or desirable system under some constraint. Optimality conjures up the notion of something that solves a problem or does a job in a cost-minimising fashion. Alternatively formulated, perfection is an absolute, while optimality implies a catch or restriction of some sort. A perfect system is the best in any situation, an optimal system is the best in some given situation. The underlying theme of OT highlights this difference well; in OT, perfection is not usually possible[18], but optimality is possible. Optimality is

[18] There may be cases where a particular candidate doesn't violate any constraints, thus making it perfect, but this is not the typical case.

achieved by violating as few constraints as possible, while concurrently ensuring the correct ordering of constraints. Thus, optimality in OT is the best representation under the specific constraint restrictions of the language in question; the best in some given situation.

With this distinction in mind, let us turn to language, and specifically, the minimalist view of language in the narrow sense. A perfect solution to the problem of mapping between sound and meaning is not the same as an optimal solution. A perfect solution would be devoid of all imperfections, while an optimal system would allow imperfections that were unavoidable. As has been discussed above, imperfections in this mapping do indeed exist. The minimalist claims these to be only apparent, as they result from outside systems. Under the definition of perfection given here, the source of the imperfections is irrelevant; it is the mere fact that they exist that precludes classifying the system as perfect. Indeed, the constraints posed by the outside systems on the computational component are just the type of restriction or catch spoken of here in relation to optimal systems. Consequently, we would need to characterise the mapping system as minimalism views it, as, at best, optimal[19] [20].

3.4.1.1 Satisficing and Meliorizing

Viewing the computational component as optimal rather than perfect does not cast any doubt on the central claim of this chapter that the minimalist narrow language faculty cannot have evolved in a gradual adaptationist manner. Optimality is the best possible situation given certain conditions. Above, it was noted that natural selection is often construed as an optimising agent. However, when subjected to further scrutiny, the term used is not quite appropriate. Herbert Simon (Simon (1957), Simon (1984)) introduces the term *satisficing*, claiming that natural selection appears not to search for optimality, but instead to stop once it reaches any reasonable solution to a problem. Once a phenotype emerges that can cope with its environment well enough to survive and reproduce, then evolution is content. Simon (1984:138) notes that "...no one in his right mind will satisfice if he can equally well optimize; no one will settle for good or better if he can have best. But that is not the way the problem usually poses itself in actual design situations."

[19] I will, however, continue to refer to the minimalist view in terms of 'perfection' for the sake of consistency.

[20] In chapter 6 even the optimal view of language will be empirically challenged.

Natural selection is just one of these situations. Natural selection does not, in fact, optimise. As Orzack & Sober (1994) put it: "[t]he claim that a trait is adaptive differs markedly from the claim that it is optimal." In terms of the fitness landscape discussed in section 3.3.1, optimising means reaching the highest peak possible given the current conditions, whereas satisficing means merely reaching some point that is higher than the current position. Note that the optimal point may in some limited cases be the global maximum, but that even where circumstances prevent this, optimising always means reaching a higher peak than satisficing; the only requirement of a satisficing point is that it represents a movement in an upwards direction. This search process has often been likened to climbing in a mountain range while blindfolded or in dense fog. Starting at some random point, the only option is to climb. Once we get to a point where we can go no higher we are at a maximum. However, there is nothing to say that it is the global maximum; it is far more likely that it is a local maximum. Evolution works similarly: each gradual change to the genotype moves the phenotype in a particular direction in evolutionary space. A change in one direction may block subsequent changes in different directions, these different directions leading to a more optimal phenotype. An accumulation of gradual changes will accordingly result in a phenotype that, while good enough, is not the best it could have been given an alternative route through the space of possibilities. As Dawkins (1982:39) puts it: "selection in favour of local optima prevents evolution in the direction of ultimately superior, more global optima."

Yet, *satisficing* also seems to fall a little short in its description of gradual adaptive evolutionary processes. As Dawkins (1982:46–47) rightly complains: "[t]he trouble with satisficing as a concept is that it completely leaves out the competitive element which is fundamental to all life." For this reason, he introduces yet another term to capture the details – *meliorizing*. From Latin *melior* meaning 'better', meliorizing achieves an intermediate between optimising and satisficing, which allows for the fact that natural selection doesn't always (in fact, rarely) arrive at the best solution, but at the same time allows for the constant testing of possible improvements in the organism. In other words, once natural selection has come up with a solution to a problem, it doesn't just sit back and do nothing. It will always try to find better and better solutions to that problem. For example, the first solution it finds may be a clumsy one; it will then try to find a more efficient solution. The key is that natural selection looks for *better* solutions, but not the *best* solution.

The differences and relations between the concepts of perfecting, optimising, meliorizing, and satisficing can be captured by the inclusive hierarchy detailed in figure 3.2. Any system that is perfect is by definition also optimal, in that the best in any situation entails the best in some given circumstance. In turn, an optimal system is not just the best in some given situation, but inherently better than some competitor (thus, meliorizing). Finally, a system that is meliorizing is not just better than some other system, but is also good enough to carry out some function (satisficing). Moving from the innermost to the outermost circle in the diagram thus represents an increase in the superiority of the solution. Adaptation by means of natural selection should be placed in the meliorizing area of the hierarchy:

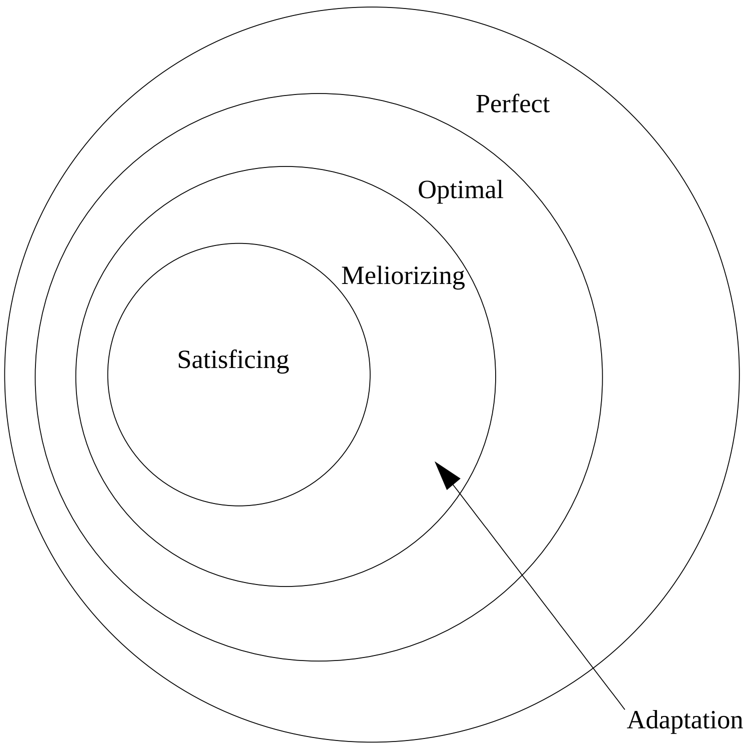


Figure 3.2: Inclusive hierarchy of perfect, optimal, meliorizing, and satisficing systems

Returning from this aside on satisficing and meliorizing, we can sum up by noting that in much of the minimalist literature, optimality and perfection are erroneously equated. A clear difference between these two terms can and should be drawn, only the former being applicable to minimalist argumentation. Nevertheless, despite this clarification, the minimalist narrow language faculty remains so conceived as to be an impossible feat for a gradual adaptationist evolution to achieve, as adaptation is a meliorizing, rather than an optimising process; that is, adaptation results not in an organism which is the best in its current situation, but in one which is simply better than the other options.

3.4.2 Perfection versus Optimality versus Economy

Armed with a clearer idea of the conceptual split between perfection and optimality, let us now turn to comparing another term often appealed to in the minimalist literature – economy. Again, the quotations in section 3.2.1 manifest the parallel drawn between this and perfection. Once more, such parallels can obscure vital details, and clarification is called for.

As has been noted above, the minimalist view of a perfect language faculty derives from two classes of economy; representational and derivational. Language is the perfect solution to meeting the interface conditions because it is the most economical solution. Economy, then, appears to be interpretable as efficiency. Indeed, economy can be defined as efficient or sparing expenditure of resources. Efficiency, in turn, can be defined as being effective with a minimum of effort.

Like the perfection-optimality issue, economy and perfection are not *a priori* equivalent. This is theory-internal minimalist argumentation. In fact, in many domains, the perfect or optimal solution to a problem would not be an economic or efficient one. Imagine a passenger jet designed only with efficiency in mind. Although economical, the lack of redundancy and replication would lead to safety issues. The tradeoff that must be practised to give a fault tolerant system then results in an optimal but inefficient solution. In nature, there are numerous examples of non-economic solutions to problems, some of which will be discussed in section 3.5.1 below. In language, from a functionalist perspective, the best solution to successful communication is not economy; although the speaker may favour economy from an efficiency perspective, an economic utterance is likely to cause problems of comprehension for the hearer.

So, where exactly does economy fit into the minimalist picture? The computational system is considered to be perfect by virtue of the fact that it is the most economical system possible. Such rationalisation may be a reasonable heuristic, but exceptions to the rule highlight the difficulty with minimalist rhetoric. A distinction needs to be drawn between the characteristic of perfection and the ingredient which, for the MP, is the source of this characteristic. In a general sense, economy does not mean either perfection or optimality, and neither of the latter concepts necessarily entails the former.

3.4.3 *Perfection versus Optimality versus Economy versus Adaptation*

We have concluded that the perfection assumed by the MP is better understood as optimality for the simple reason that an entirely perfect system will be entirely free from blemishes, yet minimalism concedes that there are significant (apparent) imperfections in the system. Furthermore, we have suggested that a clearer demarcation of terminology is also required in relation to economy. Economy is the basis for perfection (optimality) in the MP, but the concepts are not equivalent. The most economic solution to the legibility conditions gives rise to a system which is near-perfect, suffering only from imperfections imposed by external systems; hence optimal.

In section 3.3.1 above, adaptation through natural selection was likened to optimisation. We have seen that this analysis is flawed. What is left at this point in the chapter is to question whether any of the three characteristics discussed – perfection, optimality, or economy – can possibly emerge on an evolutionary timescale through gradual adaptive processes. Does adaptive evolution give us perfect systems, optimal systems, or economic systems?

3.4.3.1 *Perfection through Adaptation*

As a meliorizer, not an optimiser, and certainly not a perfecter, adaptation by means of natural selection does not lead to perfect systems. Indeed, it will sooner lead to imperfections. The section which follows will be concerned with this very issue. The lack of perfection in the natural world is highlighted by examples of redundant and badly designed organs. Examination of numerous such examples will emphasise the discord between the minimalist view of language and gradual adaptationist evolutionary accounts.

3.4.3.2 *Optimality through Adaptation*

Like perfection, a meliorizing agent will not usually produce optimality. Although the constant aim is for better and better solutions, the best solutions are often out of reach. In terms of the hill-climbing analogy, it is possible that given a random starting point, simply moving upwards will lead to the highest peak, or the most optimal phenotype. However, the likelihood of this outcome is not high given a large search space with numerous local optima.

3.4.3.3 Economy through Adaptation

Economic and efficient systems can emerge through gradual adaptive evolutionary processes. However, non-economic redundant inefficient systems are much more likely to emerge from the same evolutionary processes[21]. Yet, nature does provide examples of highly economic adaptation. For example, evolution works by adapting already present genetic material that has been seen to be effective, rather than starting afresh with each new problem. Nevertheless, as the constraints that operate on evolution will show in the next section, such economy is rare in nature. Gradual adaptation predominantly generates uneconomical organisms.

Of course, all of the above discussion is trivial unless there is a criterion against which perfection/optimality/meliorization can be gauged. In other words, if we state that some organism is optimal, or some adaptation results in a better organism, the question is 'optimal in relation to what?', or 'better in relation to what?' However, answering such questions is far more complex than might initially appear to be the case. In such cases, there are generally multiple criteria, often at odds with one another[22]. As Sober (1984:175) notes: "[i]t would be absurd to assume that natural selection must perfect a characteristic relative to each of its functions." There are always trade-offs; that is, a characteristic "...will be selectively advantageous if the *overall* benefits outweigh the costs, compared with other characteristics that happen to be present in the population" *(ibid)*. For the purpose of the current discussion, we can thus (somewhat crudely) designate as the overall gauge for language the particular problem which the environment posed for our ancestors, to which language was the solution. The nature of this problem will then depend on one's viewpoint; for Chomsky it is the need to map between phonological representations and conceptual representations, for

[21]Of course, redundancy is a kind of efficiency; redundancy can be adaptive (as will be seen in later sections of this and the next chapter). However, the point is not that economy should be universally equated with perfection, but that, as this is the parallel drawn by the MP, this particular characterisation is used here to highlight the incompatibility of the minimalist language faculty and gradual adaptationist evolution.

[22]The issue of competing motivations will be returned to in chapter 6.

Pinker & Bloom (1990) it would be the need to communicate complex propositions through a serial channel[23]. Thus, language can be considered perfect if it fulfils the need in question in the best manner possible, independent of the circumstances, or the processes resulting in language can be considered meliorizing if the system is better than its predecessors, better than the alternatives available, yet not the best, either in all, or in just the current circumstances.

This section of the chapter can be brought to a close with the following strict definitions which will be used to inform the rest of this and later chapters.

Perfection : An ideal; the best possible in all circumstances and under all conditions. Perfection is an absolute measure, with no room for degrees thereof.

Optimality : The best possible given certain conditions or restrictions. Optimality is a graded concept.

Economy : Efficiency and moderation in the employment of resources or in the application of procedures. Gradient levels of economy are possible.

Adaptation[24] : The iterative and cumulative modification of organisms leading to an increase in their fitness relative to their current environment. Such modifications are undirected but constrained[25].

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[23]It should be recognised that there may not be just one function for which language evolved. It may also not be the case that the current function of language was also the function for which it evolved (Fitch *et al.* 2005). Such issues will not be addressed in any detail in this thesis. At a high level, I take a fairly traditional adaptationist stance on this question, maintaining that the prime function for which language evolved was communication, while recognising that this does not necessarily entail that each and every property of the system was directly selected for this function - some may be spandrels or exaptations, as noted in section 1.3. The evolutionary scenario I outline in sections 5.4.2.1 and 5.7.4 reflects this general adaptationist view.

[24]Note that adaptation as defined here refers to a process; it can equally well be defined in terms of a resulting trait, as Sterelny & Griffiths (1999:217) do: "[a] trait that exists because natural selection has favored it is called an *adaptation*."

[25]Adaptation thus differs from drift, the latter a purely random walk through genotypic space, with any changes which are non-neutral with respect to the fitness of the organism occurring purely by accident.

3.5 Perfection in Nature

The incongruity of the minimalist theme of perfection and gradual adaptationist evolution is this: perfection (or indeed optimality or economy) does not arise in nature as the result of gradual adaptive evolutionary processes. Such processes instead give rise to characteristics which might be considered the antithesis of perfection: for example, redundancy and duplication. These claims will now be explored more closely by investigating exactly what we find in nature. That is, are all adaptations imperfect? Do perfection, optimality, or economy exist anywhere in nature, and if so, what is the explanation for their emergence if it is not gradual adaptation?

As remarked, gradual adaptive evolution generates systems and organisms that are a hotchpotch of parts, just good enough for the job they need to do. The nature and evolutionary history of such hotchpotched systems will be the subject of enquiry of this section. Following this, the reasons that gradual adaptation will only engender such systems will be considered.

3.5.1 Imperfection

What Maynard Smith (1994) refers to as the strong form of adaptationism – that all organs are perfectly adapted – will be shown to be false both with examples of imperfection and examples of perfection. The latter will be seen to arise by non-adaptive means, the former through the adaptive process of natural selection. It is important at this point to define what will constitute an imperfection for the purposes of this empirical exercise. Minimalist perfection is characterised as resulting from economy and efficiency in a system; a perfect system must be the most economical possible. To align the argumentation here with this minimalist specification, an imperfect system or organism will be understood to be one in which there exists redundancy or duplication of function or structure; an uneconomical system, in other words.

Let us turn now to enumerate some of the very many examples of such imperfection that exist in nature. Functional redundancy through duplication is illustrated by the existence in humans of two kidneys, although we can survive perfectly well with only one. Another similar example is the fact that the human brain seems to be able to re-align itself when faced with a trauma. Very young patients who suffer damage to certain parts of their brain can use the undamaged parts to regain the functionality that would previously have been instantiated through the damaged area.

Human organs also manifest a redundancy of a more severe kind. While functional duplication involves more than one means of carrying out some function, vestiges have no current place at all in the organism. The human vermiform appendix is one such example. In modern humans, the appendix is thought to serve no purpose[26], its existence does not appear to increase fitness in any way. In fact, removal of the appendix is often necessary, and causes no ill effects. Not only is the mere existence of the appendix in humans an imperfection, the structure of the organ itself is also imperfect. The frequent and sometimes fatal infections that the appendix gives rise to are caused by an inadequate entry point which promotes blockage (Theobald 2003). What perfect organ would induce such failings?

Another vestige is the male mammalian nipple. In this case, the vestige is not left over from an earlier evolutionary stage in which it performed some function relevant for survival, but rather might be argued to be left over from an earlier embryonic developmental stage before sex differentiation occurs (Symons 1979).

Further uneconomical imperfections are birds' excess flight feathers, and the pathway of the mammalian recurrent laryngeal nerve. Birds need only a proportion of the 30 to 88 flight feathers on their wings in order for flight to be a possibility (King & McLelland 1984). The recurrent laryngeal nerve in mammals follows a circuitous route that seems imperfect and uneconomic. By travelling from the brain to the larynx posterior to the aorta, the nerve is significantly longer than it needs to be. While in humans the extraneous nerve material may not add up to too much, in a giraffe, it is estimated to be almost twenty feet (Smith 2001).

Human wisdom teeth provide a final imperfection. The third molars tend to be larger than our other teeth, and this results in problems of fit in many modern humans. The smaller jaw of the modern human cannot accommodate the wisdom teeth very well, resulting in pain on eruption or in impacting. As with the appendix, removal of the wisdom teeth brings the bearer no harm. Thus imperfection here is a combination of structural suboptimality and functional redundancy.

[26]There is certain skepticism of this claim, and some suggested functions have been proposed. See Williams & Myers (1994) for a review.

All of the imperfections mentioned here arise in nature as the result of gradual adaptive evolution, and their less than perfect (and, in fact, also less than optimal) nature can be accounted for in terms of the processes of gradual adaptation and the restrictions thereon. Sober (1984:175) notes that natural selection does not guarantee that the adaptations found in nature are perfect. In fact, the examples here suggest that natural selection usually falls short of perfection. The appendix exists in modern humans because it existed in our ancestors. At an earlier evolutionary stage, the cecum functioned to digest cellulose in our herbivorous ancestors. The appendix is a small blind-ended tube connected to the cecum. In modern humans, its existence is therefore assumed to be merely a residual of an earlier requirement. The male nipple, as mentioned above, is thought to exist for reasons of energy saving. That is, nipples develop in the embryo at the three to four week point, prior to the later (about six to eight weeks) differentiation of the embryo into male or female form. As Gould (1992) has noted, evolution seems to take a path of least resistance, or a path that will lower energy costs; the male nipples are simply left as they are not maladaptive.

Wisdom teeth are imperfect due to the size of the modern human jaw. While our ancestors had larger jaws that comfortably accommodated the larger third molars, jaw size has decreased significantly over evolutionary time. This adaptation has been gradual, although the basis it was selected for is controversial. One argument is that the abilities of early humans to cut food down into smaller pieces, and use fire and tools to cook it led to a decreased requirement for teeth to break down the coarse abrasive food. A more recent argument (see, among others, MacGregor (1985)) holds that the jaw decreased in size to allow the brain to increase in size. In either case, that the change has been gradual is buttressed by the fossil record.

As for the recurrent laryngeal nerve, the explanation is again based on an earlier body plan which has changed over time. Mammalian predecessors were configured in such a fashion that the recurrent laryngeal nerve followed the most economic path from brain to larynx. However, changes in the shape of the body and the location of the larynx relative to the heart mean that what was originally a relatively straight path has been shifted and detoured to become longer and uneconomic. That the changes which resulted in this current situation were gradual is likely given that each small change would have made little difference to the path of the nerve, and it is only given the cumulative effect of many of these minor alterations that the inefficiency becomes apparent. It is unlikely that a sudden mutation which at once shifted the position of the organs relative to each other would have stretched the nerve and shifted its pathway too; in such a case, the organs would presumably have simply re-aligned themselves with the current path. Thus, the imperfection in this case is due to nature's inability to look forward in time (as will be further discussed in section 3.5.3.3 below).

The evolutionary history of the human kidneys, the human brain, and the flight feathers of birds share a common theme. In these cases, the inefficiency stems from a robustness inherent in biological systems. For a kidney to be of use to its host it must be in one hundred percent working order; it does not exhibit the graceful degradation manifest in many other organs. Thus, should we only have one kidney, even minor damage to it may be fatal. In order to overcome this problem, nature has had the clever idea of bestowing us with a duplicate. For most of us, we will never need to rely on both of our kidneys, but for that small percentage that do, the redundancy is adaptive.

In a similar way, the redundancy of function in the human brain, and the redundancy in structure of bird flight feathers can both be explained as adaptive emergency backups. Trauma to the brain which results in this type of re-alignment is almost always severe; the alternative being a huge deficit of fitness in the individual involved. Unable to fly, a bird might be subject to predation. Thus, a bird with only the exact number of feathers required for flight is only one feather away from possible fatality. With an extra store in case of such eventualities, the fitness of the bird is less likely to endure such assault.

These are just some of the many instances of imperfections in nature. We can draw a three-way distinction between the examples given as follows:

- ***Redundancy***
  Redundancy is illustrated by human kidneys, human brain re-alignment, and birds' flight feathers.
- ***Vestiges***
  The human appendix, male mammalian nipples, and wisdom teeth represent vestiges.
- ***Inefficiency***
  The recurrent laryngeal nerve exemplifies inefficiency – the very opposite of economy.

Some further generalisations can be made about these three types of imperfection. *Redundancies* tend to be adaptive; that is, they yield robustness to failure of a system where this could be fatal. *Vestiges* are not currently adaptive, but are left-over adaptive solutions to earlier problems. The appendix was an earlier adaptation for digestion, and the wisdom teeth an earlier adaptation for grinding coarse foodstuffs. Nipples are an adaptation in females but develop in the embryo before it has become male or female; thus in males they represent a left-over from an adaptive decision made at an earlier embryonic rather than evolutionary developmental stage. Interestingly, vestiges are not adapted out of the organism unless they cause possible fatality. In other words, evolution will not do more work than it needs to. Although congenital absence of the vermiform appendix is attested (though rare) (Greenberg *et al.* 2003), indicating the possibility of a gradual adaptation in action, all male mammals still have nipples; while an appendix may become infected and potentially kill its host, nipples are doing male mammals no harm. *Inefficient structures* are also not current adaptations, but result indirectly from earlier gradual adaptation to other parts of the system. Thus, the recurrent laryngeal nerve in its earlier, more economic form was itself an adaptation, but later incurred disturbance due to gradual adaptive changes to other body parts, and became (somewhat) maladaptive.

In sum, imperfections may be directly adaptive, or the result of some other adaptation. Perfection as the result of economy of structure or function and lack of redundancy does not, however, arise in nature through adaptive evolutionary processes.

3.5.2 Perfection

Turning now to examine the instances of perfection in nature, recall that perfection will be understood in this context following minimalist characterisation; absolute economy and optimality in solutions to problems. Any system in nature which does appear to embrace these attributes will be seen in the following discussion not to arise in the same manner as the imperfections met in the preceding section. Principally, perfection emerges not through typically biological processes, such as selection and adaptation, but rather as the result of physical laws.

A commonly discussed example of the 'perfection' of nature is the existence of Fibonnaci numbers in phyllotaxis. The number of petals, florets, leaves, or seeds existing on many flowers and plants constitutes a number on the Fibonnaci sequence. While this property alone is not sufficient grounds for assuming perfection (a Fibonnaci number isn't intrinsically economic or optimally non-redundant in any way), the arrangement of this specific number of leaves or petals does give rise to economy and optimality. The leaves of a sunflower, for example, when viewed from the top down, are organised in such a way that no leaf is entirely covered by any leaf on the layer above it, and thus each leaf receives equal sunlight. Each layer of leaves on the stem, working downwards, consists of a number of leaves which constitutes the subsequent number on the Fibonnaci sequence to the previous layer.

These facts are explained by the laws of growth and form, rather than by any adaptive process. The leaves, petals, seeds or florets of the plant in question develop from the apex of the plant at different times over its life. Geometric laws determine how newly grown elements will all fit into the area available, and do so in a regular fashion. Consider the tightly packed florets of the daisy, for example. The florets are all situated at the same angle to each other[27]. Douady & Couder (1992) give the following explanation for this perfect development: the newly developing florets (or leaves, petals, or seeds) are travelling at a specified velocity, and so they repel each other like magnets. The angle at which they develop is then optimal in that it allows each and every element to be as far away from every other one as possible. While the nature of the repelling forces is unclear, what is clear is the fact that there is no evolutionarily biological reason for these patterns. Thus, this case of perfection cannot be explained by adaptive evolution.

Similar patterns and explanations thereof are found elsewhere in nature. The eye spots of the peacock's tail are a reflex of underlying skin patterns, which, in turn, follow geometric laws determining how each newly grown feather can be packed into the available space. Again, this reflects minimalist perfection in that the arrangement that results is the optimal solution to the problem of organising the feathers.

Darwin (1861) and D'Arcy Thompson (1961) are among those that have argued that the honeycomb of the bee is as perfect as it could be. Each cell of the comb has a strictly hexagonal shape, and each layer of cells is nested into the next

[27]The angle is 137.5°, the golden or noble angle (see Jean (1994)).

perfectly, the cells all standing at an angle of 120° from each other. The hexagonal shape is not only elegant and symmetrical, but it is also the optimal shape for economising wax, and hence minimising metabolic costs for the bee. Thus, the bee honeycomb has all the features that a minimalist equates with perfection – it is economic in structure, it does not exhibit redundancy, and it is the optimal solution to the bee's problem of where to keep their larvae, and store honey and pollen.

A widely accepted explanation for this perfection is D'Arcy Thompson's[28]. Claiming that it is "fantastic to assume that the bee intentionally seeks for a method of economising wax", D'Arcy Thompson (1961:115) proposes that mathematical laws governing growth and form are responsible for the perfection of the honeycomb. In the same way that when soap bubbles become stuck together they are forced into a lattice of hexagons, so when individual bees are concurrently building honeycomb cells side by side physical laws force them into this particular structure. The messy shape of the individual cells of queens highlights that it is the interaction between cells which leads to the hexagonal lattice. Thus, perfection again arises from physical, rather than biological laws.

Chomsky himself has compared the study of language to the study of snow crystals (Chomsky 2004:150ff) in that both exhibit perfection. A snow crystal is a hexagonal prism, perfectly regular and symmetrical, and highly elegant in its structure. Once more, this morphology arises through physical laws of growth and form. The physical make-up of the water molecules determines the six-sided plan for the crystal, and the temperature and humidity conditions govern which of the many possible crystal types is formed. However, despite the parallel drawn between the minimalist language faculty and a snow crystal, there is a fundamental difference. While language has a function, a snow crystal does not. As noted earlier, perfection can only be defined in terms of a particular problem that needs to be solved, or a function that needs to be fulfilled[29]; the snow crystal appears to be perfect only on geometric and aesthetic levels. Nevertheless, while this example does not provide a strictly valid contrast to the imperfections of the

[28] Although there have been proposals to explain this perfection in terms of natural selection (see Ball (1999) for a review of von Frisch's (1974) ideas).

[29] For language, we have noted that the question of function can be answered in an adaptationist manner - language is *for* commuincation - or in a Chomskyan manner - language is *for* mapping between conceptual representations and phonological representations. Discerning whether language is indeed perfect will depend on which of these functions we take to be the correct one. However, on neither view is language perfect; chapter 4 shows this for the communicative interpretation, and chapter 6 for the Chomskyan interpretation.

preceding section, what it does serve as is the archetypal example of what the minimalist means by 'perfection'.

Perfection in nature, then, is to be explained in terms of physical rather than biological processes. If language is to be equated with examples such as the snow crystal or the honeycomb, it too begins to look like a system whose explanation belongs in the physical sciences rather than the biological sciences. Consequently, we are left with two alternative paths to pursue. The first possibility assumes that the minimalist is right about language; that the faculty is simply a basic atomic computational system, limited in its application to the central recursive operation of Merge. If minimalism is indeed an accurate representation of language, then the physical explanation for its existence may be reasonable; that is, if language really is perfect, then there is no call for a gradual adaptationist evolutionary account for its emergence. An explanation which embraces the physical processes of growth and form, leading to efficient, economical, non-redundant (i.e. perfect) systems can answer the question of how the language faculty arose in our species. On the other hand is the possibility that a gradual adaptive evolutionary account is more suitable for the subject of inquiry. If this turns out to be true, then it must be the case that minimalism is fundamentally flawed in its outlook; that constraints of economy and perfection are not felicitous for language. So, the choice appears to be this: show that minimalism is correct, and rule out the gradual adaptationist evolutionary account, or show that gradual adaptationism is correct, and rule out the MP. Thus the incompatibility of minimalism and gradual adaptationism is real, but that incompatibility itself does not force adoption of one or other position. The choice between two standpoints that the incongruity presents must be determined empirically. This will be the concern of the chapters which follow.

3.5.3 Constraints on Perfection

The question that now needs to be addressed is this: why do gradual adaptive evolutionary processes give rise to so much imperfection but rarely, if ever, to perfection? This section will outline some of the very many reasons for this situation. It will be seen that this asymmetry arises because evolution does not act in a vacuum apart from all other processes and pressures. Evolution is subject to restrictions and constraints on the direction it may take, and this means that the perfect solution is often out of reach. The following paragraphs will enumerate some of these constraints.

The major constraints that will be discussed here can be divided into three categories; availability constraints, developmental constraints, and historical constraints. The first refers to restrictions imposed by the material available to evolution, the second to the type of limit levied by the manners in which organisms develop on an evolutionary timescale, and the third to obstacles that arise as a result of the passing of time.

3.5.3.1 Availability Constraints

Natural selection can only work with what is available to it. By definition, natural selection chooses among possible solutions; hence there must be variation in nature. However, if the variety of material available does not include that which is needed to reach the global optimum, then perfection will not be realised, and the organism or system that results will be sub-optimal or imperfect in some (albeit perhaps small) way. Dawkins (1982) illustrates this point with the following example: although it would be beneficial for cattle farmers to be able to breed for sex, in the same way they can breed for high milk yield, or hornlessness, it is not possible, as the relevant genetic variation does not exist (Fisher (1930), cited in Dawkins (1982)). Thus, evolution cannot source its material from a non-existent supply, no matter how much fitter the organism would be.

Another constraint of this class is the cost of materials. In selecting a particular solution to a problem, an engineer will concern himself not simply with designing the optimal system, but will consider also the cost of the materials he uses. Evolution will not provide the optimal solution to a problem, if that problem could be alternatively solved using cheaper materials. As Dawkins (*ibid*:46) puts it: "[t]he best design is the one that satisfies the criterion specification at the least cost. Any design that achieves 'better' than the specified criterion performance is likely to be rejected, because presumably the criterion could be achieved more cheaply." In evolution, unlike engineering, 'cost' refers not to economic value, but rather to associated consequences in other parts of the system. For example, it is well known that we have larger brains than our ancestors, and indeed further growth of the organ might seem desirable. However, the reason that hominid brain increase has not continued at the same rate is that this would entail growth in the size of the skull, and this in turn would cause difficulties during childbirth, as well as the problem of stabilising a large head on our relatively small bodies. Gradual adaptive evolution through natural selection does not reach perfection if there are adverse effects elsewhere.

3.5.3.2 Developmental Constraints

A number of varying types of constraints can be thought of as falling under this second heading. What all have in common is that the restrictions imposed are somehow the result of the processes that take place in evolution.

Dawkins (*ibid*) discusses the fact that selection can be understood to operate at a number of different levels - the gene level, the individual level, the group level, and so on - and these different views can lead to observing imperfections. That is, selection at one level may lead to imperfections at another level. The classic example of this is cases of heterozygous advantage, such as sickle cell anemia. An individual with two copies of the β-globin allele (homozygous) will have resistance to malaria, but will suffer from sickle cell anemia. An individual who has just one copy of the β-globin allele (heterozygous) will also have malarial resistance, but in addition will not suffer from sickle cell anemia. If we assume selection to take place at the level of the gene, the β-globin gene is selected for based on the fitness it bestows on its host organism when it is heterozygous. However, at the level of the individual organism, in cases where the gene is homozygous, the imperfection is obvious.

Genetic processes such as drift and linkage provide another set of developmental constraints. For example, random drift in the genotype space, caused, for example, by binomial sampling errors in the transmission of alleles from one generation to the next in sexually reproducing populations, may result in a population with a quite altered genepool, which, in turn, may rule out adaptive mutations that were previously possible. Cain (1989) argues that such stochastic processes are a minor disturbance, causing imperfections only at lower levels of observation (i.e. the genetic level rather than the major class level). Nevertheless, drift may impose restrictions on meeting the global optimum.

A final constraint to consider in this category is unpredictability in the environmental conditions. That is, the organism develops over evolutionary time to become adapted to the general conditions of the environment around it. However, at certain times, the environment may not behave as expected, and the organism is not equipped to deal with such situations. One such example is when predators camouflage themselves to appear part of the benign environment (Dawkins (*ibid*)). While the organism has developed to deal with the usual patterns of behaviour that its environment exhibits, it can never reach perfection if it can be outsmarted by an unusual environmental behaviour.

3.5.3.3 Historical Constraints

The third species of constraint on reaching perfection through adaptive means is typified by the example of the recurrent layngeal nerve discussed in section 3.5.1 above. The current uneconomic pathway of the nerve in mammals indicates that natural selection has no foresight. When the earlier pathway of the recurrent laryngeal nerve evolved in the mammalian ancestor, evolution had no way of telling that later changes to other aspects of the organism would lead to the imperfect situation we now have. Selection operates on the material available at a given point with respect to the environmental issues bearing on the organism at that time. There is no way for selection to foretell what the future will bring. In other words, a move towards today's optimum may hinder reaching tomorrow's optimum. In Pittendrigh's words, adaptive organisation should be understood "...not as Paley's perfection demanding an intelligent designer, but rather as a patchwork of makeshifts, pieced together...from what was available when opportunity knocked, and accepted in the hindsight, not the foresight of natural selection" (Pittendrigh 1958:400).

A further type of historical constraint has to do with time lags and changing conditions. In other words, the environment may change in such a way as to make the optima of times past a disadvantage to the organism today. A number of examples are discussed by Dawkins (*ibid*) in relation to this constraint. One is the hedgehog anti-predator strategy. While at an earlier point in the evolutionary history of the hedgehog, curling up into a ball and displaying its prickles was enough to fend off any predators it might encounter, in modern times this strategy is insufficient. When the hedgehog meets a motorised vehicle, simply curling up into a ball is not going to save it. Another instance of a time lag in evolution has to do with the moth's use of celestial bodies for navigation. While in times past, small bright areas of light would have been suggestive of a navigational aid, in later times, they also became suggestive of a death-trap. Thus, moths' tendency to self-immolation in candle flames is a result of the fact that environmental change has negated earlier optimal adaptation.

These are just some of the many limits that are put on gradual adaptive processes reaching perfection. Others include accidents of history, natural selection's inability to keep up with perpetually changing conditions, and compensation – inefficiency in one arena being tolerated because the organism is highly adaptive in another. The point these examples make is simple: perfection will not be reached through gradual adaptive evolution. Instead, what we are prone to find is imperfection; that is, redundancies, inefficiencies, and uneconomic elements.

3.6 Conclusions

In this chapter, the fundamental minimalist notion of perfection has been pitted against the fundamental evolutionary process of adaptation, the clear result being that any initial suspicion of a congruence between the two is unfounded.

In the MP, perfection is measured in terms of the mapping between the external sound and meaning systems, is better rephrased as optimality as the mapping is always subject to constraints imposed by these systems, and is equated with economy in the form of minimal machinery to create the mapping. Imperfection, on the other hand, is redundancy, duplication of function and structure, and inefficiency.

In evolution, adaptation is not a perfecting, not even an optimising, but rather a meliorizing process, is subject to various types of constraint, and does no more work than it needs to. As a result, the biological processes of gradual adaptative evolution do not give rise to optimal characteristics or organisms, but rather to redundant, inefficient ones.

The minimalist thesis of economy and perfection thus gives us a system which flies in the face of all the evidence from evolutionary biology. Such a system must therefore be subjected to intense scrutiny. In chapter 6, this scrutiny will take the form of a critical analysis of the MP's adherence to its central themes. If the framework is shown there to flout the axioms that give it its name, the right way out of the problem of discord highlighted here will become clear. Before that, the next chapter will develop the incompatibility of minimalism and adaptation yet further, firstly, by considering one more fundamental claim of the MP – that language is simple – and secondly, by taking a deeper look at the features that systems evolving by gradual adaptation possess.

CHAPTER 4

Simplicity, Complexity, and Evolvability

4.1 Introduction

Chapter 2 outlined in detail what the language faculty looks like when viewed through the minimalist lens. Chapter 3 further examined the minimalist claim that the language faculty, under this conception, may be perfect. In that latter chapter, this perfection was shown to be closely related to issues of simplicity and economy. That is, the minimalist interprets the language faculty as consisting of limited machinery, which operates in an economic fashion. This was illustrated in section 3.2.5. Thus, the simplicity and elegance of the language faculty is what makes it perfect, in the minimalist's eyes.

This chapter will be concerned with the second issue formulated at the end of chapter 1: the issue of simplicity, in isolation from perfection. A brief review of the ways in which the minimalist language faculty can be interpreted as simple will be followed by an examination of the opposite standpoint - that the language faculty is, in fact, highly complex, intricately organised, and operates in an elaborate, and sometimes, tangled manner. This will motivate a discussion of the issues surrounding measuring complexity, and what it might mean for the language faculty to be complex, or indeed, simple. These issues will then be directly linked to the evolutionary possibilities of the language faculty, firstly by questioning the accuracy of assumptions that evolution proceeds in the direction of greater complexity. Following this, the methodological choices made by the minimalist, which were hinted at in chapter 3, will be subjected to scrutiny, and it will be shown that the assumptions made lead to a system of language whose evolutionary possibilities are both highly constrained, and biologically unlikely. In the final section of this chapter, the question of what an evolvable system of language would look like will be informed by detailed examination of a number of characteristics closely associated with the property of evolvability.

4.2 The Simplicity of the Minimalist Language Faculty

The minimalist language faculty differs from the system envisaged in other frameworks primarily through reduction of the apparatus it entails to only that which is conceptually necessary (see section 2.3.3). Levels of representation are fewer, as are permissible operations, and objects subject to these operations (more specific details are offered below). As Lorenzo & Longa (2003:652) explain: "...the MP envisages a conception of the initial state (S_o) of FL [the faculty of language] far less articulate than the one defended by the GB Model, with all its rich articulation of grammatical modules, principles of grammaticality, grammatical levels of representation and grammatical categories of all sorts."

Chomsky (1995a) notes that the beginnings of minimalism are discernable from at least the early 1960's, if not before. Although generative grammar at that time posited highly complex rule systems, there was even then an attempt to abstract away from these systems to more general principles. X-bar theory later made this project more specific, showing that phrase structure grammars can all be conceived of as fitting into a general framework, which is underlain by a common architecture for all phrase types. Nevertheless, as section 4.3 below will show, the simplicity that the system boasts under the MP vastly outstrips that hinted at by X-bar theory. X-bar theory is, after all, just one of a number of equally important interacting modules which combine to account for the language faculty in a GB schema.

The nitty-gritty of minimalist simplicity has been covered (if not, in all cases, explicitly, then implicitly) in chapter 2. Here, I will re-iterate this by briefly reviewing a number of relevant points from the literature:

- The only levels of representation are the interface levels; Deep Structure, Surface Structure, and any other levels additional to those at which the computational system interacts with the systems of sound and meaning are superfluous (Lasnik 2002a).
- Constraints on derivations are deduced from general economy considerations, rather than having any alternative motivation (Lasnik 2002a).
- No extra steps are taken in a derivation, and no extra symbols are posited in a representation, where 'extra' is defined as those that are not interpretable at the interfaces; such steps and symbols are ruled

out by the principle of Full Interpretation (Chomsky (1991a), Chomsky (1995a), Lasnik (2002a)).

• The five compositional operations of GB:
1. forming DS from X-bar theory,
2. the transformational cycle mapping DS to SS,
3. the covert transformational cycle mapping SS to LF,
4. mapping LF to the semantic interface,
5. mapping SS to PF
have been reduced to just one - Merge (Chomsky 2004).

• There is no direct interaction between the two interfaces; the computational system mediates between these (Chomsky 1995a).

• The principles that are posited to be part of Universal Grammar may only involve elements which function, or are interpretable, at the interfaces (Chomsky 1995a).

• All relations that hold between elements in a derivation must be local (Chomsky 1995a).

• The complexities of X-bar theory are eliminated and replaced by a bare phrase structure which allows no X′ levels (and in some versions no XP or X^o levels (Chomsky 2001)) (see section 5.4.1.1) (Chomsky 1995a).

• The only objects that exist in and drive the derivation are lexical features (Chomsky 1995a).

• Operations must be motivated; they cannot be applied optionally or arbitrarily (Chomsky 2002a).

• Simpler operations are preferable to more complex ones. Thus, Merge is preferable to Move because Move is comprised of Merge plus Agree plus pied-piping (Chomsky 2001).

• There is no look-ahead in the course of a derivation; computation is locally determined only (Chomsky 2002a).

• The only features that a lexical item can have are those that are interpretable at the interfaces, i.e. properties of sound and meaning (Chomsky 2002a).

• The Inclusiveness Condition states that no new features can be introduced in the course of the derivation; all features that are part of the derivation are determined at the point of lexical insertion (Chomsky 2002a).

• More economical computations block less economical ones. Thus, for example, longer movements are blocked if shorter ones are available (Chomsky 1998).

4.3 The Complexity of the Non-Minimalist Language Faculty

The view of the language faculty that is championed by Steven Pinker (Pinker 1994), and upheld by others in the linguistics and cognitive science communities (e.g. Jackendoff (2002)), in many ways directly opposes the central tenets of minimalism. In the place of a system where maxims of economy and simplicity rule is one which presents a machinery that is substantial and multifarious. The subsections which follow outline the complexity that can be attributed to the language faculty.

In the preceding chapter, the simplicity of the minimalist language faculty was highlighted by comparing it to the system proposed by GB theory. Importantly, it is not necessary to adopt the GB approach to language to observe its complexity[1]. As the following subsections will show, the claims that are made with respect to complexity in the language faculty could be theoretically formulated in a number of ways; no particular architecture must be assumed in order to claim complexity in the language faculty[2].

4.3.1 Pinker and Bloom

Pinker and Bloom's seminal paper (Pinker & Bloom 1990) is the most prominent example of gradual adaptationist thinking with respect to human language. For them, the computational linguistic system is complex by virtue of its consisting of many interacting parts, and is adaptive by virtue of its appearing to have been designed to fulfil a particular function - to communicate complex propositions. They list a substantial set of properties of the language faculty. Each of these properties is argued to be adaptive given its appearance of design for a particular communicative function. That is, each element has a job to do, and that job involves "...mapping a characteristic kind of semantic or pragmatic function onto a characteristic kind of symbol sequence..." (Pinker & Bloom 1990:713). Moreover, each component of the system does not merely carry out some job, but importantly it is tailored specifically to this very purpose. This, in turn, suggests

[1]As noted in chapter 3, the work of this thesis is not to compare available generative (or non-generative) approaches, but to examine the evolutionary plausibility of just one of these approaches (the MP). On occasion, the specifics of an alternative approach are called on to aid clarification of the pertinent points; this should not lead the reader to the assumption that I necessarily hold these alternatives to be evolutionarily superior.

[2]The obvious exception to this is section 4.3.3. Although certain of the quotations to be found in Chomsky's pre-minimalist work claim complexity in the language faculty without specifically attaching it to a particular framework, in a more general sense, this interpretation is obviously theoretically biased. It is, nevertheless, interesting to draw attention to this earlier, more complex picture of the language faculty that Chomsky paints.

a piecemeal evolutionary scenario, each adaptive property the domain of a semi-autonomous emergence[3]. The language faculty is, then, a composite interaction of multiple elements, each playing its part in the adaptive whole. In other words, individual functions cooperating to yield the workings of the entire system emphasise that the system should reasonably be viewed as complex.

Two points are important, before going any further. The first is to draw a crucial three-way distinction between the complexity of specific languages, the complexity of language as a general phenomenon, and the complexity of the language faculty. The first type of complexity would hardly be denied by any linguist of any of the world's languages. The second type is again independent of theoretical persuasion. It is the third type of complexity which concerns us in this chapter. Crucially, we should take care not to confuse these three aspects of linguistic complexity. The second point reminds us that it is not simply the language faculty, but the narrow interpretation of the language faculty, which is under discussion. Although Pinker and Bloom do not overtly make the distinction between the narrow and broad language faculties, the components they list clearly belong to the former by virtue of being uniquely linguistic and uniquely human (see chapter 5).

Some of these many adaptive properties are presented below. Pinker and Bloom's list is a relatively uncontroversial set of properties of a language faculty that bestows on humans specific linguistic knowledge. The point is thus not that minimalism denies such features of language, but that its model of the language faculty is such that this wide-ranging set of properties is reduced to a minimal machinery. Other models of the faculty (GB theory, for example) account for the same set of properties in more elaborate fashions.

- The major lexical categories such as verb, noun, and adjective, the building blocks of the grammar, have particular distributional patterns, which "...are exploited to distinguish basic ontological categories such as things, events or states, and qualities." (Pinker & Bloom 1990:713).

[3]The term semi-autonomous is used, as if the individual elements of language were to be able to work together to any degree, their evolution must have been connected in some manner.

• Co-occurrence restrictions hold between major and minor lexical categories. For example, articles are found together with nouns, but not with verbs.

• The major phrasal categories are constructed around a major lexical item, supplemented by additional affixes or phrases which further specify the entity or event.

• Rules of concatenation and linear orderings thereof within the phrase mirror the semantic relations of the underlying proposition.

• The role of linear order can also be undertaken by case affixes which allow semantic relations to remain transparent even in cases of non-canonical order. In such cases, linear order can "...be exploited to convey relations of prominence and focus..." (*ibid*).

• By selecting from a set of pronouns and anaphoric elements the one with the correct coreferential semantic properties (gender, animacy etc.), repetition of elements in the proposition can be avoided.

• Entire propositions can be combined using complementisers or particular structural configurations (so-called 'control' structures), clearly indicating the relation between the combined propositions.

Pinker and Bloom themselves note that the above is just a partial list of the intricacies of the system. They briefly suggest others to be found in additional domains (such as the rules of prosody and segmental phonology). Given any system which consists of numerous parts, each with a specific part to play in the system as a whole, without a map of the system's internal workings, an analysis of that system as complex would seem to be a justifiable conclusion to arrive at.

A final note on Pinker and Bloom's complexity thesis is the suggestion of a different type of complexity - that is, one not directly related to the interaction of multiple component parts - in their list. This is the redundancy that the language faculty exhibits. This characteristic of language has been mentioned in the previous chapter, and will be examined in more detail in section 4.8; the example given by Pinker and Bloom is the fact that both case affixes and linear order can equally (and often concurrently) indicate the semantic role relations that obtain between elements of the proposition.

4.3.2 *Pinker and Jackendoff*

Pinker & Jackendoff's (2005) arguments for a complex language faculty follow in a similar vein to that of Pinker and Bloom. A direct response to Hauser *et al.*'s (2002) paper, the central claim of Pinker and Jackendoff is that the language faculty in its narrow sense must be interpreted as complex and adaptive due to the vast number of heterogeneous elements, none of which can be attributed to Hauser, Chomsky and Fitch's proposed central recursive operation. A similar argument is proposed and extended in section 5.3; here, I will briefly examine the claim of complexity apart from any implications for recursion.

Complexity in this argument stems from the many co-adapted traits of language that the MP is claimed to omit from its remit of explanation. These include some which are better characterised as belonging to domains within the broad language faculty. However, Pinker and Jackendoff convincingly justify the complex view by appealing to components whose inclusion in the narrow language faculty would seem to be unequivocal. These include the large variety of rules of inflectional and derivational morphology, the 'surface semantics' of word order phenomena, such as topicalisation and focusing strategies, and the phrase structures required for modification[4]. A system that encompasses all these aspects of the grammar requires explanation beyond the simple atomic architecture supposed by minimalism.

Complexity through redundancy is also mentioned by Pinker and Jackendoff[5]. The examples employed in their argumentation include the redundancy of entries in the lexicon (Pinker & Jackendoff 2005:30), and the redundancy found in encoding semantics into words and sentences (*ibid*:29). Their most striking illustration of redundancy is the manner in which four different devices are available for conveying semantic relations - phrase structure, linear order, agreement and case - and the fact that more than one of these devices is often used concurrently.

[4] Seuren (2004), too, offers discussion of the many phenomena that the minimalist language faculty cannot account for due to its highly simple realisation: subject and predicate raising, copying phenomena, e.g. negative concord, conjunction reduction, cliticisation, quantifier floating, secondary case assignment, and more. Some further discussion of Seuren's criticisms of the MP can be found in chapter 6.

[5] As was noted above, redundancy has been and will be further discussed in more detail in other sections of this thesis. I will therefore refrain from elaborate discussion of Pinker and Jackendoff's particular examples.

4.3.3 Pre-Minimalist Chomsky

As has been pointed out before by others (e.g. Seuren (2004), Pinker & Jackendoff (2005)), it is interesting to observe the not infrequent remarks on the complexity of the language faculty in Chomsky's pre-minimalist work. From *Aspects of the Theory of Syntax* (Chomsky 1965a) through to *Language and Problems of Knowledge* (Chomsky 1988), the complexity and modularity of the language faculty is not simply acknowledged, but clearly forms the basis on which many of the ideas therein are predicated. The following selection of quotations, taken from work spanning over twenty years, illustrates the conception of the language faculty as a complex, intricate, and modular system, that is maintained during this period by Chomsky[6].

The *Aspects* model posits a syntactic component comprised of a base component plus a transformational component. In turn, the base component is defined as consisting of a categorial subcomponent, which is made up of a set of context-free rewrite rules, and a lexicon consisting of lexical entries and redundancy rules. The transformational component is posited to contain rules which translate deep structures into surface structures. This architecture, with its not insignificant number of rules belonging to different rule types, its built-in redundancy, and its various interacting components, provokes Chomsky to the conclusion that "...study of language is no different from empirical investigation of other complex phenomena" (Chomsky 1965a:4).

The story in *Reflections on Language* (Chomsky 1975b) is not much different. Here, the question is asked, based on the fact that "...human cognitive systems...prove to be no less marvellous and intricate than the physical structures that develop in the life of the organism": "[w]hy, then, should we not study the acquisition of a cognitive structure such as language more or less as we study some complex bodily organ?" (*ibid*:10). This cognitive system is here described as "...an intricate structure of specific rules and guiding principles..." (*ibid*:4), and the purpose of the work is detailed as "...to give some idea of the kinds of principles and the degree of complexity of structure that it seems plausible to

[6]In these earlier writings, Chomsky offers reflections on both complexity of language and complexity of the language faculty; the following quotation, for example, illustrating an observation of the first type. "A human language is a system of remarkable complexity." (Chomsky 1975b:4). Again, we must remember to take care not to confuse these.

assign to the language faculty as a species-specific genetically determined property" (*ibid*:79).

The era of GB theory brought a clear restructuring of the model of the language faculty. The traditional construction-driven grammar is replaced by one in which specific rules are eliminated in favour of simpler principles. However, these simpler principles derive from various different modules that the grammar is assumed to consist of. Thus, "[t]he full range of properties of some construction may often result from interaction of several components, its apparent complexity reducible to simple principles of separate subsystems" (Chomsky 1981:7)[7]. It is here that "[t]his modular character of the grammar..." (*ibid*) is first highlighted. Moreover, its contribution to the complexity of the language faculty is clearly articulated: "[t]hough the basic properties of each subsystem are quite simple in themselves, the interaction may be rather complex..." (*ibid*:344).

The modularity and complexity of the language faculty is further argued for and upheld in later writings. In *Knowledge of Language*, the system is referred to as "...a complex biological system..." (Chomsky 1986b:43-4), while *Language and Problems of Knowledge* suggests that the computations carried out by the (narrow) language faculty "...may be fairly intricate..." (Chomsky 1988:90).

It is only in the early 1990's - the beginning of minimalist thinking - that the Chomskyan view of the language faculty begins to shift significantly in its focus, highlighting simplicity rather than complexity as its defining property. In chapter 6, the specifics of the MP will be scrutinised once more. The key question of that chapter will be whether the language faculty under the minimalist view really is minimal. The conclusions drawn will reveal that the architectural framework of the MP shows significant complexity, emphasising the central claim of this chapter that a simple, atomic, economic language faculty is off-target.

4.3.4 Adaptive Complexity

The evolutionary implications of the current discussion are taken one step further by examining complexity in combination with another feature that language

[7]The use of the word *apparent* here suggests that the complexity may not be real; however, *apparent complexity* refers to the construction in question (an aspect of a particular language), rather than the language faculty itself. The language faculty's complexity is illustrated by the several components and their constituent principles which must interact to achieve the construction.

can be argued to possess - adaptiveness. Pinker & Bloom (1990:709) famously argued that "...natural selection is the only scientific explanation of adaptive complexity", where adaptive complexity is understood as describing "...any system composed of many interacting parts where the details of the parts' structure and arrangement suggest design to fulfil some function." In other words, if a system shows evidence of being complex, while at the same time showing evidence that this complexity is directly related to the job(s) that the system undertakes, then the only possible evolutionary path that the system could have taken is one of gradual adaptation by means of natural selection.

The preceding sections have outlined the evidence of complexity in language. In fact, it is precisely the complexities of section 4.3.1 that Pinker & Bloom use to illustrate that language shows evidence of the type of design that is confirmation of adaptive complexity. Thus, if the function of language is communication, and more specifically, communication of complex propositions through a serial medium in an efficient manner, the intricate structure of the language faculty including the above listed properties looks deliberate and rational. For example, differing lexical categories, supplemented by modifying elements serve to fulfil the function of distinguishing the types, and the particular instances, of entities and situations that one might need to communicate about. Rules of ordering and combination, and devices such as case, which reflect underlying semantic relations serve to fulfil the function of identifying the associations of entities in the proposition to each other. Anaphors and pronouns which obviate repetition, and control structures and complementisers which allow propositions to be combined, serve to fulfil the function of making communication as efficient as possible.

Language thus seems to be not simply complex, but adaptively complex. As "...adaptive complexity is the key reason why one should reject nongradual change as playing an important role within evolution...the only way for complex design to emerge [being] through a sequence of mutations with small effects" *(ibid:711)*, we are left with a compelling reason for assuming natural selection as a fundamental force in the evolution of the language faculty[8], and hence a rationale for coming down on the gradual adaptation side of the choice set at the end

[8]Although the stance taken by Pinker & Bloom strongly advocates gradual adaptation for language, there is a weaker position, where natural selection is the main, but not the only, process involved in the evolution of the language faculty, which is entirely compatible with the empirical facts. That is, while the particular features of language mentioned by Pinker & Bloom point to gradual adaptation, other features of the language faculty may have taken alternative paths.

of the last chapter.

To summarise, a view of the human (narrow) language faculty as highly complex and intricate is not without its advocates (which interestingly includes an earlier Chomsky). Without having to attach this judgement of what the language faculty might look like to any particular theoretical framework or architectural choices, discussion from the literature has provided evidence in favour of viewing language as both complex and adaptive. Later in this chapter, this complexity of the language faculty will be linked once more to the evolutionary questions we wish to answer, highlighting the compatibility of such a conception with the story from evolutionary biology. Before this, the next section will take a closer look at what we mean when we invoke the term *complexity* as defining the language faculty.

The point is that gradual adaptive processes cannot be ruled out *in toto* for the narrow language faculty.

4.4 Measuring Complexity

A crucial question arising out of the preceding discussions is how we measure complexity (or indeed simplicity). Foregoing argumentation has been based merely on the intuitions we hold as to what these terms connote. However, our investigation would profit from more explicit and exact scientific designations. Thus, questions such as the following need to be answered. What type of evaluating criteria should we employ in deciding if the language faculty is simple or complex? Does there exist a gradient scale ranging from simplicity to complexity? If so, where on the scale does the proposed language faculty change from being simple to being complex? In terms of the non-minimalist language faculty, how many modules means that the system is complex? If two posited modules were collapsed into one, would that be enough to make the faculty simple, or is the cut-off point lower? In terms of the minimalist language faculty, how many more operations or levels would need to be added in order to make the system complex? Is it the atomicity of the minimalist system that makes it simple, and the modularity of the non-minimalist system that makes it complex, or is there more involved?

Interestingly, we find in Chomsky's early work (Chomsky (1957), Chomsky (1965a)) evidence of related thinking. There, he proposes an evaluation metric for measuring the complexity of grammars. Later applied to phonology too (Chomsky & Halle 1968), the evaluation metric measured the naturalness of grammatical rules, and grammars more generally. A rule of a grammar was considered less natural, and hence more complex than another, if it needed a larger number of features of UG to express it. The metric was applied to the problem of language acquisition by assuming that the child chooses from among the set of possible grammars consistent with the data which he receives as input the one with the lowest evaluation measure. This idea is, of course, problematic for a number of reasons. As was soon noticed, naturalness could not be equated with complexity, as certain less natural processes could be expressed with only few feature symbols. This also meant that simply counting symbols would not suffice as a metric for explaining acquisition. The nature of the evaluation metric that the child uses thus became less and less clear. With the advent of the GB era, and a stronger focus than ever before on the problem of language acquisition, the evaluation metric disappeared entirely, taking with it any prospects for answers to the questions above in the generative literature[9].

Questions of the sort posed here have also been asked in relation to complexity in the language faculty itself (rather than in the rules of specific grammars), although the probing has perhaps not been so specific. Commentators on Pinker and Bloom's paper, for example (e.g. Lewontin (1990)), pick up on this very issue. However, it is not only in the domain of language that such questions need to be answered. We can equally ask questions along these lines about any system, natural or artificial. A recent upsurge in attempts to begin to untangle these issues has led to the emergence of an area of scientific research the specific concern of which is identifying the nature of complexity and systems to which this term can be applied - known as complexity theory or complex systems theory. The puzzles that complexity theorists work on are, however, currently far from resolution.

A related comment, concerning what it is that we are assuming needs to be measured, from an evolutionary perspective, is appropriate here. This discussion will be (mostly) concerned with the phenotypic complexity of the language faculty. An alternative question would be the level of genotypic complexity that the language faculty suggests. That is, is the amount of genotypic space that the language faculty takes up substantial or minimal? Are there very many or very few genes contributing to the structure and functioning of the language faculty? Presumably, if an exact answer could be given to the question of how many genes are involved, a measure of how complex or how simple this number is would not be beyond calculation[10]. Perhaps, for example, the measure could be determined by comparison of the relevant number of genes to the total number of genes involved in human cognition. Evolutionarily speaking, this question has obvious import. For example, if the genotypic complexity of the language faculty was found to be low, minimalist promotion of phenotypic simplicity, and the saltational evolutionary account which follows (see section 4.7 below for detailed discussion), would appear more credible. However, as will be examined briefly in section 4.7 below, the little we do know about the genes for language suggests that the genotypic complexity of the language faculty is more likely to be significant. Nevertheless, for definitive answers to this question, we

[9]See Boeckx & Hornstein (in press) for further discussion.

[10]However, even this calculation might not turn out to be as simple as it initially appears. Recall the observation of Maynard Smith & Szathmáry (1995) that calculating the complexity of an organism in terms of the DNA content of its genome reveals lilies and lungfish to be forty times as complex as humans, a result that certainly defies our (albeit anthropocentric) intuitions.

must wait for future research in the field of genetics to admit evolutionary linguists to a position where such genotypic complexity can be calculated.

4.4.1 Simplicity as Economy

Brighton (2003) equates simplicity with economy of the type spoken of in chapter 3. In section 3.3.2 the distinction between economy of statement and economy of process was introduced, and it was shown that minimalist theorising strives for both of these economies in a way that other approaches to the language faculty do not. In his discussion of simplicity as a guiding principle in language, Brighton uses the terms *explanatory simplicity* and *cognitive simplicity*. These are simply alternative aliases for the concepts we met earlier. The former is simplicity in the account given for some phenomenon; in other words, economy of statement. The latter is simplicity in the working of some system, in this case, specifically some cognitive system; or economy of process. To repeat an observation made in chapter 3, the simplicity or complexity of the language faculty that is in question in this chapter derives from both types of economy. We are concerned both with what the language faculty is made up of, i.e. levels of representation, categories and objects, rules and operations, etc. (its explanatory simplicity), and how it functions, i.e. whether there are functional redundancies, whether derivations are economic, etc. (its cognitive simplicity).

Brighton, sympathising with the minimalist point of view, suggests that "...the language faculty might be the smallest piece of biological machinery that meets the requirements of the interface conditions..." (Brighton 2003:99); in other words, suggesting that "...the language faculty could be the shortest program capable of transforming between PF and LF." (*ibid*)[11]. However, this proposal alone does not provide any evidence for taking on board the simplicity view. Even if the language faculty is the smallest possible piece of machinery, or, in computational terms, the shortest possible program capable of undertaking some job, this does not guarantee simplicity if the job to be undertaken is complex. In the same way that the minimalist's claim that the language faculty is the most parsimonious that it could be does not entail that it is necessarily simple, the smallest possible machinery could still be relatively complex[12]. These claims do not void the need

[11]See the discussion below of computational and informational complexity for the specifics of such a proposal.

[12]Note that this is a different point to that being made in this and earlier chapters of this thesis, that the MP is methodologically unsound. The issue here is whether the results of the methodology are a minimal, simple language faculty. This point will be returned to in chapter 6.

for some empirical measure of the level of complexity in the system.

4.4.2 Computational versus Informational Complexity

Two possible means of measuring complexity are discussed by Gell-Mann (1995). Computational complexity is measured by the time it would take a standard universal computer to perform the task in question. Informational complexity is measured in terms of the length of a message that can convey the relevant information. A number of issues arise from attempting to fit the language faculty to either of these measures.

Looking first at computational complexity, the initial question must be what the task to be undertaken is. Assume that we take the task to be that which the MP assigns to the language faculty[13]. Then, the computational complexity of the language faculty would be defined as the time it takes for a standard universal computer to create a mapping between signals and meanings. However, although this addresses the cognitive simplicity of the system, it has nothing to offer in measuring the explanatory simplicity of the system. That is, while there may be some way to determine how complex the functioning of the language faculty is, it is difficult to see how a computational procedure could assess how simple or complex the make-up of the system is. It can have little to say about whether the number of modules, rules, operations, objects, etc. is too few to be considered complex, or too many to be considered simple.

As noted above, although in general terms, economy of statement and economy of process are independent questions, both aspects must be attended to in determining where the language faculty sits on the simplicity-complexity scale. If the architecture of the faculty is simple (few components, limited levels of representation, etc.) yet its functioning is complex (vast redundancy, uneconomic derivations, etc.), can we truly characterise the system as simple? Conversely, if the faculty is architecturally complex (many components, various levels of representation, etc.) while being functionally simple (little interaction, no redundancy, economic derivations, etc.), is the system legitimately complex? It is the employment of the components of the system in its functioning that determines the level of complexity or simplicity involved. Thus, an atomically organised

[13] We make this assumption on the grounds that it is ultimately the MP that is under review in this thesis.

system which carries out its job by employing a single central operation in a non-redundant fashion is contrasted with a heterogeneous composite system whose interacting parts come together in intricate ways in order to achieve its function.

The pertinent question in terms of informational complexity is what the information to be encoded is. Again, the answer will be two-fold: both the structural details, and the functional details of the system. In contrast to computational complexity, informational complexity could provide us with a measure capable of telling us something about the structure of the language faculty. Without investigating the details of exactly how informational complexity might be applied to the system (an enterprise of considerable proportions, well outside the scope of this thesis), it is possible to imagine that a message could somehow be constructed to encode the architectural details of the language faculty. Turning to the functional details of the system, however, we come up against a problem similar to that posed by computational complexity. It is very difficult to clearly envisage how measuring complexity on an informational scale could be applied to the operation of the language faculty. Perhaps, as Brighton suggests, one could formulate a message which conveys the transformation between sound and meaning in some manner, but it is, at least intuitively, unclear as to how such a message would encode such aspects of the functional details as derivational paths, or the level of interaction of component parts.

It would appear, then, that both informational and computational complexity may be insufficient for measuring the two aspects of the language faculty that contribute to its complexity/simplicity, at least on an initial superficial consideration. A third possibility, combining aspects of computational and informational complexity is Kolmogorov complexity (see e.g. Li & Vitanyi (1997) for detailed discussion). The basic idea of Kolmogorov complexity is that the complexity of some object can be measured in terms of the length of the computer program which can output the object. The underlying theme of this measure of complexity is compression; the more random an object is, the less it can be compressed, hence the longer the program which outputs it will be, and thus, the more complex it is. But how can this complexity measure be applied to the language faculty? Again, the answer to this question is far from obvious, and a great deal more work would be required to even begin to establish any compatibility.

The difficulty and enormity of the problem of measuring complexity and simplicity is highlighted especially well within the domain of Kolmogorov complexity by the fact that the problem of computing the Kolmogorov complexity of any object is intractable (Chater 1999). That is, it is impossible to tell if the object in question is incompressible, and hence it is impossible to return an exact value for its complexity. Thus, although an elegant theory, Kolmogorov complexity can be utilised as a guiding principle only; it cannot be practically employed.

The point that the preceding discussion raises is this: nowhere in the literature, be it minimalist or anti-minimalist, are claims of simplicity or complexity of the language faculty accompanied by independently supported empirical measures. One of the reasons for this is the sheer difficulty of the problem. A definitive measure of complexity, applicable to various domains, is generally assumed to be beyond current scientific understanding. Thus, although the preceding sections have clarified what is intuitively simple about the minimalist language faculty, and what is intuitively complex about the non-minimalist language faculty, we are unfortunately left no closer to being able to evaluate these characteristics logically and accurately. Intuitions will have to suffice until endeavour in complexity theory advances.

4.5 The Direction of Evolution

Returning to the ultimate issue of this thesis - the evolutionary plausibility of the MP - we will now consider another hotly debated topic. The question is this: does evolution entail growth in complexity? That is, is there a general trend in evolution for systems to move from simple to complex? The stance taken here will be somewhat intermediary; as Maynard Smith & Szathmáry (1995:3) put it, the increase in complexity in evolution is "...neither universal nor inevitable." Nevertheless, the intuition that more complex systems and organisms have emerged later in the history of life is an assumption that is not unfounded. It will be seen that in certain types of systems as a result of certain types of factors, complexity is likely to increase. These very systems and factors will then be shown to be especially relevant to language, and it will be argued that the complexities of language discussed above are reasonable, and that the simple system of the minimalist is less so, given evolutionary trends.

As the discussion in the preceding section clearly illustrated, the issue of how to measure complexity is far from solved. This issue raises its head too in relation to the evolutionary question under consideration here. We must thus, as others have done, predicate our argumentation on certain intuitive assumptions, recognising of course, that future research may cast a different light on things. For now, we will go along with Maynard Smith & Szathmáry (1995:3) in supposing that "...there is surely some sense in which elephants and oak trees are more complex than bacteria, and bacteria than the first replicating molecules."

Evolution by means of natural selection is understood to be unpredictable, and more importantly, undirected. For this reason, it is impossible to argue that there is a single direction in which evolution moves. Unsurprisingly, therefore, we can find examples in the history of life of both simplifying and complexifying processes. The former is illustrated by parasitism. Parasites are not only simple organisms, they evolve from more complex free-living organisms (Gould 1996). The latter, by contrast, is evident in the evolution of eukaryotes. One of the *major transitions* (Maynard Smith & Szathmáry 1995), the development of multi-cellular organisms with a cell nucleus from the more simply structured prokaryote organism is incontrovertibly an increase in complexity. Thus, adaptation does not necessarily entail growth in complexity; that a system can be more adaptive than its predecessor owing to removal of some parts is just as likely as the opposite, as is evidenced by the regressive evolution of the eyes of cave dwelling animals (Jeffery & Martasian 1998).

Indeed, it seems that not only do both simplification and complexification take place during evolution, but that the two processes oscillate, and balance each other out. Arthur (1993:144) calls this a "...a slow back-and-forth dance...", reasoning that "...growing complexity is often followed by renewed simplicity..." (*ibid*) in an effort to streamline what has become too complex. Simplification is similarly followed by complexification in order to tackle additional problems that the environment poses. The example Arthur uses is not from the natural world, yet it is clear how the analogy could be applied to living organisms and the systems that they are composed of. The 1930's piston aeroengine was a complex machine, which was later simplified by Frank Whittle into the first turbojet engine, which was essentially composed of just one moving part. However, later complexification has resulted in the modern jet engine, which Arthur claims to consist of a massive 22,000 or more parts.

A drive towards complexity is thus not a given in evolution. In fact, the seemingly conflicting paths of simplification and complexification that the empirical facts demonstrate have caused many to puzzle over the question of whether evolution implies progression in complexity. The most prominent critic of this view is Stephen Jay Gould (others include D'Arcy Thompson (D'Arcy Thompson 1961) and George Williams (Williams 1966)). A representative advocate of the complexification view is Francis Heylighen (see also Saunders & Ho (1976) and Bonner (1988)). Even Darwin cannot be firmly placed on one side or the other, his work indicating his somewhat ambivalent assessment of the situation. In the following paragraphs, I will briefly review three of the main arguments made against complexification (taken from Gould (1996)), and answers to them (taken from Heylighen (1997)).

The first argument that the anti-complexificationist, as we might call him, often advances is simply that because simplification processes also take place in evolution, there cannot be a complexity-driven direction. This reasoning is easily countered in a number of ways. For one, simplification can be interpreted as merely a streamlining process. In other words, while complexification changes the behaviour of the system, simplification (in most cases) does not. So, while some complexification process that added structure might allow the organism to carry out a new function, a process which removed structure that had already become redundant in the organism would not change its functioning to the same degree. That is, simplification is fundamentally less extreme, and affects the contour of the history of life in a lesser way than does complexification. A second comeback to the claim is that simplification seems to be rarer than complexification overall. Systems become simpler most commonly when their environments become simpler, but it is more usual for environmental pressures to increase rather than decrease. So, although simplification cannot be denied, it should not be placed on a par with complexification in the overall picture.

A second claim seen in Gould's anti-complexification book is that complexity has grown only because life began simply. That is, due to chemical and physical constraints, the first examples of life were extremely simple. As a result, the only direction available for evolution to move in was towards complexity. Gould illustrates this point by analogy. On exiting a bar, a drunkard begins to stagger along the footpath with the bar to his left and the gutter to his right. Given that the drunkard will stagger randomly, and assuming he staggers for an unlimited amount of time, he will always end up in the gutter. The reason for this is that the bar on his left blocks him from staggering further in this direction, while there is no such barrier on the right. As Gould (1996:150) puts it: "...only one direction of movement remains open for continuous advance - toward the gutter."

Again, there are two issues with this argumentation that are relevant here. Firstly, we are not primarily concerned with the reason that complexity increases in evolution, just with whether or not it does. So, if more complex systems arise merely as a side-effect of where life began, this does not affect the broader point that there is a general trend towards more complex systems.

Gould takes his point further by noting that simple systems and organisms strikingly outnumber complex ones; bacteria are vastly more common than *Homo sapiens*, for example. However, as Heylighen points out, this fact is unsurprising given a growth in complexity. More complex systems are built out of simpler ones; thus, simpler systems must have prior presence. Moreover, more complex systems will be built out of numerous simpler ones; thus, the outnumbering of complex systems by simpler ones is merely a side-effect of complexification.

The final point to be considered here has been mentioned briefly already: evolution is undirected. Therefore, the anti-complexificationist argues, there can be no trend toward complexity as this would imply a progression or advance of some sort. Once more, a counter claim can be mounted. Heylighen carefully illustrates why there is no contradiction between a growth in complexity and undirected evolution. The reasoning goes as follows: absolute and relative fitness both increase in evolutionary time, where the former is understood as an internal or intrinsic characteristic - the inherent ability to reproduce - and the latter is understood as determined by external factors - the ability to deal with the environment. While relative fitness is subject to environmental changes, and thus cannot be considered as an overall increasing property, absolute fitness can. As Heylighen (1997:) remarks: "[a]ll other things being equal, a system that can survive situations A, B and C, is *absolutely* fitter than a system that can only survive A and B." Crucially, Heylighen argues, an increase in absolute fitness requires an increase in complexity (of both the structural and functional kinds). In other words, a system able to deal with situations A, B and C is functionally more complex than one that can deal only with A and B[14]. Functional complexification often entails structural complexification, as additional parts may often be required to carry out additional tasks. Thus, although the path taken to greater complexity is random and undirected, the general trend does not contravene what we know of evolution.

The issue of directionality and progress in evolution involves many more controversies than those examined here. However, these few claims emphasise clearly the difficulty of the problem. Nevertheless, the overall message that appears from these discussions is that complexity does grow over evolutionary time. It is not the only direction that evolution can move in, but it is the more typical one.

Two further questions deserve consideration. The first is why complexification happens in the course of evolution. Gould's reasoning of it being a mere side-effect of where life began was noted above, but are there more direct accounts? The second is what types of systems complexify. We know that simplification happens when environments become less complex, or when parasitism would be advantageous, but is there some generalisation we can make about the types of systems that become more complex? Answering this latter question will

[14]It is not necessarily the case that an increase in absolute fitness always entails a growth of complexity. For example, it is true that an organism that can climb over a five metre high obstacle to escape a predator is absolutely fitter than one that can only climb over a two meter high obstacle, but there is no sense in which the first organism is more complex than the second; it is merely stronger, or has more stamina. That said, that Heylighen's assumption will hold in many but not all instances does not detract from his general point that growth in complexity and undirected evolution are not incompatible.

be deferred to the next section.

One suggested reason for an increase in complexity over evolutionary time is van Valen's Red Queen Principle (van Valen 1973). The hypothesis is this: systems or organisms do not always evolve in an entirely independent manner. Often, the development of some organism both affects and depends on the development of another (or multiple others); this is termed co-evolution. When this happens, even a very small increase in complexity in one system can quickly occasion further complexification in all co-evolving systems in a type of complexity arms race. If one system becomes slightly more complex, other systems which rely on it or access it in some way will need to increase their complexity in order to keep up. In turn, complexification in these systems will force the first system to further complexify, and so on. The same co-evolutionary complexification may take place between systems which do not interact, but which compete with each other in some manner. An analogy from economics makes this clear; in the modern technological marketplace, growth in the functional complexity of company X's product means that its competitors must also enhance their products if they are to survive.

What the Red Queen Principle does not claim is that complexity will increase constantly or infinitely. Once systems reach some trade-off point where their environment (in the form of co-evolving systems) no longer imposes a requirement for complexification, their levels of complexity may plateau. This is one way of explaining why there continue to exist many simple forms of life (such as viruses) as well as more complex ones, without having to deny complexification as a prevalent process in evolution.

4.5.1 The Direction of Linguistic Evolution

The intuitive characterisation of complexity that we came to in section 4.4 above corresponds well with both the Latin *complexus* - which signifies being entwined or twisted together - and the Oxford English Dictionary's definition of a complex object as something "...made of (usually several) closely connected parts" (cited in Heylighen (1997)). We have further noted that evolution typically results in systems that have taken on this more complex nature over time. The question now is whether language is one of these typical systems.

The MP presents a picture of the language faculty as highly simplified, yet others argue that it is far more complex than this. In order to uphold this anti-minimalist claim of complexity, we must back it up with confirmation that such complexity is evolutionarily plausible. So, we return to the second question posed at the end of the previous section - in what types of systems, or indeed in what types of circumstances, do we find complexification?

A first answer, as described above, is that systems which co-evolve with other complexifying systems are likely also to become more complex. Applied to language, we might ask what other systems language might have co-evolved with that would have driven its complexity quotient up. Received wisdom indicates that the most likely candidate is the human brain itself. Deacon's (1997) book, whose subtitle - *The Co-evolution of Language and the Brain* - reflects this hypothesis, maintains that development of the prefrontal cortex of the human brain, and development of the language faculty were intimately linked; the former providing the neural machinery, and the latter, the linguistic machinery, for symbolic reference. Dunbar (1993), too, advances a co-evolutionary story for language and the brain (albeit of an entirely different nature). An alternative co-evolving system is suggested in many of the papers of the conference entitled *Issues in Coevolution of Language and Theory of Mind*. As the moderators observe, "[a] possibility...is that language and the theory of mind have coevolved..." (Dominey & Reboul 2004)[15].

Arthur (1993:144) provides another answer to the question of where we find complexification which can be related to language. He suggests that "...there is a general law: complexity tends to increase as functions and modifications are added to a system to break through limitations, handle exceptional circumstances or adapt to a world itself more complex". Not only technology and scientific theories undergo this process, but also biological organisms. The language faculty might reasonably be thought of as a biological system which has complexified in this manner. Numerous accounts of the evolution of language are compatible with this proposal. To take one example, Newmeyer (2004) hypothesises that grammars have both cognitive and communicative bases. His thesis proposes that language began as a cognitively determined system, and later

[15] Chapter 5 will examine the relation of language and theory of mind more closely; it is enough here to notice that it represents one possible co-evolutionary relationship leading to the complexification of the language faculty.

was enhanced for the purposes of communication. The cognitive features of language are unlearnable, and thus universal, with the communicative features being learnable, and historical in nature. Such an account is clearly consonant with Arthur's suggestion of complexification. That is, the addition of communicative characteristics such as phonology, grammatical agreement, and word order phenomena, to the already existing cognitive properties such as argument structure and recursion, reflects an increase in function resulting from the pressures of a more complex world.

This section has investigated the question of complexity-driven evolution, concluding that although evolution is undirected, and both simplification and complexification are possible, the circumstances that organisms and systems find themselves in means that there does exist a complexity bias. Complexity will increase in a system forced by its environment to reach beyond the confines it currently inhabits. While complexification may be particularly driven from a functional perspective, structural complexification often accompanies it. Finally, we began the examination of the plausibility of a minimalist language faculty, given the implications of the evolutionary wisdom gathered, an inquiry which will be continued in the following section by focusing on the methodological strategies of the minimalist theorist.

4.6 Minimalist Methodology

We have seen in the preceding chapters that the driving force of minimalist studies is to elucidate a system which shows perfection in its design, where perfection is interpreted as economy both in the architecture and in the functioning of the system. In assuming this fundamental tenet, a methodological decision has been made as to how to drive the theory: "[w]ith at least a general picture of what a genuine theory of language might be like, we can contemplate some more principled questions about its nature. In particular, we can ask how 'economical' is the design of language. How 'perfect' is language, to put it more picturesquely?" (Chomsky 1998:118).

In the early nineties, when the MP emerged as the new embodiment of generative syntactic theory, Chomsky chose to drive the theory in a certain way. Choosing to formulate a model of the system which holds at its core the importance of economy and optimality is just one choice that could have been made as to how to constrain the theory of language. This decision was not based on empirical facts, but was a decision of methodology, a decision as to how the body of practices, procedures, and rules to be used by minimalists would be motivated and delimited.

In linguistics, the theory is always underdetermined by the data, and as such, something outside the empirical facts must be used to constrain the theory. Thus, it is not the making of a methodological decision *per se* that is problematic; such decisions are required in order to forge forward with a theory of language. What is problematic, however, is the particular decision that was taken. The decision to follow guidelines of perfection, optimality, and economy immediately rule out a theory of the evolution of the language faculty from a gradual adaptationist perspective, by virtue of the fact that an optimal, economic, perfect system is too atomic and undecomposable to be able to follow such an evolutionary path. In the sections that follow, the methodological choices that have led minimalists to the simple, atomic system they favour will be examined in more detail. The appropriateness of these choices to the evolutionary question will then be challenged.

4.6.1 Economy as a Constraint on Theories of Language

In the introductory chapter of this thesis, a number of possible constraining factors on theories of language were listed. We might, for example, wish our theory of language to account for the fact that the same language faculty underpins the very many different languages that are spoken (considerations of cross-linguistic variation). Alternatively, we might want to constrain our theory by drawing on the evidence for how the brain deals with language (considerations of neurological plausibility). Or, we might choose to base our theory on the facts of language acquisition (considerations of learnability). The central question of this thesis is concerned with two other such constraints. The minimalist constraint of perfection restricts our theories of language to those that strictly curtail the architectural organisation and the functional operations of the system. The constraint of evolvability restricts our theories of language to those that fit with the empirical and theoretical information provided to us by work in evolutionary biology.

The problem is that these are incompatible constraints. As noted, it may be difficult to construct a theory of language (or of any other complex system for that matter) that would conform to all possible relevant constraints[16]. Indeed, this is the reason that we find in the broad domain of linguistics very many subdisciplines, each with their own particular focus or constraint. Nevertheless, this does not mean that our theory of language should be so focused on one aspect that it ignores all others completely. That is, we should be able to recognise that a theory is flawed based on insights from other constraining factors.

A priori, economy appears a reasonable constraining factor to invoke in theorising on language. Both history[17] and intuition indicate that following Occam's razor will yield reasonable results. Yet when we look deeper, we discover that this constraint is only *economy of statement*, and the *economy of process* that the minimalist view appeals to with greater force does not deserve the same indulgence. That is, using perfection as a constraint on language theorising does not seem reasonable either *a priori* or *a posteriori*. In comparison to the other possible constraints listed in chapter 1, there is no external motivation for assumptions of perfection in the language faculty, or indeed in any system of the mind.

More importantly - and here is the crux of the matter - the constraint of perfection becomes even less reasonable when the question of the origins of language is taken into account. As chapter 3 comprehensively demonstrated, perfection is not a feature that we should expect to find in biological systems that emerge

[16]Although, this is, of course, the ultimate goal in any scientific field.

[17]For example, it is argued that the Copernican heliocentric theory of celestial mechanisms was chosen over Ptolemy's geocentric theory for reasons of parsimony. See e.g. Dreyer (1967).

and evolve through the usual processes of natural selection. Thus, the constraint imposed on minimalist theories of language takes no heed of the constraint that evolutionary linguists impose on theories of language. As the following section will show, we can go so far as to say that minimalists ignore the facts of evolution in their supposition of a simple, perfect system. This fact makes the minimalist constraint of economy and perfection not only arbitrary, but also ill-judged.

4.6.2 The Galilean Style

The methodological decision that Chomsky has taken is to formulate a theory that insists on a perfect, economic, optimal system. The methodological policy he has followed in order to accomplish this is what he terms the Galilean style. The term *Galilean style* is attributed by both Chomsky and Weinberg (1976) to Husserl (Husserl 1970). Indeed, many others - e.g. Cohen (1982), Crombie (1981), and Wisan (1981) - have spoken of this approach to the scientific enterprise, although they do not use the same term, the first in fact referring to it as the Newtonian style, the last dubbing Galileo's methods "a new scientific style". The Galilean style refers to the approach of Galilean-Newtonian physics; that is, abstraction away from the world of sense perceptions to mathematical models of how the world works. Essentially, the Galilean style says that we should set out the theory, and ignore any data which appear to refute the theory. As Chomsky (2002b:99) puts it: "...the abstract systems that you are constructing...are really the truth; the array of phenomena is some distortion of the truth."

This manner of theorising is attributed to Galileo due to his focus on understanding rather than mere description[18]. Galileo was concerned with achieving an understanding of what he saw as a 'perfect' universe through creating a machine which would duplicate it. When it became clear that such understanding was beyond the capabilities of that time, Galileo did not retreat to the comfort of simple descriptive science, but instead concentrated on achieving understanding of the parts of the universe that he could. Although this enterprise permitted Galileo to achieve a deeper penetration of certain scientific mysteries, this came at the price of having to sideline other questions and exceptions to the rules. For example, although he favoured Copernicus's theory of the rotation of the earth, Galileo could not explain why this rotation did not cause bodies to fly off the planet. He had simply to wait for later discoveries to solve this problem. Thus,

[18]See Weinberg (1976) for further discussion of (and references to) Galileo's style of doing science.

the Galilean style involves disregarding certain facts in order to come to a better understanding of part of a system, when understanding of the entire system is not a possibility. Newton (1704) put it like this: "[t]o explain all nature is too difficult a task for any one man or any one age. 'Tis much better to do a little with certainty and leave the rest for others that come after you." Over a century later, Hume (1841) echoed his sentiment: "[n]ature is not intelligible to us, and we have to lower our sights."

This seems like a sensible approach to a certain extent. As was mentioned above, it is difficult to imagine being able to devise a reasonable theory of any highly complex system which will account for all the pertinent aspects of its workings. Indeed, in a number of disciplines, the Galilean style is a well-respected way to do science. In the field of cosmology, for example, the existence of so-called *dark matter* - particles whose existence cannot be detected in the normal way by radiation, but has been established through their gravitational effects - presents numerous puzzles currently occupying physicists. Nevertheless, putting this lack of understanding to one side did not prevent discovery of the expansion of the universe[19]. In eighteenth and nineteenth century mathematics, prominent mathematicians such as Gauss and Euler followed this same scientific reasoning in ignoring the problems thrown up by Newtonian calculus (Chomsky 2002b).

It would consequently seem that we should apply the Galilean style to a certain degree no matter what our object of inquiry. However, in doing so, we should be careful about choosing the data that we disregard. It is the particular data that minimalism chooses to dismiss that causes concern. The data Chomsky chose to ignore in formulating the MP are the facts of evolution. The fact that there is an overwhelming bias towards imperfection in nature - highlighted in chapter 3 through numerous examples of redundancies, vestiges and inefficiencies - is ignored under the minimalist view. The fact that there is a general trend in evolution towards more complex rather than more simple systems - discussed in section 4.5 - is ignored under the minimalist view. The fact that evolvable systems exhibit the key characteristics of degeneracy, modularity, and robustness - to be discussed in section 4.8 - is ignored under the minimalist view. Chater (1999:275), although not addressing minimalism specifically, could not have been more on the mark when noting that the resolute drive for perfection in a theory may often cloud judgement: "[t]his preference for simplicity (or more

[19]See Krauss (1989) for an introduction to dark matter.

generally, beauty) is sometimes expressed so strongly that it even overrides the concern to fit the data."

In electing to promote perfection and economy as the defining constraints of the theory, and thus choosing to ignore the empirical facts of evolutionary biology, Chomsky has driven the minimalist system of language too far from being evolvable. By pursuing the Galilean style in this particular manner, minimalism paints a picture of a system which appears a better fit to the physical rather than the biological sciences. In the next section, this dichotomy will be explored further.

4.6.3 Physics versus Biology

Sterelny & Griffiths (1999:220) distinguish the domains of biology and physics with the observation that "...biology studies the products of natural selection, while physics does not." Clear arguments have been presented in the preceding sections and chapters (and will follow in the remainder of this chapter) which indicate that the language faculty that minimalism endorses is unlike any other product of natural selection found in the biological world. Instead, the minimalist language faculty has been more aptly compared to systems and organisms which have arisen in nature as the result of physical laws and processes.

Section 3.5.2 introduced the cases of Fibonacci patterns in phyllotaxis, the eye spots of the peacock's tail, the hexagonal organisation of the honeycomb, and the symmetrical prism of the snow crystal, as examples of simplicity and economy of design, and functional perfection in the natural world. The minimalist language faculty is comparable to these systems in a number of key details: (1) the minimalist language faculty is a natural, rather than an artificial, entity, (2) the minimalist language faculty exhibits no redundancy, (3) the minimalist language faculty is elegant and simple in its design, (4) the minimalist language faculty is the optimal solution to a particular problem. The evolutionary explanations of these systems derive from laws of growth and form, from considerations such as temperature, humidity, and geometry, from processes of self-organisation, emergence, or exaptation. The gradual adaptive processes of natural selection do not enter into the equation. The analogy drawn between the minimalist language faculty and such systems is further perpetuated with claims (differing only in their levels of overtness) of evolutionary explanations of this same kind for language:

> "There is no strong reason to believe that a biological system should be well-designed in anything like this sense." (Chomsky 1998:119)
>
> "...human language hasn't really evolved... As an exaptation, however, it can certainly emerge (as a singular epiphenomenon of a brain that got large enough for some obscure and/or trivial reason)." (Uriagereka 1998:67-8)
>
> "...perhaps these [digitality and infiniteness] are simply emergent properties of a brain that reaches a certain level of complexity under the specific conditions of human evolution." (Chomsky 1991a:50)
>
> "It is possible that what happened is... the brain was exploding for a million years, ... and at some stage some slight change may have taken place and the brain was reorganized to incorporate a language faculty... That would be like angelfish stripes, polyhedral shells, etc." (Chomsky 2002b:148-9)

So, the minimalist views language as being a system which has arisen by non-adaptive means. Yet minimalists do still hold that the language faculty is a biological entity. The nativist doctrine of innate biological machinery underlying human linguistic capacities is of equivalent foundational importance to the MP as to earlier generative theories. Thus, the minimalist believes the language faculty to be a biological endowment which has feasibly arisen by non-adaptive means due to its atomicity and perfection. The question is whether this is a plausible view to take. If minimalism were indeed correct in its assumptions of an atomic, economical system, then this possibility could not be immediately ruled out. However, one central theme has already been developed, and another will follow in section 4.8, which counter these minimalist postulates.

Firstly, language is not simple (see section 4.3 above). That is, the narrow language faculty, when not viewed through the constraining lens of any particular theory (minimalist and non-minimalist alike), manifests considerable indicia of complexity. A myriad of elaborately connected rules, pressures, and stipulations belie the simple atomicity of the minimalist system. In section 4.8 below, this claim will be further buttressed with an elaborated argument for modularity in the system. Secondly, as has been briefly mentioned in section 4.3 above, and will be fully developed in section 4.8 below, language is not perfect. That is, the narrow faculty of language exhibits not insignificant levels of degeneracy and redundancy, properties which are attributable to evolvable systems, and which strongly challenge the central tenet of minimalist theorising. Thus, it is far from clear that the minimalist delineation of the language faculty is accurate, making it difficult to uphold the hypothesis that the system arose in our species by the type of non-adaptive means normally reserved for the physical sciences.

Language is a system that is grounded in biology. As a biological endowment in our species, it hence must have evolved over a particular timescale, and in particular steps, as with our other biological endowments. The methodological decision that Chomsky has made in adopting the Galilean style, and in particular, in disregarding the facts of evolution, does not allow for this conception of language. Instead, it forces language to be a system quite divorced from other biological systems. From an evolutionary perspective then, the methodological path taken by the minimalist is beset with serious contentions. A further contention will be the subject of section 4.7. The final quotation of Chomsky's given above suggests that the evolution of the human language faculty may have taken place in one sudden step. This is implicative of a saltational evolutionary account. Section 4.7 will address the MP's implication of saltationism, yielding one more incompatibility of the economy and evolutionary constraints on theories of language[20].

[20]Of course, if one were to begin the argument at the other end, and propose a saltational account for language, then the minimalist methodology would appear to be sensible, as it would give the smallest amount of material to have to explain. However, as chapter 6 will outline, the minimalist language faculty may not be that minimal after all, demeriting the compatibility.

4.7 Minimalism and Saltationism

The MP posits a system of language which is minimal in both its computational and its representational complexity. In minimising the system in this way, language as viewed in this framework becomes less plausible from a gradual adaptationist evolutionary perspective. In fact, in reducing any system down further and further in this way, all that would seem to be left available to us, in evolutionary terms, is a saltational story; that is, an account which promotes emergence of the particular trait in one sudden leap. The simple, perfect minimalist language faculty does not warrant a gradual evolutionary account involving numerous small steps, each adding another part to the mosaic. In fact, its limited machinery makes the MP not simply unamenable to, but clearly antithetical to such an account. If language were to turn out to be as simple and economic as the MP predicts, then a small genetic change might have been enough to provide humans with the capacity. However, the evidence has been shown to point to the fact that language is really not that simple. The more complex, intricate non-minimalist language faculty, however, contradicts any saltational story.

The main question to be addressed in this section is what exactly saltation refers to in evolutionary theory. This entails many sub-questions, including: is saltationism a reasonable, plausible evolutionary process on its own terms? If yes, why is it not a reasonable, plausible evolutionary process for a complex language faculty? Does this fact then immediately rule out the MP as a theory of language, or is there any alternative evolutionary possibility to reconcile the MP with?

4.7.1 Types of Saltationism

From Latin *saltare* meaning *to leap*, a saltation is a single mutation that changes the phenotype of an organism in some radical way. In the case of the narrow language faculty, a saltational view would suppose that one genetic mutation was responsible for the emergence of the entire complex (however small or large that is assumed to be) of features, properties, and operations underlying our syntactic capabilities.

In tackling the questions posed above, an important distinction discussed by Dawkins (1983) is crucial. Dawkins draws our attention to a confusion that often arises in considering saltations in evolution, and that is that there are two different types of saltation. Using an analogy from aeronautics, he terms them

747 and Stretched-DC8. The former denotes a jump of considerable proportions, involving not just changes in magnitude of some biological property, but a large change in information content - like the metaphor of a Boeing 747 created by a tornado blowing through a junkyard (Hoyle & Wickramasinghe 1981). The latter involves a change only in the amount of some biological property; like the creation of a Stretched DC-8 from the existing DC-8 airliner, simply by elongating the fuselage. An example of the former type of saltation might be if some organism with no eye at all developed an eye in one generation. However, an example of the latter type of saltation might be if an organism developed an *extra* eye, the previous generation already having at least one, or the development of extra body segments by means of Hox genes in the evolution of both human and non-human (e.g. arthropod) limbs (see e.g. Tabin (1992), Hughes & Kaufman (2002)). While the latter cases involve simply an increase in magnitude, the information required already being present in the organism, the first involves this completely new adaptive information arising in one step[21].

It should be obvious that only the second type of saltation is plausible in evolution. The 747 type of saltation is unreasonable in any circumstances - close to miraculous - for it assumes an enormous upsurge in complexity in one go. So, although many types of changes in evolution may at first appear to constitute 747 saltations (e.g. a *Drosophila* growing a leg where it should have an antenna (Dawkins 1983)), closer inspection will reveal the prior information that forces a Stretched-DC8 saltation reading. We should thus be immediately able to rule out 747 type saltation for language. If language were to be as atomic as suggested by minimalism, then the only type of saltation that we could propose for its emergence would be a change in magnitude of adaptive information only.

However, while we should have no difficulty with saltation *per se*, no matter how we define saltation there is a problem reconciling it with a complex system such as language. There is both a theoretical and an empirical argument relevant here. The theoretical argument is familiar at this point; the narrow language faculty is more complex, more intricate, more modular, and more redundant than minimalism supposes. Given the presented perspicuity of this complexity, it is then very difficult to see how language could be simply an increase in biological

[21]This raises the point that a minimalist language faculty might be a more reasonable suggestion should we be able to show that the elements it consists of were all present elsewhere in cognition in our non-linguistic ancestors. However, as chapter 5 will illustrate, there appear to be features of the narrow language faculty which are not to be found in other cognitive domains; no work currently exists which can reduce these properties to those outside language.

information that is already available in the organism.

The empirical argument comes from the burgeoning field of genetics. Recent evidence suggests that language is underpinned by not one, but multiple genes acting in combination. Lai *et al.* (2001) report on three generations of a family who suffer from specific speech and language impairment (SLI). They have identified a point mutation in a specific gene - FOXP2 - which appears to be responsible for the deficiencies suffered. The members of the family with the mutated version of the gene exhibit a number of problems which appear unrelated: they are unable to use grammatical features such as tense and agreement inflections, they have difficulties in speech production and imitation, they struggle with general (non-linguistic) orofacial movements, and they show problems in picture naming, in word recognition tasks, and in grammatical comprehension. The fact that their difficulties are in both domains of comprehension and production rule out many other possible explanations (such as indirect consequences of speech impairment, for example).

It seems then that FOXP2 exhibits a good deal of pleiotropy (where pleiotropy is understood as the ability of a single gene to affect multiple phenotypic traits). While some of the deficits clearly fall into the narrow interpretation of the language faculty, others belong in the broad faculty, even in systems beyond that. This evidence has a number of consequent implications which impinge on the saltational view that the MP suggests. Firstly, the multiple and wide-ranging effects of the aberrant FOXP2 gene point to the fact that language is a complex web of interwoven, yet distinct parts, rather than the atomic undecomposable unit of minimalism, further discrediting not just the minimalist view, but the evolutionary account which it requires. Secondly, FOXP2 is a gene that is responsible for switching on other genes (a forkhead, transcription factor[22]). This means that the difficulties suffered by those with the mutated version of the gene could be the result of FOXP2 not being able to switch on few other genes, or equally many other genes, but importantly, language is not controlled by one single gene. If the language faculty has complex genetic underpinnings, we might wonder how one single mutation could have yielded it. Thirdly, the FOXP2 gene is not human-specific (although the human allele is), but is found in species as distantly related from us as mice and yeast (Marcus & Fisher 2003). This suggests that if species without language capabilities also have the gene, its responsibilities must extend

[22]See Granadino *et al.* (2000) for explanation.

to non-linguistic domains too. If this is indeed the case, it simply highlights the gene's pleiotropy, and the fact that this pleiotropy is not confined to one cognitive domain. This, in turn, suggests that there may be a great deal of such pleiotropy at work in the genes for language, and if this is correct, not just the broad language faculty, but the narrow language faculty too, is likely to be controlled by many genes indeed.

An interesting proposal put forward by Worden (1995) appears at first glance to stand in opposition to this assumption. Using a mathematical model, Worden calculates what he calls a 'speed limit' for evolution. That is, the maximum amount of genetic information that could possibly differ between humans and our primate ancestors, given that the rate at which the phenotype evolves is dependent on the strength of selection on particular traits, and the fact that selection pressures are subject to limitations. Arriving at a rate of only a few bits per generation, Worden proposes that the total difference between human and chimpanzee brains cannot amount to more than 5KB of genetic design information. This, it is argued, cannot be enough to code the entire language faculty, so the conclusion is drawn that much of the language faculty must be composed of genetic material that our ancestors use elsewhere in cognition.

If we then suppose that this shared genetic information is responsible for the broad language faculty (excluding FLN), does this leave enough additional genetic information to maintain the anti-saltational line for the narrow language faculty? The answer to this question bears on a point made earlier in this section of the chapter. If saltation cannot be interpreted as the introduction of entirely new genetic material in the organism, then even 5KB is enough to rule it out. Thus, although Worden's findings intimate that the estimation driven by the FOXP2 findings might not be accurate, a saltational evolutionary account for the narrow language faculty remains implausible.

It is important to remember that modelling and calculating genetic differences in this way is far from an established and accepted scientific method, and advances in the field of genetics are likely to cast new light on Worden's results. For example, it is not clear from Worden's presentation whether the genetic information in question includes genes of the FOXP2 type, which switch on other genes, which would complicate the picture somewhat. That is to say, there is as yet no definitive answer to how complex the genotype of the language faculty is. Nevertheless, the current evidence clearly reinforces the conceptual difficulty of a saltational account, putting the minimalist perspective on an even weaker footing.

4.7.2 An 'Apoptotic' Explanation

It has been shown that the saltational story compatible with minimalism suffers from a number of flaws. Certain of these flaws have shown the minimalist thesis itself to be implausible. However, before prematurely closing the debate, let us ask if there is any other evolutionary possibility that the MP leaves open. It turns out that there is one; what we might call an 'apoptotic' account, drawing an analogy with the developmental process of apoptosis (mentioned briefly in section 4.5 in relation to cave-dwelling animals).

Apoptosis is a streamlining or sculpting mechanism which allows more simplified organisms and systems to be fashioned from more complex ones. Also known as *programmed cell death*, apoptosis is the process by which cells 'commit suicide' (as opposed to necrosis where injury causes cell death). Cells are systematically killed off during the development of human fingers and toes; the tissue between them is removed in order that separated digits can form. In the development of the frog, the tail of the tadpole contracts on its metamorphosis by means of apoptosis. A further example is the resorption of eye cells in animals living in dark caves where vision is of no use (Jeffery & Martasian 1998).

An 'apoptotic' account[23] recognises the possibility that natural selection may remove properties of a system just as it may add new ones. This type of account for the narrow human language faculty would hypothesise that our current syntactic capacities are a streamlined version of what our ancestors may have possessed. That is to say, earlier stages in the evolution of language may have been characterised by greater inefficiency, and greater confusion; the earlier language faculty would have been a good deal more chaotic. The system would then have been stripped down to remove such inefficiencies and unnecessities. The minimalist might extend the argument with the supposition that the system that emerged from these 'apoptotic' processes was thus more economic, simpler, plausibly atomic, and as a result, perfect.

[23] Apoptosis is a process that occurs in ontogenetic development rather than phylogenetic development. Thus the account here does not suppose a literal reading of the term; in other words, it does not place cell death at the centre of linguistic evolution. The inverted commas indicate that it is simply an analogy.

The question is how reasonable an account this is for language; how could such a stripping back process emerge and proceed? A possible suggestion is that it could be driven by Baldwinian evolution (Baldwin 1896). The Baldwin Effect refers to selection for learning ability; in other words, while parents cannot pass on their acquired phenotypic traits to their offspring genetically, they can pass on genetically an ability to learn such traits[24] [25]. The proposal for an 'apoptotic' account of the evolution of the language faculty would then look something like the following. An initial state of randomness and disorganisation in the language faculty would get refined through experience to produce a more useful, less chaotic (and eventually, atomic and perfect, according to minimalists) system. The process would begin with a small number of language users employing their language faculty in such a way as to increase efficiency (by choosing, for example, less complex structures to express some meaning, or by employing fewer operations in the creation of the mapping). The ability to learn to factor out the complexities and redundancies of the language faculty would then be selected for, given the advantages that a more efficient system would bestow. Randomness and complexity would decrease exponentially, eliminating all that is not conceptually necessary, given that fitter individuals (those better at maximising efficiency) produce more offspring.

This story has as an advantage that it is gradual in nature; there is no sense of conceptually difficult saltations. In terms of compatibility with the MP, this would thus appear to be a feasible alternative to saltation. However, concerns also arise, even at this very unelaborated stage. For one, the manner in which the initial complex, disorganised, chaotic language faculty emerges remains unclear. A further issue is whether apoptosis (and the analogous Baldwinian processes for language) really does result in perfect systems. Although the answer to this hinges directly on the controversial interpretation of perfection, taking the understanding developed in the preceding chapter, perfection can only be attained through apoptosis if both the function of the cells in question, and the structural product of the cells are removed. Heylighen (1997) argues that in the case of cave-dwelling fish, "...we see that the material infrastructure of the fish's eye is still mostly there, it just does not work anymore." Yamamoto & Jeffery (2000) confirm that although there is reduction in the structure of the cave fish's eye,

[24]See Deacon (1997) and Yamauchi (2004) for discussion of Baldwinian language evolution.

[25]One suggestion of Baldwinian evolution of a non-linguistic nature is the emergence in certain adult human populations of lactose tolerance, which is argued to have been triggered by an increase in dairy farming (Deacon 1997)

there is not a complete loss. In other words, there is functional but not structural dissolution, and thus, functional but not structural perfection, as inefficiency remains in this latter realm. If both structurally and functionally apoptosis (or its relevant counterpart processes) brought about the elimination of all redundancy, it might constitute a better fit for the minimalist's evolutionary demands.

Despite this, the fact remains that even if 'apoptosis' is a plausible evolutionary scenario for the minimalist language faculty, the empirical uncertainty of such a view of the system remains. 'Apoptosis' is not at all so consonant with the more complex stance which has been developed in this chapter. The degeneracy and redundancy of the narrow language faculty that have been and will be further argued for below grossly contravene an 'apoptotic' account; the streamlining processes should have eliminated these. Furthermore, it is difficult, from a conceptual point of view, to imagine how such core features of the narrow language faculty such as case and agreement or tense and aspect might be sculpted from an earlier amorphous entity. Thus, the conclusion we must come to with respect to an 'apoptotic' account for the evolution of the narrow human language faculty is that if minimalism were to be correct about its vision of the system, 'apoptosis' might be a feasible, if still somewhat opaque, possibility. However, a more complex, non-minimalist language faculty is virtually impossible to reconcile with the 'apoptotic' scenario.

Assuming the minimalist thesis, then, forces us into a position where language is seen as an atypical biological system, a system which cannot be explained by the normal adaptive evolutionary process of natural selection. However, if natural selection is the explanation *par excellence* in biology for complex adaptive systems, of which language has been shown in this chapter to be an example, we need to be very careful about adopting the assumptions of the MP, or indeed any assumptions that prevent us from positing an evolutionary explanation involving natural selection (at least to some extent).

In this section, I have shown that the minimalist system of language is compatible only with a saltational or perhaps an 'apoptotic' account. The predictions of a gradual adaptationist account are strikingly incongruous with the tenets of minimalism. The birth of minimalism in the generative enterprise therefore constitutes the adoption of a set of postulates which rule out, from the very beginning, gradual adaptationist evolutionary plausibility. In the final section of this chapter, further evidence from evolutionary biology will be used to expose the flaws in this adoption, revealing that three key properties of systems which evolve in the usual manner of gradual adaptation are in fact, plainly evident in language.

4.8 Evolvability

The minimalist perfect language faculty has been shown to be the very antithesis of typical biological evolutionary processes. Thus, language as the MP views it takes on a form that is not easily reconciled with a gradual adaptationist perspective. As noted in chapter 1, in order to progress with any analysis of the language faculty, we need to constrain our theories in some way. There, it was proposed that donning the evolutionist's cap leads to an exciting and intelligent manner in which to constrain our theories of language.

The language evolutionist should be concerned with considerations of evolutionary plausibility. In other words, we need to use studies in evolution to provide us with knowledge about how biological endowments, such as language, evolve. Approaching the issues that this chapter has presented from a different angle, this section will consider what an evolutionarily plausible theory of language might look like. In other words, if we use considerations of evolvability to constrain our theory of language, what features would the system be predicted to have?

In order to begin to answer this question, we need to understand what is meant by evolvability. Some definitions follow:

> "[T]he genome's ability to produce adaptive variants when acted on by the genetic system." (Wagner & Altenberg 1996:970)
>
> "The...capacity to be able to reach "good" solutions via evolution." (Nehaniv 2003:77)
>
> "The ability of a population to produce variants fitter than any yet existing." (Altenberg 1994:47)
>
> "[A]n organism's capacity to generate heritable, selectable, phenotypic variation." (Kirschner & Gerhart 1998:8420)

In other words, a system is evolvable if it produces variants that can be acted upon by natural selection. In addition, a system will be evolvable if it can reduce lethal mutations, while at the same time reducing the number of mutations required in order to produce novel phenotypic traits (Kirschner & Gerhart 1998). In other words, if mutations may be lethal, the system will be better off with a lower mutation rate. However, mutations are required in order for novel variation to be generated, so there must be a tradeoff of some sort. A system which can generate novel variation through few mutations will therefore fare best.

A brief aside here bears on the discussions of the following sections. It is important to note that although evolvability and adaptiveness are entirely separate characteristics - the former being the ability to produce variants, the latter being the ability to adapt to a changing environment - there are overlaps between the two which serve to blur the boundary. That evolvability and adaptiveness are conceptually distinct is clear if one imagines an in principle possible system that is evolvable without being adaptive; that is, if the variants produced were not in any way selectively advantageous. In practice, however, the variants that evolvability gives rise to must be adaptive; if they were not, they would not be viable alternatives for selection to opt for, and the system would not evolve. Thus, although the abstract theoretical line drawn between evolvability and adaptiveness is clear-cut, the actuality is far less so.

The next logical step is to question what properties of a system are characteristically associated with its capacity to evolve. In the evolutionary biology literature, a number of such properties are discussed. These include, but are not restricted to, redundancy, duplication and divergence, recombination, robustness, degeneracy, weak linkage, symmetry, and modularity. In the following sections, I will examine in detail three distinct but highly interrelated properties: degeneracy, modularity, and robustness. The biological details of each characteristic will be followed by an investigation of its application to the central issue of this chapter. That is, each of these features will be shown to be a property not of perfect systems in general, nor specifically of the minimalist language faculty, but of imperfect systems whose evolutionary history is underpinned by gradual adaptations.

4.8.1 Degeneracy

The first property to consider which is intimately linked with a system's ability to evolve is termed *degeneracy*. Degeneracy is ubiquitous in nature, observable at nearly every hierarchical level of development in the biological world. Degeneracy occurs in a system when more than one sub-system can carry out a particular function.

Recent work in a number of related fields such as evolutionary biology and complex systems theory (Edelman & Gally (2001), Solé *et al.* (2003), Tononi *et al.*

(1999)) has succeeded in clearly differentiating this property of evolvability from the similar and often confused property of redundancy. Redundancy has been identified as directly opposing the perfection of the minimalist language faculty. Many of the imperfections in nature that were discussed in chapter 3 were defined as such by virtue of their functional and structural redundancy. Here we will replace redundancy with degeneracy; the distinction drawn in the literature is crucial to the arguments that follow.

While redundancy may be understood as the carrying out of a function by more than one identical sub-system or structure, degeneracy is found only when the structures that carry out the same function are *not* identical. Man-made systems are usually redundant; the engineer typically deploys duplicate backup sub-systems in order to counter possible failure in the system. Conversely, biological organisms are usually degenerate rather than redundant. Certain of the cases examined in chapter 3 can now be recast in the light of this distinction. For example, brain re-alignment in cases of damage involves new, different brain matter undertaking the tasks usually reserved for the damaged area (Hertz-Pannier *et al.* 2002).

Degeneracy is a useful and valuable property of biological systems for the simple reason that it leads to greater evolvability. The question is, what is the connection between these features? In section 3.5.1, redundancy was argued to be advantageous due to its increasing the robustness of a system. Degeneracy too, leads to robustness; a degenerate system has more chance of being able to cope with the difficulties and puzzles that the environment might throw at it by virtue of having more than one strategy to solve such a problem.

Degeneracy leads to what are known as neutral networks (Ebner *et al.* 2001) – complex systems in which there are multiple adaptive peaks of equal height (fitness). In terms of the adaptive landscape of Sewall-Wright, evolvability is enhanced in such cases because although traversing the solution space in a particular direction may lead the organism away from an optimum, there will be another optimum of commensurate fitness just around the corner.

Another advantage of degenerate systems is their propensity to modularity. Modularity will be discussed separately in the next section of this chapter. At this point its applicability to evolvability will be simply assumed. Degeneracy can engender modularity in the following manner. Multiple structures in a system are capable of functioning in the same (or some overlapping) way. Where all these structures are fully intact and operable, this means that there is certain slack in the system. The unused structures can then be exploited by evolution by being adapted to new purposes, a process known as differentiation. Although the duplicate structure is no longer available for its original function, the organism as a whole is better adapted to its environment through its capacity to deal with an extra problem. The sub-systems now manage different aspects of the organism; indeed, their operations may be so far removed from each other as to be considered the domain of separate modules[26]. In other words, degeneracy is a key property of evolvability because it allows evolutionary processes to produce a greater number of variants upon which selection can act by applying duplicate structures to differing functions.

The advantages that degeneracy affords to an organism ensures that it is a selectively advantageous property; the degenerate system is thus likely to outperform the non-degenerate system in the evolutionary battle. In other words, degeneracy is not just a key to evolvability, it is a key to adaptiveness; it is a property that allows the organism to adjust and function within its changing environment. There are two main reasons for assuming that degeneracy is adaptive, and hence that organisms may evolve to become more degenerate. The first is the resulting modularity that becomes possible. Modularity (as will be seen below) is itself reasonably considered adaptive due to the fact that it allows different parts of a system to be affected differentially. If degeneracy produces modularity, and with that the robustness against environmental damage that modularity brings, then it will be selected for in evolution where possible. The second reason for viewing degeneracy as adaptive is that without it all mutations have the propensity to be lethal. That is to say, if only one sub-system is capable of carrying out a particular function in a system, any mutation which disables that sub-system may result in total breakdown of the entire system, and in turn, the entire organism of which it is part. Therefore, in organisms where mutation rate is high, degeneracy is not just desirable, it is imperative if the species is to have a life span that will make any impression on the evolutionary record.

[26]There is naturally an implicit tradeoff here between modularity and degeneracy; the assumption must be that gradual adaptive evolution will not lead to a situation where the advantages of differentiation and subsequent modularity outweigh the benefit of degeneracy and its associated robustness (see section 4.8.2 below).

Degeneracy is primarily manifested in systems that are complex, and that exhibit a high mutation rate. If complexity is understood as "...an interplay between functional specialization and functional integration" (Edelman & Gally 2001:13767), degeneracy follows as an intuitive pre-requisite. That is, the capacity of structurally distinct parts of the system to carry out the one function facilitates functional integration, while functional specialisation is maintained by the fact that degeneracy is not total; total degeneracy would upset the modularity-degeneracy tradeoff referred to above and further discussed in section 4.8.2 below. In contrast to such complex systems, simple systems neither offer the requisite structural opportunities for degeneracy to emerge, nor do they benefit from degeneracy in the same manner; with a lighter functional load, the simpler system requires less in the way of backup.

The germaneness of mutation rates is that if a system is rarely subject to mutations, then degeneracy, and the robustness it entails, are not a high priority. On the other hand, if a system has a high mutation rate, then damaging mutations are a significant threat, and consequently, the protection offered by degeneracy is beneficial.

It was stated above that degeneracy exists at almost every level in biology. A number of the most prominent examples will now be briefly reviewed[27]. In immunology, degeneracy appears in the form of different antibodies' abilities to bind to the same antigen (Edelman 1974). Thus, there are a number of different ways for the immune system to identify and neutralise foreign objects such as bacteria, parasites, or viruses. Importantly, these alternative immunoglobulins are distinct in structure, indicating that it is appropriate to talk of degeneracy but not of redundancy.

In neurobiology, degeneracy is exhibited by the network of neurons and the synapses which connect them. Edelman & Gally (2001:13765) discuss the fact that the vast number of connections in the brain cannot be genetically hardwired, and thus there will be various different connection patterns found both across and within species. However, the fact that these "...many different patterns of neural architecture are functionally equivalent..." means that "...functional neuroanatomy is highly degenerate." In other words, many distinct patterns can carry out the same functions. Therefore, if one pattern of connections is ruled

[27]See Edelman & Gally (2001) for many more examples.

out for whatever reason, another equally successful arrangement will be available.

The genetic code also manifests degeneracy (Zubay (1998), Edelman & Gally (2001)). Gene sequences are comprised of units known as codons, each of which has three nucleotides. However, there are many more three-place codons than there are amino acids. Thus, multiple codons can code for the same amino acid. Specifically, it is the third place of the codon that generates the degeneracy; that is, the third position can be subject to transposition without affecting the resulting amino acid. For example, the codons UAU and UAC both code for the amino acid tyrosine, while the codons GCC, GCA and GCG all code for alanine. Again, the result of this degeneracy is robustness through tolerance to mutations.

A final example comes from the processes of depth perception in human vision. A number of systems, such as lens convergence, occlusion, and stereopsis are known to have overlapping ranges of function (see Marr (1982)). That is, depth perception is degenerate due to the ability of different sub-systems of the visual system to carry out the same functions (to a certain extent). Damage to one of these sub-systems would therefore not disable depth perception in its entirety.

With a clear picture of what degeneracy is, and how it affects the natural world, we can now return to the subject of this chapter. The question is, does degeneracy manifest itself in simple, atomic, perfect systems such as the minimalist language faculty? The answer is a resounding no. In other words, degeneracy is the remit of systems that evolve in a gradual adaptive manner, not those that have the physical or mathematical basis seen to be associated with perfect systems.

Perfection as defined by the MP is closely linked to efficiency and economy. Only systems that are as efficient and economic as they possibly can be in all situations are deemed to be perfect. A degenerate system, on the other hand, cannot be classed as perfect. Perfection would not allow for multiple coding of functions; a perfect system would instead demand the simple pairing between one function and one operation, or with efficiency in mind, perfection might suggest a higher function to sub-system ratio, with multiple functions being carried out by one and the same operation.

Evolvability has been defined as the capacity to generate variation on which natural selection can work. That variation must crucially offer better phenotypic solutions. As a principle feature of evolvability, degeneracy increases this capacity through robustness and modularity, which both allow fitter variants to be offered (albeit in slightly different ways). Thus, degeneracy is applicable to systems that evolve through gradual adaptive processes. Solé *et al.* (2003:23) note that "[t]o a large extent, degeneracy is intimately associated with tinkering in evolution: it reflects the re-use that is made of different parts of a system in order to achieve similar functions." Tinkering is not a property of perfect systems; chapter 3 showed that they arise instead through exact physical processes. Tinkering, and hence degeneracy, are thus properties of meliorizing, not perfecting (see section 3.4).

In chapter 6 the minimalist view of language as a perfect system will be subjected to further scrutiny. Here, a suggestive pointer to the issues to be addressed there can be made in relation to the issue of degeneracy. Looking at language through a non-minimalist lens, there are clear examples of degeneracy to be found. One general example found in most if not all of the world's natural languages is synonymy; multiple signals are associated with the same meaning. If the signal is the structure and the meaning is the function in the earlier definition of degeneracy, two synonyms will differ in their phonological structure, but will express one and the same meaning. This example may be problematic if one takes the view that true synonymy does not exist (see e.g. Cruse (1986), Clark (1992)), but recall that degeneracy may be interpreted as an overlapping range of function.

A less controversial example of degeneracy in language is the use of more than one grammatical structure or procedure to indicate the same grammatical relation (multiple sub-systems expressing the same function). One common instance of this is the use of both word order and inflectional morphology to reflect case facts. That is, the language faculty offers two available devices for carrying out one task. This example highlights the fact that linguistic degeneracy too is partial, and occurs where there is integration of functional specialisation with functional integration. A final degeneracy to consider here with respect to language relates back to one of the imperfections discussed in section 3.5.1. Where aphasia is suffered at a particularly young age, patients are seen to exhibit the re-alignment possibilities that allow for them to regain control of their language faculty using alternative sub-systems of the brain (Hertz-Pannier *et al.* 2002). In other words, structurally different areas of the brain can carry out the same linguistic functions.

It seems then that the language faculty is in several different ways hugely degenerate when viewed from a typically functional position. The MP has little to say about any of these degeneracies; they are nevertheless real, and thus hint at a further reason for coming down on one side of the dichotomy presented at the end of chapter 3 rather than the other.

4.8.2 Modularity

A second property which has been much discussed in both the developmental and evolutionary biology literature in recent times is modularity. Although consensus on how exactly to interpret the term is sparse, we can understand modularity to refer to a feature of a system that is organised into sub-systems or components, such that each component's functional responsibility maps to a bounded portion of the phenotype space, and components interact with each other in highly specific ways. Raff (1996) delineates biological modules as genetically specific, hierarchically organised units, that can interact with each other, and that are capable of undergoing transformations on both developmental and evolutionary timescales. Also known by the terms *dissociability* (Needham 1933), and *compartmentation* (Gerhart & Kirschner 1997), modularity is best understood as a claim about the nature of the genotype-phenotype mapping. The details will be explored below.

Although the question of how to recognise a module is one that has not yet been resolved (the discussions in Schlosser & Wagner (2004) are evidence of this), and there remains an issue surrounding how isolated a character must be to be considered a module (Raff & Raff 2000), there is some substantial consensus that we can take on board. Wagner (1995b) defines a module as "...a complex of characters that 1) collectively serve a primary functional role 2) are tightly integrated by strong pleiotropic effects of genetic variation and 3) are relatively independent from other such units." Similarly, Calabretta *et al.* (1998) characterise a module as "...a collection of characters at different levels that are all responsible mainly for a single function." The discussion which follows will then assume a module to be delineated with the following two requirements (Meyers 2004) in mind. Firstly, the constituent parts of the module must be physically or temporally close. Secondly, the parts must share responsibility for a common function or trait.

The relation of modularity to evolvability is that modularity allows for differential evolution. In other words, the characters of a system that is comprised of independent yet interacting modules can vary independently of each other, and selection can consequently act on one module without adversely affecting others. A mutation in one part of the system will not interfere with the rest of the system if, as a whole, it is organised into semi-autonomous units, and hence a mutation in one module is less likely to be lethal to the entire system. Thus, with such a construction, evolvability is enhanced in the organism through an increase in phenotypic variation combined with a parallel decrease in pleiotropic damage (Kirschner & Gerhart 1998).

A further important feature of modularity is its gradedness. A system can be more modular or less modular, the level of modularity (among other factors) determining how evolvable the system is. The degree of modularity in a system was briefly hinted at in footnote 26. There, it was noted that there must be a tradeoff between the levels of degeneracy and modularity in a system. The issue is this: in a degenerate system multiple different structures can have an identical or overlapping functional remit; we can think of this in terms of the genotype-phenotype map as multiple genes coding for the same trait. In the same way that redundancy through duplicate genes allows selection to diversify the functions that the genes are responsible for, the excess in a degenerate system permits the selective constraints on one of the genes to be relaxed, which in turn permits mutations on this gene to lead to a new function emerging (Wagner (2000), Coissac *et al.* (1997)). Modularity then obtains if the remit of the new and previous functions are sufficiently behaviourally removed from each other.

However, consider the following (admittedly highly simplified) scenario, outlined in figure 4.1. Imagine that at time *t* a trait (T1) is degenerately coded for in an organism by three different genes (G1, G2, G3). This trait is part of a module (M1) also occupied by other traits (T2, T3...) by virtue of their combined contribution to a common process (Meyers 2004). Similarly, other modules are comprised of one or more traits which are each coded for by one or more genes. Differentiation and subsequent modularisation results in only two of the initial three genes (G1, G2) being able to code for the specified trait (T1), the other (G3) having been appropriated by selection to answer a new pressure (T7). This gene and the new trait it codes for may equally form an entirely new module, or may become part of an existing one (M2) if the new trait somehow enhances the functioning of the process that defines that module.

At this stage (time *t*+1), the organism is still highly evolvable. However, if further differentiation and modularisation were to occur (G2 to code for T8, a trait of an entirely new module (M4)), leaving only one of the original three genes (G1) for the specified trait (T1), degeneracy would have been wiped out altogether in the organism. The robustness that degeneracy entails would no longer be available, and the levels of evolvability of the organism would drop. Thus, for evolvability levels to remain high, the modularisation that degeneracy permits may only operate within constraints set by the resulting levels of degeneracy.

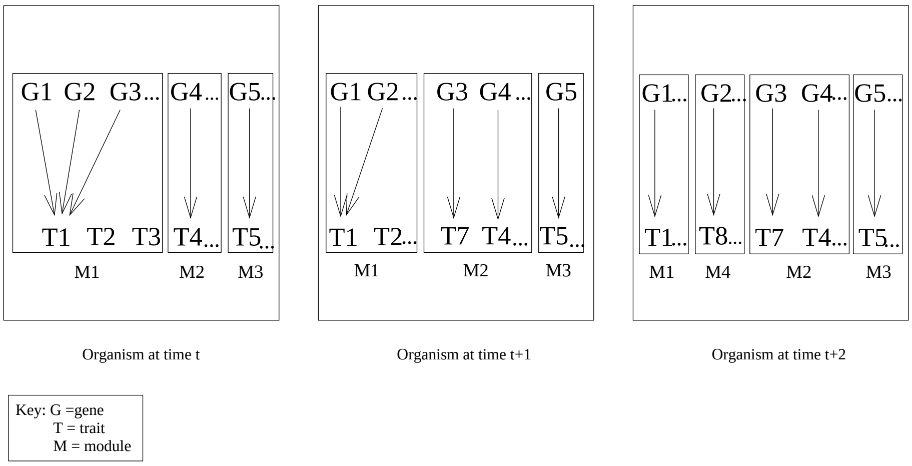


Figure 4.1: The tradeoff between degeneracy and modularity for evolvability

Figure 4.1 highlights a crucial aspect of modularity - its implications for the genotype-phenotype map. The two opposing properties of pleiotropy and degeneracy are relevant here. We know that degeneracy refers to the ability of multiple structures to carry out the same function, or in the mapping terms of figure 4.1, the ability of multiple genes to code equivalently for the same trait. Pleiotropy, in contrast, is the coding for multiple traits by the one gene (see discussion of FOXP2 in section 4.7.1 above, for example). Pleiotropy is often typically exemplified by the human disease PKU (phenylketonuria), where a mutation in a single gene brings about reductions in hair and skin pigmentation as well as causing mental retardation. Both degeneracy and pleiotropy cause systematic coupling in the genotype-phenotype map to be upset. In the same way that there is a tradeoff between degeneracy and modularity, when a system is highly modular, pleiotropic effects are constrained; thus, a system that is highly modular has a genotype-phenotype map with few pleiotropic effects, while a non-modular system is characterised by a high degree of pleiotropy.

In fact, there is a little more to the balancing act than this. Modular systems are more specifically characterisable as those systems in which degeneracy and pleiotropy in the genotype-phenotype map are limited with respect to structures serving differing functions, falling instead within a single functional complex (Wagner & Altenberg 1996). In other words, modularity rules out unrestrained inter-modular pleiotropy and degeneracy, yet it still permits these features intra-modularly. As a result, the advantages that degeneracy and pleiotropy bring to the organism[28] are not closed off by its modularity. Furthermore, a balance between pleiotropy and modularity is advantageous. That is, while unbounded pleiotropy may be damaging to the organism as a result of the high interference levels it provokes, modularity prevents such deleterious effects by lowering the interference suffered by the entire system when perturbation is suffered by just one part.

Although these advantages would seem to point to an adaptive account of modularity, it is still unknown if this is the case, or if modularity is simply a side effect of the way natural selection shapes the genotype-phenotype map (Wagner 1995a). Clearly, being modular helps the more complex organism. In fact, Marr (1976:485) has noted that "[a]ny large computation should be split up and implemented as a collection of small sub-parts that are as nearly independent of one another as the overall task allows", for the reason that the alternative is too hard for either the engineer or selection to debug. There are two main possible ways in which modularity may arise discussed in the literature. One has been spoken about already - the emergence of modularity as a result of degeneracy (see also Altenberg (1994) on modularity through gene duplication). The second is what is termed *parcellation*. Essentially, parcellation takes place when both pleiotropic and degenerate effects are suppressed differentially; while these features are restricted between functionally dissimilar characters, they are augmented between functionally similar characters. The genotype-phenotype map will, as a result, have complex many-to-many associations in functionally proximate areas of the space, but will lack this intricacy between functionally distant areas. Parcellation is thought to be achieved through a combination of directional and stabilising

[28] Pleiotropy has as its primary benefit the fact that it increases variational potential, hence evolvability (see among others Hansen (2003)).

selection (Wagner 1996).

The next question is in what type of systems or organisms do we see modularity. As with degeneracy, there is a correlation between the existence and levels of modularity in a system and its complexity. Calabretta & Parisi (2003) confirm that modularity restricts the interference of parts in a complex system; specifically, they argue that behaviourally complex organisms tend to show modular genotypes as this reduces the neural interference that otherwise emerges. This is consistent with Bonner's conception of gene nets: "...a grouping of a network of gene actions and their products into discrete units during the course of development", and his claim that gene nets occur with greater frequency in more complex organisms: "[t]his general principle of the grouping of gene products and their subsequent reactions...becomes increasingly prevalent as organisms become more complex. This was not only helpful and probably necessary for the success of the process of development, but it also means that genetic change can occur in one of these gene nets without influencing the others, thereby much increasing its chance of being viable." (Bonner 1988:174-5). The use of modular design in engineering and computer science highlights complex systems as those situations in which it is most useful. Of course, just because some property is useful does not mean that evolution will grant it. Nevertheless, as is backed up by modelling work such as that of Rueckl *et al.* (1989), it is clear that where modularity does appear, it is not in simple systems.

Examples of modularity abound. In all cases, the relevant systems are behaviourally and genetically non-transparent. All multicellular organisms are modular in their structure; cells are both structural and functional units, which are self-contained, and which partition the organism in such a way as to prevent collapse resulting from local damage (Kitano 2001). Likewise, at a lower level of organisation, eukaryotic cells are made up of structurally separate units known as organelles, which are functionally specialised. At a higher level of organisation, proteins are arranged in modules (e.g. pathways), although these do usually exhibit a certain amount of functional degeneracy. Developmental modules, such as limb buds - structurally separate units which form in the embryo, and develop into structurally and functionally separate components of the adult morphology - are the rule in organisms that are more complex (see Gilbert *et al.* (1996), and Bolker (2001) for further discussion).

Modularity is a concept that is also familiar in the cognitive sciences. The modularity of mind thesis proposed by Fodor (Fodor 1983), and upheld (albeit to different degrees) in Sperber (2002), Carruthers (2003), and Samuels (2000), essentially articulates the view that the human cognitive system is composed of (semi-)autonomous modules each responsible for separate behavioural complexes. If the Swiss army knife model (Cosmides & Tooby 1997) of human cognitive capacity is on the right track, it provides evidence of modularity in perhaps the most complex of all biological systems.

Unlike degeneracy, there is no *a priori* reason that perfect systems cannot be modular. In fact, modular man-made systems, such as computer programs, machines, and buildings, often seem to be the ideal solution to the particular problem at hand. If perfection is interpreted as it is in the MP as efficiency, and economy in the system, modularity itself is not ruled out; it only becomes impossible if it encompasses any pleiotropy or degeneracy. However, consider again the perfect systems discussed in section 3.5.2: the honeycomb, the sunflower, the snow crystal. Modularity is in fact ruled out for these perfect organisms for the following reason. Such systems do not have gradual adaptive evolutionary histories, but following the outline of modularity developed here, it can only bear upon those systems which do follow such an evolutionary development. Both of the two possible processes described above responsible for modularity emerging in an organism are necessarily gradual. In addition, modularity has been analysed as being itself an adaptation, or alternatively the by-product of some other adaptation relating to the nature of the genotype-phenotype map.

The delineation of the language faculty that the MP relies on also rules out a modular view of this perfect system. As previously discussed, the minimalist views the narrow language faculty as precisely not modular in nature. Instead, a small set of central grammatical operations apply to all features equally and in the same manner.

In contrast, a foundational aspect of the earlier generative GB theory was its modularity. In that framework, the grammar was viewed as comprising individual units, each responsible for one of the central processes of the grammar (case assignment, theta assignment, x-bar theory, control theory, binding theory, bounding theory, etc.). In this way, modularity allowed features common to different types of structures to be unified, eliminating the need for rule-based grammars to account for each and every possible structure independently. As

Chomsky (1981:7) puts it: "[t]he full range of properties of some constructions may often result from interaction of several components, its apparent complexity reducible to simple principles of separate subsystems." The MP has further refined the grammar by eliminating certain of the GB modules altogether (e.g. bounding theory), and by re-analysing the remit of the others as the feature matrix of particular lexical items (e.g. case and theta roles), or simply derivative of the recursive Merge operation (e.g. x-bar theory).

The question now is whether language can be interpreted as exhibiting this fundamental property of evolvability when considered outwith the minimalist schema. We can distinguish two interpretations of modularity with respect to language. The first, external modularity, is the view that the language faculty itself is a module within the larger cognitive domain. That is, language is informationally distinct from other cognitive systems. The second, internal modularity, is the conception that is germane to the issues here; that there is modularity within language. By displaying internal modularity, the language faculty would proclaim one of the key characteristics of evolvability, offering yet more evidence for choosing between the alternatives laid out at the end of section 3.5.2.

That the language faculty in its broad sense exhibits internal modularity has long been backed up by studies in many areas of linguistics, including first and second language acquisition, and neurolinguistics. The MP too supports the division of the faculty into the three main modules of phonology, semantics and syntax. Jackendoff articulates the modular architecture well in one particular manner in his *Representational Modularity* thesis (Jackendoff (1998), Jackendoff (1999), Jackendoff (2002)). This particular instantiation of the modular view sees the modules as deriving specifically from the representations they use. Where representations differ, separate modules must be proposed. Thus, phonology is a different module from syntax in that the former represents information in terms of intonation, stress, and syllables, while the latter focuses on lexical categories (noun, verb, adjective etc.) and functional categories (number, person, tense etc.). Similarly, semantics must be considered distinct from both of these modules due to its representing information in terms of conceptualised physical objects, events, properties, intentions etc. Additional modules composed of correspondence rules (interface modules) are proposed to allow the parallel central modules to communicate; that is, correspondence rules, such as lexical items made up of phonological, syntactic, and semantic features, determine relations between composite units of representation belonging to each module.

Recently, experimental evidence from studies of linguistically impaired children has brought the modularity debate (in both its external and internal forms) to the fore. Cases of SLI (Specific Language Impairment) have been interpreted by many (see Rice *et al.* (2004) and van der Lely (2004) among others) as providing confirmatory evidence for the division of the broad language faculty into modules. Although the dispute is far from solved, the positing of an impairment specifically affecting the syntax of the sufferer (G(rammatical)-SLI) has led some researchers to further posit theories of SLI which support the internal modularity of the narrow language faculty too. The Extended Optional Infinitive (EOI) theory of Rice (Rice *et al.* 2004) proposes that certain G-SLI sufferers exhibit a deficit that can be precisely accounted for by one aspect of their syntax - tense and agreement marking - while all other aspects of the narrow language faculty, the broad language faculty, and other cognitive domains remain intact. The Representational Deficit for Dependent Relations (RDDR) proposal of van der Lely and Battell (van der Lely & Battell 2003) suggests that a sub-class of G-SLI patients have problems only with movement in the syntactic component, exhibiting optional application of movement operations. Again, in such cases, all other aspects of the syntax, and broader cognition, are advanced to be unharmed.

If these interpretations of the data turn out to be valid, then these proposals suggest that the narrow language faculty may reasonably be thought of as itself modular in nature. Although the modules hinted at by the EOI and RDDR theses do not necessarily fit directly with modules suggested by syntactic theories (for example, tense and agreement marking in GB theory are assumed to be essential elements of both the Case theory module and the Binding theory module)[29], there is no *a priori* reason why they could not form core modules of the narrow language faculty. Definitive proof for or against the internal modularity of the narrow language faculty is thus for future research to uncover. However, the suggestions that current research in psycholinguistics and neurolinguistics (among other areas) present intimate that this fundamental feature of evolvability may be a very real property of language.

[29] Although some versions of GB theory do posit a discrete movement theory module (see e.g. Ouhalla (1999)).

4.8.3 Robustness

As the previous sections have made clear, robustness is closely linked to the properties of degeneracy and modularity. Importantly, robustness should not be thought of as a property on the same level as degeneracy or modularity, although it too leads to greater evolvability of an organism. While robustness derives from degeneracy and modularity, neither degeneracy nor modularity derive from robustness. However, robustness should not be equated with these two properties either; that it is a distinct feature should be clear from the fact that it not only derives in different ways from degeneracy and modularity, but that it can also fall out of other properties of evolvability such as those mentioned at the beginning of section 4.8, again in differing manners.

Much of the discussion above has outlined the nature and advantages of robustness; some additional detail is nevertheless still required. Firstly, robustness needs to be defined precisely. We understand robustness as the ability of a system to withstand potential damage. That is, robustness is exhibited in an organism that is flexible and plastic. De Visser *et al.* (2003) define robustness as "... the invariance of phenotypes in the face of perturbation." However, this definition does not capture the fact that perturbations can come in two different forms, leading to two different categories of robustness. What might be termed *genotypic robustness* is a change in structure without a concomitant change in function. That is, mutations in the genotype space can prevail while the organism remains phenotypically stable. This is the type of robustness that degeneracy entails; it is the neutral network mentioned above. *Phenotypic robustness*, on the other hand, obtains in cases of change in function without an associated change in structure. In other words, the genotype space remains stable while multiple environmental challenges can be addressed phenotypically.

Like degeneracy and modularity, robustness is beneficial to a system for its instrumentality in enhancing evolvability. Likewise, the situations in which robustness is most advantageous are those in which the chances of perturbation are highest; the capacity to resist mutational or environmental disturbance is of relatively low value in organisms not subjected to high levels of perturbation. Thus, like degeneracy and modularity, robustness is particularly advantageous in complex organisms where (genetic) mutation rates are high. The predominant domain of robustness thus follows the same characteristic outline as that of degeneracy and modularity; the organisms and systems which show robustness are typically identified as complex, gradually adapting and subject to high levels of disturbance.

We can then talk of robustness as being underlain by two central principles: degeneracy and modularity. It is through degeneracy that backups are available to the system in case of possible lethal perturbation. Degeneracy allows for a system to accumulate neutral mutations, which then become visible to natural selection, and evolvability is increased through their use in creating more phenotypic variations from which selection can choose. Modularity permits sub-systems to be treated differentially, such that perturbations are restricted to affecting only parts, rather than the whole organism, thus increasing the likelihood that such perturbations will not be lethal to the organism. In other words, evolvability is increased through reduction of the number of lethal mutations.

It would consequently appear that the adaptiveness of robustness is unquestionable, given its implications for evolvability[30]. Consider, however, another possibility. It could equally be the case that robustness is not directly selected for in a system, but emerges as a by-product of selecting for fitter systems. An organism will be fitter if it exhibits such properties as modularity or degeneracy. Modularity and degeneracy, in turn, give robustness for free. Although the puzzle of whether robustness is itself directly adaptive or is merely a consequence of adaptation for other traits is currently unresolved[31], what is unquestionable is that robustness is a property of systems that evolve gradually in an adaptive manner, not perfect systems that arise abruptly through non-adaptive processes.

Apart from the derivable robustness manifest in the examples discussed in the previous two sections, examples can be pointed to in all aspects of biology. At the level of the organism, physiological homeostasis illustrates the nature of

[30]Importantly, robustness should not be equated with adaptiveness. It might initially appear that robustness is nothing other than fitness, but robustness and fitness can and should be decoupled. It is possible to imagine organisms that differ in robustness yet are equally fit, as well as organisms that differ in fitness yet are equally robust. While being able to run faster constitutes an increase in fitness, it does not bestow greater robustness. In contrast, while a chameleon's camouflage capabilities are more robust than the sandlance's (*Limnichthyes fasciatus*), as the former can change colour thus allowing it to blend into many differing environments, while the latter can only hide itself in the coral rubble of the ocean floor (Schwab *et al.* 2005), the fitness of both species is equal, given the fact that although the chameleon's surroundings may be ever changing, the sea bed always has the same appearance. The point is that these concepts are different, although there is significant overlap and hence fuzziness surrounding them.

[31]See De Visser *et al.* (2003) for discussion of these and other feasible explanations for the emergence of robustness.

robustness (De Visser *et al.* 2003). An equilibrium is maintained in the organism by feedback control mechanisms which ensure that the organism can cope with fluctuating environmental conditions within tolerable limits. Examples of phenotypic robustness such as osmoregulation (the regulation of water and mineral salts in the body) and the control of sugar concentrations in the blood highlight the adaptive benefit of invariance to perturbation.

Further examples of robustness at this and other biological levels include the fact that variation in the genotype of the developing embryo appears to have little or no effect on the resulting adult organism (Wagner 2004), and the robustness of the metabolic network to variation in and removal of chemical reactions (De Visser *et al.* (2003), Wagner (2004)) – genetic robustness. Again, what is clear in these examples is the focus on systems with a gradual adaptive evolutionary history.

Perfect systems, such as the minimalist language faculty or the daisy florets, tend not to exhibit robustness. As noted previously, such systems do not enjoy the principal determinants of robustness. Robustness through degeneracy must be ruled out in the minimalist's perfect system as duplicate structures or functions would contravene the guiding criteria of economy and efficiency. The minimalist language faculty (and other perfect systems) is an atomic undecomposable unit. In other words, language as viewed by the minimalist is the very opposite of modular in structure. For this reason, robustness that is achieved by means of modularity is impossible in such systems too.

Yet, robustness does seem to be discernable in language when it is considered from an alternate, functional angle. Sign language shows archetypical robustness of the broad language faculty to environmental perturbation; that is, when the normal channels of acquisition and development are unavailable, language will develop in an alternative medium (Perlmutter 1993). Further, robustness in the narrow language faculty is manifest in the rife incomplete information in communication. In discourse events, the signal often does not contain all the features that it could for the relevant meaning. Conversely, meaning is often underdetermined by the utterance. Nevertheless, in all such cases, the robustness of the system ensures that comprehension, and hence communication, is successful.

In conclusion, searching for key indications of an evolvable nature for the narrow language faculty has resulted in much evidence to convince us that using evolution as a constraint on theories of language is a profitable choice. Essential properties of evolvability can be clearly identified in language. Importantly, using evolvability as our constraining factor has been shown to rule out a minimalist conception of the language faculty, as it does not permit the defining properties of an evolvable system. The properties of modularity, degeneracy, and robustness point incontrovertibly to a system with a complex and intricate heterogeneous composition. The minimalist narrow language faculty is decidedly not characterisable in this manner. Its simple atomicity runs counter to the fundamental features of evolvability, illustrating the principal difficulty that arises from attempts to synthesise minimalism and evolution: the minimalist narrow language faculty is not evolvable.

4.9 Conclusions

This chapter has explored a number of different issues, venturing down a variety of diverse avenues in the process. Yet, the deductions made at each turn are highly interconnected.

The central minimalist claim of simplicity of the language faculty was examined, the conclusion arrived at being that the language faculty, even in its narrow sense, really does look more complex than the atomic system the MP forces one to accept. The empirical evidence cited by Pinker & Bloom (1990) and Pinker & Jackendoff (2005) additionally showed that language is not only complex, but adaptive and complex, the significance of this being that natural selection must have had at least some part to play in the evolution of the system. At the end of chapter 3, the incompatibility of the MP and gradual adaptation was formulated in terms of a choice of research path to follow. This conclusion thus provides one reason for choosing the path of gradual adaptive evolution rather than the path of structural and functional perfection.

Next, it was shown that in evolution there is a bias towards more complex systems, and that this bias is reflected specifically in systems which are forced to reach outside of their current confines and possibilities, systems which co-evolve with other complexifying systems. It was argued that both of these characteristics are reasonable and likely for the human language faculty, thus further supporting the delineation of language as a complex system.

Two evolutionary processes which are amenable to the perfect language faculty of minimalism were then arrived at. Analysis showed both saltation and the 'apoptotic' account to be at best difficult for the system at issue, both because of the phenotypically complex, and genotypically pleiotropic nature of language, and in the latter case because it leaves the emergence of the initial chaotic language faculty unexplained. Although this evidence does not directly suggest the route we should take in relation to the gradual adaptation versus perfection dichotomy, it intimates that a complex system must involve a non-saltational, non-apoptotic evolutionary account.

Finally, investigation of three principal properties of systems that are evolvable showed these to be ruled out for a minimalist language faculty by virtue of the fact that they can only emerge gradually in complex adaptive systems, not abruptly in atomic, simple systems. Yet, the narrow language faculty does appear to exhibit cases of these three properties. Although this does not strictly promote adopting the gradual adaptation line, it does provide an impetus against choosing the perfection route.

CHAPTER 5

Recursion as the Key Innovation in the Evolution of the Narrow Language Faculty

5.1 Introduction

In this chapter, the argument will take a somewhat different tack. Up to now, it has been the general theoretical themes of the MP that have been under attack from an evolutionary standpoint. In chapter 6, the specifics of minimalist syntactic theories will be examined in a similar light. Before that, this chapter will put one evolutionary hypothesis, which is clearly consonant with minimalist thinking, under the spotlight.

The proposal of Hauser *et al.* (2002) that recursion may have been the crucial step in the evolution of the human language faculty was introduced briefly in the earlier chapters. Essentially, they claim that the core component underlying language is recursion, and that all other intricacies and peculiarities of our linguistic capacity are the result of the recursive component having to interface with systems of the brain which are external to language, but are called upon in the course of processing language. As the one property which permits human language to be given the label of *unique*, what is interesting from an evolutionary view is the emergence of recursion[1].

[1]The claim made by Hauser *et al.* (2002) is not incompatible with Chomsky's often stated position in his earlier work that language is unique as a biological system. Their paper does not deny that language is unique in the biological world, it simply provides a more specific proposal about what makes it unique. Independent of this is the implication of the recursion-only hypothesis that the language faculty is simple, which is clearly at odds with Chomsky's earlier view of the language faculty as complex, as discussed in section 4.3.3.

It is important to take heed of the authors' disclaimer. They do not "...define FLN as recursion by theoretical fiat..." (Fitch *et al.* 2005:183). Indeed, in places, they appear to retreat to a weaker position. However, as they also note, "[t]he contents of FLN are to be empirically determined" (*ibid*:182). That is, the recursion-only hypothesis is just that, a hypothesis about the nature of language and its evolution, and the only way to prove or disprove it is to examine the empirical data. That is precisely what this chapter will do – use the empirical data to assess the hypothesis that "...FLN only includes recursion..." (Hauser *et al.* 2002:1569).

Section 5.2 will examine in detail what the term *recursion* refers to. Following this, section 5.3 will look at the question of what is special in language; is it only recursion, or are other properties unique? Section 5.4 will return to the work of defining recursion, contrasting it with phrase structure. In section 5.5, I will take up the issue of semantics, and the important role it plays in human language recursion. Section 5.6 will examine the uniqueness question - is recursion to be found in any domains outside human language? Cases of human language which lack recursion will be analysed in section 5.7, lending weight to the fundamental claim of this chapter that the recursion-only hypothesis is flawed. Finally, some conclusions will be drawn, setting the scene for chapter 6.

5.2 Definitions

In order to fully understand the implications of the claim made by Hauser *et al.* (2002) that recursion is at the core of human language, and indeed, is the only feature of the language faculty which places our communication system in a different dimension to all other communication systems, we need to be very clear on what is meant with the term *recursion*. In this section I will review a representative selection of definitions of the term that have been proposed in literature in both linguistics and computer science, with a view to developing a definitive understanding on which the rest of this chapter will be based. The definitions will be followed by examples of recursion that are relevant to linguistics and computer science respectively, which will aid comprehension of the pertinent points. Following this, I will examine in detail the different types of recursion, and the differences between iteration and recursion.

5.2.1 Linguistics

In the domain of linguistics, recursion has long been an important term. Since the dawn of generative grammar, recursion has been invoked as an explanation for the fact that human language exhibits the property of discrete infinity; that is, we can invent novel phrases and sentences all the time, just by combining the finite lexical items we have access to in new ways. However, despite its significance, the assumption in linguistic circles seems to have been that the term itself requires little explanation, as if its link to Humboldt's aphorism were enough of a clarification. Definitions of recursion in the linguistics literature are generally somewhat opaque. Little textbook space is given over to the concept and less still is offered for explaining the contrast between it and the oft-confused iteration. Moreover, those definitions which are advanced contrast hugely in where they place the burden of explanation.

The first set of definitions is based on the discrete infinity of language. Lobeck (2000:37) asserts that "[r]ecursion expresses the property of language that we can generate phrases of indefinite length." Adger (2003:20) further suggests that "[l]anguages are recursive in nature, allowing linkage between an infinite array of meanings and an infinite array of structures." Carnie (2002:57) offers a definition that links the property of discrete infinity to recursion in the phrase structure rules which generate the grammatical sentences of a language: "[r]ecursivity is the property of loops in the phrase structure rules that allow infinitely long sentences, and explain the creativity of language." The phrase structure rules in figure 5.1 below exhibit the loops that Carnie is referring to. A grammar with these rules will allow us to generate sentences such as (1):

(1) He knows that I know that John met Mary.

$$
\boxed{\begin{array}{l}
\mathrm{S} \rightarrow \mathrm{NP\ VP} \\
\mathrm{NP} \rightarrow \mathrm{(det)\ N\ (CP)} \\
\mathrm{VP} \rightarrow \mathrm{V} \left\{ \begin{array}{c} \mathrm{NP} \\ \mathrm{CP} \end{array} \right\} \\
\mathrm{CP} \rightarrow \mathrm{C\ S}
\end{array}}
$$

Figure 5.1: An indirectly recursive phrase structure grammar

The loop that Carnie talks of is achieved by the fact that the entire sentence contains a noun phrase which contains a CP which in turn contains another sentence[2]. The indirect nature of the looping gives this type of recursion its name – *indirect recursion*.

A number of other definitions use the looping exhibited in phrase structure rules as pivotal to the explanation of recursion. Christiansen (1994:13) formalises this by stating that "[r]ecursion entails that the non-terminal symbol on the left-hand side of a rule reappears on the righthand side of the same or another rule." This definition of course overgeneralises in that all non-terminals (apart from S) must appear on the right-hand side of a phrase structure rule if they are to be used, but that re-appearance alone does not entail recursion. What is specifically recursive is if (i) the non-terminal appears on both sides of the same rule, or (ii) it appears on the right-hand side of a rule whose left-hand side consists of a terminal/non-terminal that appears on the right-hand side of the rule in which the original non-terminal appears on the left-hand side, or (iii) the loop is even more indirect. For example, in figure 5.1 the rule for a non-terminal (S) expands to include a non-terminal (NP) whose rule expands to contain a non-terminal (CP) whose rule expands to include the initial non-terminal (S). Lobeck (2000:36) describes recursion as "...the property of phrase structure rules to generate phrases of the same category." Pinker (2003:18) says that "[a] phrase is defined as a sequence of phrases, and one or more of those daughter phrases can be of the same kind as the mother phrase." Horrocks (1987:37) is more explicit: "[i]f a given symbol appears on both the left-hand side of some rule and on the

[2] In fact, this also holds of the VP in this grammar.

right-hand side of some rule, the first rule can re-apply to the output of the second, and the second can re-apply to that of the first, or to that of some rule that depends for its application on the prior application of the first..." In fact, to some linguists it appears that recursion and phrase structure are synonymous. In section 5.4 I will return to examine how synonymous these terms in fact are.

A third type of definition of recursion in the linguistics literature homes in on the notion of embedding, and in particular, embedding of identical constituents. These definitions refrain from linking recursion quite so directly to the specifics of formal grammars, a fact which allows these definitions to be slightly more accessible. Kirby (2002:1) defines recursion as "...a property of language with finite lexica and rule-sets in which some constituent of an expression can contain a constituent of the same category." Newmeyer (2004) offers a less formal, but more intuitive explanation: "[r]ecursion is sentences embedded inside of sentences inside of sentences, ad infinitum." Pinker & Jackendoff (2005:4) again appeal to the existence of "...a constituent that contains a constituent of the same kind." Trask (1993:229) offers the following: "[t]he phenomenon by which a constituent of a sentence dominates another instance of the same syntactic category." A further similar definition is given by Trask (1999:261): "[t]he occurrence in a sentence of a syntactic category containing within it a smaller instance of the same category". A final definition of recursion which stresses the embedding of identical constituents is that of Carnie (2002:22) when he states that recursion is "...the ability to embed structures iteratively inside one another."

A number of other definitions and discussions of recursion involve talk of iteration. These definitions can be divided into two types - those that confuse or collapse the concepts of iteration and recursion, and those that define recursion as being opposed to iteration. Into the first category falls the definition offered in Radford (1997:526): "[a] recursive operation is one which can be repeated any number of times." According to this definition, recursion is simply the application of something over and over again, which, as will become clearer as this chapter progresses, is not enough of an explanation.

Hurford (2004:560), on the other hand, contrasts iteration: "[i]teration is doing the same thing over and over again, until some criterion is met" and recursion: "[a] recursive procedure is (partially) defined in terms of itself." Pinker

& Jackendoff (2005:4) too note the crucial difference between two types of recursion: "Tail recursion can be mimicked by a computational device that implements simple iteration, where one instance of a procedure can be completed and forgotten by the time the next instance has begun. Nested recursion, however, cannot be mimicked by iteration..." The importance of this distinction will be returned to in section 5.2.3.

To summarise, we can divide the definitions of recursion found in the linguistics literature into a number of categories, shown in table 5.1.

Discrete Infinity	*Phrase Structure Rules*	*Embedding of Constituents*	*Recursion = Iteration*	*Recursion vs. Iteration*
Lobeck (2000)	Christiansen (1994)	Kirby (2002)	Radford (1997)	Hurford (2004)
Adger (2003)	Lobeck (2000)	Newmeyer (2004)		Pinker & Jackendoff (2005)
Carnie (2002)	Pinker (2003)	Pinker & Jackendoff (2005)		
	Horrocks (1987)	Trask (1993)		
		Carnie (2002)		

Table 5.1: Definitions of recursion from linguistics

5.2.1.1 *Discussion*

The definitions of recursion that the linguistics literature offers have been seen to fall into a number of categories depending on where the stress of the explanation is placed. Within each category, some definitions are more informative than others, yet many of the definitions surveyed are lacking in some way.

Of those in the *Discrete Infinity* category, none are formal enough, giving us only a vague intuition as to what is meant by the term. Those in the *Phrase Structure* category come closer to being formal definitions, yet they also have a number of problems.

Most definitions fail to differentiate between two important types of recursion. These types will be discussed in detail in section 5.2.3, but for now a short commentary is necessary in order to clarify the nature of the inadequacy of the definitions. The two types of recursion in question are known as *tail recursion* and *embedded/nested recursion*. The former is understood simply as the type of recursion which occurs at either end of a phrase or sentence. In other words, the self-embedding of phrases is at the edge. The latter type of recursion occurs in the middle of a phrase or sentence. The importance of the difference may seem questionable at this point, but as we will see in later discussions, these differences bear strongly on the claim of Hauser *et al.* (2002), and in a larger context on theories of the evolution of language.

A further issue with the definitions above is the fact that Carnie (2002) uses the term 'iteratively' in his definition, which could lead to confusion. In fact, the most obvious and most serious concern with the explanations discussed is that only two acknowledge that there is a contrast between iteration and recursion. As we will see in section 5.2.3 below, equating the two can lead to a fundamental difficulty.

5.2.1.2 *Examples*

In this section I will use examples of different types of recursion in language to aid comprehension of much of what has gone in the previous section. In the last section, I briefly introduced a distinction between tail recursion and nested recursion[3]. We can now illustrate these different varieties of recursion.

Tail recursion is the type of recursion that exists when a phrase is embedded within a phrase of the same type only at the beginning or end of a sentence or phrase[4]. In other words, the embedding happens at the 'tail' of the sentence or phrase[5]. This variety of recursion is common in natural language in a number of oft-used constructions. In order to illustrate this, we need to further divide tail recursion into two types: left-branching and right-branching. Left-branching recursion occurs when the embedding is seen at the left-hand end or tail of a sentence or phrase[6], as in (2), while right-branching recursion exhibits embedding at the right-hand end of the sentence or phrase, as in (3).

(2) Mary's aunt's brother's dog's ball is in the garden.
(3) the man that kissed the girl that John met in the bar that Bill recommended.

In (2) the entire NP contains a head noun *ball* as well as a modifying NP *Mary's aunt's brother's dog's* which in turn contains a head noun *dog* and a modifying NP *Mary's aunt's brother's*. Again, this contains a head noun *brother* and a modifying NP *Mary's aunt's*, and finally, this NP consists of the head noun *aunt* and a modifying NP *Mary's*. So, each NP has another smaller NP embedded in it, until we reach the final one. Each NP is embedded at the left edge, and there is no material to the left of the embedded NPs, so the embedding is at the tail, and the recursive NP is an example of tail recursion.

In (3), the recursive embedding happens at the right-hand edge. The entire NP consists of a determiner *The* followed by the head noun *man* followed by a modifying CP *that kissed the girl that John met in the bar that Bill recommended*. In

[3]These concepts have been discussed using many different names. I will use *tail recursion* and *nested recursion* throughout to avoid confusion.

[4]The term 'tail' recursion may intuitively suggest only recursion at the right edge; indeed, in the computer science literature, this is how it is generally used. However, I will use the term here to cover recursion at either the left edge or right edge of a sentence or phrase; at either the beginning or end of a procedure or structure.

[5]Note that it is possible to have tail recursion in a phrase where the entire sentence that contains that phrase is not tail recursive, e.g. *The building that everyone I know lives in just collapsed*. In this case, the subject NP is recursive but the sentence is not. In what follows, the terminology 'sentence or phrase' should not be understood as meaning that in cases like this, the sentence is also tail recursive, but rather that tail recursion can apply to both phrases and sentences, and it is the case under consideration in any instance that will determine whether we are dealing with a phrase or a sentence.

[6]Note that when the embedding occurs at the start as in left-branching recursion, it is often referred to as head recursion.

this case, each CP contains a phrase which has a smaller CP embedded in it. Thus this is indirect recursion. The largest CP contains the NP *the girl that John met in the bar that Bill recommended*, which in turn contains the CP *that John met in the bar that Bill recommended*. This consists of a head complementiser *that* followed by a sentence, which in turn contains a NP *the bar* which is modified by a CP *that Bill recommended*. Here the recursivity arises from the embedding of a CP indirectly inside another CP at the end of the sentence.

Nested recursion is so called because it refers to embedding that is nested inside a phrase or sentence, such that material exists on both sides of the embedding. It does not occur at either edge of the sentence. Examples of nested recursion are more difficult to construct[7], but centre-embeddings such as (4) illustrate the phenomenon.

(4) The mouse the cat the dog chased bit ran.

Here, the subject noun phrase that comes first in the sentence belongs with the verb that appears in final position, the second subject NP belongs with the penultimate verb and the third subject NP belongs with the first verb. In this way, the embedding is always in the centre of another phrase. So, the sentence *the dog chased* is embedded in the centre of the sentence *the cat bit* which is embedded in the centre of the sentence *the mouse ran*. The embedding is surrounded on both sides by additional material, so it cannot be classed as tail recursion.

5.2.2 Computer Science

In the realm of computer science the definitions of recursion that are proposed in the literature are somewhat more formal, as is the nature of the discipline. As with the definitions from the linguistics literature, I will review a representative selection, pointing to both their shortcomings and their usefulness.

Here again, the definitions lack a single common thread. One type of definition places a great deal of importance on the repetition of a process. Loeper *et al.* (1996:153) assert that "[r]ecursion and iteration are two equivalent ways in programming for repeatedly performing a specific task." Arnow & Weiss (1998:494)

[7] The reason for this is that nested recursion is known to cause more processing difficulties, and complex cases are thus found only rarely in natural language.

state this in more formal programming terms, saying that "[r]ecursion and iteration both result in the controlled repeated execution of a body of code." These are quite sparse in their explanation, and also fall into the trap of not clearly or adequately distinguishing between recursion and iteration.

A two-way distinction must be made to account for the majority of the definitions of recursion offered in the computer science literature. The first set of definitions refers to self-reference; the fact that an object can be defined in terms of itself. This is *structural* recursion. The other type of definition revolves around the fact that some process or procedure can invoke itself (or, in computational terms, some function, algorithm or method can call itself). This is *procedural* recursion.

Loudon (1999) states that "[r]ecursion allows something to be defined in terms of smaller instances of itself." The definition offered by Aho & Ullman (1995:25) is almost identical: "[r]ecursion is a technique in which a concept is defined, directly or indirectly, in terms of itself." A succinct procedural definition is put forward by Harel (1993:31): "[r]ecursion is the ability of a subroutine or procedure to call itself." The Science Fair Projects states that "[r]ecursion is a way of specifying a process by means of itself" and goes on to explain that "...complicated instances of the process are defined in terms of simpler instances, and the simplest instances are given explicitly." Loudon (1999) states that "[a] recursive function is a function that calls itself", and expands by explaining that "[e]ach successive call works on a more refined set of inputs, bringing us closer and closer to the solution of a problem." A final procedural definition is the one given on Sparknotes.com: "[r]ecursion is a technique in which a function calls itself on a smaller problem of the same type in order to simplify the problem to a solvable state."

Liu & Stoller (1999:73) use a procedural definition which, in addition, points to an important aspect of recursion not mentioned in any of the definitions so far: "[r]ecursion refers to computations where the execution of a function or procedure calls itself and proceeds in a stack fashion." The important feature which this definition alludes to is represented by the push-down stack. A stack is used in computer programming to hold data in such a way that access to that data is restricted. An element can be 'pushed onto' the stack to be stored, or it can be 'popped off' the stack to be retrieved. A stack is a last-in-first-out type of storage device. The pertinent point is this: recursion requires that we always have some way of keeping track of what point in a procedure we have got to, so that when we return from the recursive part of the action, we know where to pick up. Consider the sentence in (5) – a simplified version of (4) above:

(5) The mouse the cat bit ran.

Here we have a case of centre-embedding, a type of nested recursion. When parsing such a sentence we first encounter the NP *the mouse*, but on reaching the next word, we realise that we are entering a recursive component. We parse the phrase *the cat bit* with no problems, but on exiting from the recursive component, we need to have some way of remembering where we were when we came across that phrase. In other words, on entering the recursive call, we need to store the first NP somewhere so that when we reach the final verb we can associate it with that. A stack is the type of data structure that allows us to keep track in such a way; it permits us to keep adding to memory until a certain point, and then to repeatedly retrieve from memory[8].

Section 5.2.3 will examine the difference between iteration and recursion in some depth; however, at this point it is significant to note that the computer science literature offers us a number of explanations which do take heed of the difference. Liu & Stoller (1999:73), in addition to the definition of recursion above, define iteration as "...repeated execution of a piece of code by explicitly updating a store and performing jumps." They further observe that "[r]ecursion is usually coded as recursive functions..." while in contrast "...iteration is usually programmed as loops." A further contrastive definition of iteration is given on Sparknotes.com: "[i]teration is a programming construct where looping is used to complete an action multiple times."

One final point of interest is the additional information given by Loudon (1999) in his explanation of recursion. He notes that "...a recursive process has a winding and an unwinding phase. In the winding phase, each recursive call perpetuates the recursion by making an additional recursive call itself. The winding phase terminates when one of the calls reaches a terminating condition. Once the winding phase is complete, the process enters the unwinding phase, in which previous instances of the function are revisited in reverse order." Looking again at sentence (4) from above, we can interpret what this means. If we consider

[8] Note that unlike nested recursion, tail recursion does not require keeping track in the same way. This issue will be further discussed in section 5.2.3.

the start of each embedded phrase to be a recursive call, we can say that on processing the entire sentence, when we reach the NP *the cat* we are making a recursive call, and hence winding. On reaching the NP *the dog* we are making a further recursive call, and so we wind once more. This recursive call reaches its terminating condition when we encounter the verb *chased* as this terminates the embedded phrase *the dog chased*. So, at this point we start to unwind. We unwind again when we reach the next verb *bit* as it terminates the previous recursive call – the phrase *the cat bit*. Reaching the verb *ran* terminates the outermost phrase *the mouse ran*, so the unwinding phase is now complete:

(6) [$_1$ The mouse [$_2$ the cat [$_3$ the dog chased $_T$] bit] ran]
............................R^W..........R^W..........................R^U...R^U.....T

(Key: R = recursive call; W = winding phase; U = unwinding phase; T = terminating condition)

To summarise this section, we can map the definitions of recursion from the computer science literature onto the following table:

Repetition	*Structural Recursion*	*Procedural Recursion*	*Stack Implementation*	*Recursion vs. Iteration*	*Winding & Unwinding*
Loeper *et al.* (1996)	Loeper *et al.* (1996)	Harel (1993)	Liu & Stoller (1999)	Liu & Stoller (1999)	Loudon (1999)
Arnow & Weiss (1998)	Aho & Ullman (1995)	Science Fair Projects		Sparknotes	
		Loudon (1999)			
		Sparknotes			

Table 5.2: Definitions of recursion from computer science

5.2.2.1 Discussion

Generally speaking, the definitions from the computer science literature have more to offer in terms of specifics than those from the linguistics literature. However, there are still some issues with these definitions.

The definitions in the *Repetition* category, as was observed earlier, fail to distinguish between recursion and iteration. Those in the *Structural Recursion* and *Procedural Recursion* categories are a step up; however, the latter group contains explanations that may be somewhat difficult to understand due to the technical jargon used. If we are to come to a full understanding of these, we will need to be able to abstract away from this terminology. Unfamiliar technical terminology is again the issue with Liu & Stoller's (1999) discussion of the stack requirements of recursion, although the general issue is highly significant, and thus their definition deserves certain recognition.

Finally, I will again re-iterate the importance of descriptions which distinguish between iteration and recursion. While the definitions from Liu & Stoller (1999) and Sparknotes.com clarify this point, it is relatively difficult to ascertain from their presentation exactly what this distinction might mean for natural language. Section 5.2.3 will analyse and attempt to resolve this issue.

5.2.2.2 Examples

I will now present examples of recursion that are discussed in the computer science literature. While these examples may be quite difficult to associate with natural language at a superficial level, they will aid our understanding of the issues which pertain to language at a more abstract level.

The literature refers to a number of algorithms which are best solved using a recursive procedure. I will discuss two of these. The first is the factorial function. In this case, we want to work out the factorial of some number[9]. The algorithm given in figure 5.2 will solve the problem recursively.

[9]Where the factorial of an integer is that integer multiplied by all integers between it and 1, i.e. the factorial of 5, written 5!, is equal to 5x4x3x2x1.

```
FUNCTION Factorial (num):
  IF num = 0 THEN:
    return 1
  ELSE num * Factorial(num-1)
```

Figure 5.2: Recursive factorial function

To solve the problem of computing the factorial of an integer, we break the problem down into a smaller problem of the same type (the factorial of that integer - 1). As the Loudon (1999) and Sparknotes definitions observed, we are now working at solving a smaller, more refined version of the original problem in order to solve that original problem. We keep doing this until we reach 0.

A second example is what is known as the Towers of Hanoi problem. Essentially, the problem is the following. Imagine we have three towers (A, B, and C), with three discs[10] of decreasing sizes stacked on the first of the three towers (A). We need to move all the discs to tower B, moving only one at a time, and never placing a larger disc on top of a smaller one. In order to accomplish this, we may use tower C as a holding tower[11].

A recursive function such as that given in figure 5.3[12] will accomplish this task:

```
FUNCTION MoveTower (disc, source, dest, spare):
  IF disc == 0 THEN:
    move disc from source to dest
  ELSE:
    MoveTower(disc - 1, source, spare, dest)
    move disc from source to dest
    MoveTower(disc - 1, spare, dest, source)
  ENDIF
```

Figure 5.3: Recursive function to solve Towers of Hanoi problem

The essence of the recursion in this algorithm derives from the way we understand the problem and how to go about solving it. No matter how many discs

[10]Different instantiations of the problem use different numbers of discs. For the sake of brevity as well as ease of understanding, the number of discs used here is limited to three.

[11]Actually, all towers will be used to hold items temporarily during the process - see below.

[12]Adapted from the website of Carl Burch at Carnegie Mellon University : http://www-2.cs.cmu.edu/ cburch/survey/recurse/hanoiex.html

there are in the problem, essentially we want to move the largest disc to tower B, and put all the smaller discs on top of this in decreasing order. Now, to move the largest disc to tower B, we must somehow remove all the smaller discs first, and tower B has to be empty. This involves a series of moving the discs between all three towers, never putting a larger one on top of a smaller one, until tower B is empty and the largest disc is the only disc sitting on one of the other two holding towers. Once we can move the largest disc to tower B, the problem becomes how to get the next largest disc to sit on top of it. To solve this, we need to move all discs smaller than that one off it, and not put them on top of the largest disc. In the case of three discs, at this point in the solution the second largest disc (disc 2) will be sitting on tower C with the smallest disc (disc 1) on top of it. Therefore, disc 1 must be moved off disc 2, and then it can be placed on top of the largest disc sitting on tower B. If we keep going, and in cases where the number of discs is larger than three, the problem will be repeated for each smaller disc until the puzzle is complete. Again, this is a case of solving a smaller version of the original problem.

5.2.3 Recursion versus Iteration

In this section I will examine in more detail the differences alluded to above between the concepts of iteration and recursion. This will be important for examination of the claims of Hauser *et al.* (2002), and other issues of the place of recursion in language evolution which will dominate later sections of this chapter.

Simply put, the difference between iteration and recursion is this: the former involves mere repetition of an action or object, each repetition being a separate act that can exist in its entirety apart from the other repetitions, while the latter involves the embedding of an action or object inside another action or object of the same type, each embedding being dependent in some way on the action/object it is embedded inside.

Some real-world examples will help to get the point across here. Consider a recipe in a cook book. In order to follow a recipe for baking a cake, say, we might be given instructions like the following: "Stir the mixture until it becomes smooth". This instruction involves us completing some action over and over again until we reach a certain point (a terminating condition). This is procedural iteration – each mixing action that we undertake is a separate act, and does not rely on the actions that have gone before it or will go after it. In fact, iteration allows for any of the repetitions of an action to be removed from the entire process without the end result being altered. So, one mixing action in the middle of the arbitrary number of them can be eliminated, and we will still reach the terminating condition of the mixture being the required consistency.

An example of procedural recursion, in contrast, is the cutting of a cake into an even number of pieces. Imagine you have sixteen guests at a party and each needs to get a slice of cake. How might you go about cutting the cake so as to ensure sixteen even pieces? First you would cut the cake in half, giving you two pieces. You would then cut each of those pieces in half, giving you four pieces. Each of those four pieces cut in half again would give you eight, and a final division of each piece in half will leave you with the requisite sixteen pieces. This is an example of what is known in the computer science literature as the *divide-and-conquer* principle. It is recursion as the output of each action is the input to the next action; that is, one half of the cake is the result of the first division, and this half is then the input to the next dividing action - the next action will result in this half being divided in two. Furthermore, each dividing action must necessarily take place in order; unlike procedural iteration, we cannot remove any of the intermediate steps and still end up with the same result. For example, after first dividing the whole cake in half, we then divide one half (call it half-1) in half (to give quarter-1 and quarter-2), and then each quarter is divided in half (to give eighth-1, eighth-2, eighth-3 and eighth-4), and so on. However, removing the step which divides half-1 into quarter-1 and quarter-2, and then continuing, is not possible, given that we need to have quarters first before we can get eighths.

As a further example, recall what happens when you look into a mirror that is arranged at a certain angle to another mirror. Not only do you see a reflection of yourself in one mirror, but that reflection contains a reflection of yourself in the other mirror. This reflection, in turn, contains a reflection of yourself in the first mirror, which contains a reflection of yourself in the second mirror, and so on. Only limitations in our perceptual system force the recursive reflections to stop at some point. This is an example of structural recursion – each reflection is embedded inside a different reflection, and each embedding relies on the larger reflection existing.

In contrast to this, a real-world example of structural iteration is the make-up of a brick wall. The wall is made from some arbitrary number of bricks; its structure can be thought of as being broken down into a simple repetition of one brick over and over again. This is iteration rather than recursion in that the repetition is simply that; there is no sense of one brick being embedded inside another, and again, we can remove an arbitrary brick from the iteration and the structure remains. The iteration is structural in that we are considering the form of the wall, rather than the process of building it[13].

In considering the definitions of recursion from the computer science literature, it was noted that recursion involves keeping track or adding to memory using a stack, while iteration does not. This is an important and defining difference between these two concepts. Consider the examples we have just seen. In baking the cake, or in considering the make-up of the brick wall, we do not need to keep track of what point we are at, or store in memory how many times an action has been completed. All we need to know is what the terminating condition is – e.g. when the mixture is the right consistency. At that point we can stop the repetitions. Conversely, when cutting a cake into an even number of pieces, or considering the reflections in the mirrors, we need to know where we are. If we lose track of what point in the cake cutting we have reached, we don't know whether we need to keep dividing the piece we are on or return from that recursive process to divide a piece which we left off earlier.

In section 5.2.2.2 above we considered two algorithms which typify the use of recursion in computer programming. In fact, we can write programs which will solve these problems equally well but which use iteration as opposed to recursion. The computer science literature tells us that any algorithm that can be implemented recursively can also be implemented iteratively[14].

Figure 5.4 below gives the iterative version of the factorial algorithm:

[13]If considering the process of building a wall, we might in fact conceive of two iterative actions. Building a brick wall as consisting of building layers of bricks; that is, we iteratively combine bricks to give a layer, and then we iteratively combine layers to give a wall. In this case, we could say that the procedure is hierarchically organised with layer-building embedded inside wall-building. However, iteration embedded inside iteration does not give recursion as the embedded action is not identical to that which it is embedded inside.

[14]This statement will be moderated somewhat in the following section.

```
FUNCTION Factorial (num):
  declare temp
  set result = 1
  FOR (temp = num; temp ≠ 0; temp –)
    result = result * temp
  return result
```

Figure 5.4: Iterative factorial function

For examples such as these, the recursive code is easier to read and understand. Iterative algorithms are often very long and opaque. However, if we can implement all recursive code iteratively, what does this tell us? The next section will examine this question.

5.2.3.1 Types of Recursion

Section 5.2.1 introduced the distinction between two types of recursion – tail recursion and nested recursion. We saw that tail recursion can be either right- or left-branching, and that nested recursion in natural language is found in centre-embeddings. In this section I will examine the difference between tail and nested recursion in more depth, concentrating on some more significant contrasts than the mere surface details mentioned above.

The importance of the difference between tail recursion and nested recursion is made clearer by the terms which Christiansen (1994) uses for these concepts. He refers to tail recursion as *iterative recursion* and nested recursion as *non-iterative recursion*. In fact, Christiansen is among those who specifically note that tail recursion is better thought of as iteration.

Although tail recursion does involve embedding of phrases within phrases of the same type, the fact that this embedding is always at the phrase edge means that it looks a lot more like simple repetition than do the examples of nested recursion (e.g. (4) and (5) above). In fact, if we were to add even one more embedding to the nested recursive sentence in (4) we would have severe processing difficulties with it, while we could add many more embeddings to sentence (2) and not encounter the same issues:

(7) The mouse the cat the dog the fox attacked chased bit ran.
(8) Mary's aunt's brother's friend's uncle's neighbour's dog's ball is in the garden.

So, tail recursion appears to be more like simple iteration in that we can seemingly repeatedly add more and more embedded phrases, while we cannot seem to do this with nested recursion. Why is this? The answer lies in two related facts. Firstly, tail recursion does not require us to keep track of where we are in the same way that nested recursion does. Secondly, nested recursion involves long-distance dependencies whereas tail recursion does not. A long-distance dependency can be defined as follows:

> *Long-distance dependency*: A long-distance dependency is a relation between two elements or positions of a phrase or sentence which may be separated by any arbitrary distance, such that the existence and shape of one element is regulated by the other.

The relation in question could be semantic in nature (as is the case with the dependency formed by long-distance wh-movement); it could also be syntactic (as in agreement patterns marked on distant elements of a phrase). Nested recursion involves such dependencies because of the fact that the embeddings occur in the middle of a sentence or phrase. The phrase that begins before the embedded phrase does not end until after it; in other words there is a dependency between the beginning of the phrase and the end of the phrase and it is a long-distance dependency because there is intervening material. So, in (7) above, there is a dependency between the NP *the mouse* and the verb with which it agrees *ran*, but there are phrases which separate these elements. In fact, the only local (i.e. non-long-distance) dependency in (7) is between the NP *the fox* and the verb *attacked*. A tail recursive phrase or sentence does not have such long-distance dependencies simply because the embedded phrase appears at an edge.

Nested long-distance dependencies entail the need to keep track in a stack fashion[15]. If we are to parse a nested recursive sentence such as (7), we need some way to hold the NP *the mouse* in memory so that we can retrieve it once we reach the element with which it agrees. If we have no long-distance dependencies, we have nothing we need to keep track of, so tail recursion does not

[15]Note that a single centre-embedding does not have this memory requirement.

demand this property. The only dependencies found in tail recursive language are local. For example, the tail recursive NP in (8) *Mary's aunt's brother's friend's uncle's neighbour's dog's ball* involves only local dependencies. There is no sense of keeping track in the same fashion as with nested recursion; in parsing this tail recursive NP we do not need to store the first modifying noun we come across (*Mary's*) on a stack and place each following noun on top of this, popping them off when we reach the head noun of that phrase (*ball*)[16]. The memory requirements of nested recursion can also be framed in formal language theoretic terms. To generate nestedly recursive strings such as (7) we require a type 2 context-free grammar, and the type of automaton associated with a context-free grammar is a pushdown automaton (i.e. a finite automaton which makes use of a stack). On the other hand, tail recursive strings such as (8) can be generated by a less powerful type 3 machine, which doesn't incorporate a stack.

We can now return to answer the question that was left open at the end of the last section, that is, if recursive algorithms, such as the factorial algorithm, can be coded alternatively in an iterative fashion, what does this tell us about the type of recursion involved? If we examine again the pseudocode given above for the recursive solution to the factorial problem, we will now see given our understanding of the difference between tail and nested recursion, that it is tail recursive. That is, the recursive call to the function is situated at the end of the algorithm. The recursive call is not embedded in the middle of the algorithm in the sense of nested recursion. Furthermore, there is nothing to be done once the final recursive call returns. Importantly, only tail recursive algorithms can be re-coded iteratively; this option is not available for nested recursive algorithms.

Let us now examine the distinction between tail recursion and iteration in some more detail. Consider (9) and (10):

[16]In example (8) this tail recursive NP is the subject of an entire sentence. Although there is no long-distance dependency between the head noun and the verb in this case, a sentence with a tail recursive object NP exhibits such a dependency:

(a) I saw Mary's dog's ball.

Not only does this not require a stack memory (as it doesn't involve nested long-distance dependencies), this dependency is no different to the one formed between the verb and the head noun of the object NP in (b), although we would not make a case for recursion here:

(b) I saw the blue ball.

The point is that the long-distance dependency in (a) is independent of the recursion exhibited in the object NP. While nested recursion entails long-distance dependencies within the recursive phrase itself, tail recursion does not.

(9) Jack ate $[_{NP1}$the sandwich$_{NP1}]$ and $[_{NP2}$the doughnut$_{NP2}]$ and $[_{NP3}$the apple$_{NP3}]$.
(10) $[_{NP1}[_{NP2}[_{NP3}$John's$_{NP3}]$ mother's$_{NP2}]$ neighbour$_{NP1}]$ bought the car.

At the level of the string, it looks like we are dealing with the same thing - repeated NPs. However, the difference between these cases becomes clear at the level of the structures. Pragmatic issues aside, the labelled brackets given in (9) and (10) reflect the typical structures that would be assigned to such strings - a flat structure for the former, and a recursive structure for the latter. The brackets given are a proxy for the underlying semantics; the NPs in (9) are essentially independent of each other, while there are modification relations that hold between the NPs in (10). One way to tell that these are the correct structural interpretations is to consider what happens when we transpose the NPs in (9) and (10). In the former case, the meaning remains unaltered, whereas in the latter case, the meaning changes. Transposing two of the NPs in (9) gives us (9'):

(9') Jack ate the sandwich and the apple and the doughnut.

(9') is semantically equivalent to (9), where we can measure equivalence in terms of truth conditional semantics. That is, the propositions[17] *a-d* in (11) are all true in both cases:

(11) a. ate'(jack', sandwich')
b. ate'(jack', doughnut')
c. ate'(jack', apple')
d. ate'(jack', sandwich') & ate'(jack', doughnut') & ate'(jack', apple')

On the other hand, transposing two of the NPs in (10) gives us the non-semantically equivalent (10'):

(10') John's neighbour's mother bought the car.

The referent picked out by the agent of (10) is different to the referent picked out by the agent of (10'). We can see this in that if we imagine a model world where the facts in (12) hold (among others), the truth values of the propositions in (13)

[17] Propositions are represented in a simple predicate logic where the predicate appears outside the parentheses, with its arguments ordered inside the parentheses. Both predicates and arguments are represented with primes to indicate that they are not English lexical items.

are different for (10) and (10′).

(12) a. Mary is the mother of John.
b. Susan is the neighbour of Mary.
c. Joe is the neighbour of John.
d. Sarah is the mother of Joe.

(13) a. bought′(susan′, car′)
b. bought′(sarah′, car′)

(13a) is true only for (10) while (13b) is true only for (10′).

In other words, there appear to be ordering constraints which hold in cases such as (10), but not in cases such as (9). This would indicate that we are dealing with tail recursion in (10) but only with simple iteration in (9). So, although much of the computer science literature tells us that tail recursion might as well be thought of as iteration, and although recursive algorithms such as the factorial algorithm can indeed be coded iteratively, in natural language, semantics forces tail recursion and iteration to be understood differently as it indicates a difference in structure which is not visible simply by considering the strings. The strict ordering requirement in tail recursion that is lacking in iteration can thus be used as a tool to differentiate these in natural language.

The discussion in this and the preceding sections has introduced many sub-categories of iteration and recursion. In summary, I will now give clear explanations of recursion and iteration, followed by two figures which map out all the sub-categories noted, differentiating them, and listing relevant examples and requirements for each.

Iteration : Iteration is the simple, unembedded repetition of an action (procedural) or object (structural) an arbitrary number of times.

Recursion : Recursion is the embedding at the edge (tail) or in the centre (nested) of an action (procedural) or object (structural) an action or object of the same type. Recursion entails that the output of the current embedded action or object will become the input of the next. Furthermore, nested recursive embedding leads to the existence of long-distance dependencies, and thus the need for keeping track or adding to memory.

ITERATION

Structural	Procedural
e.g. Brick wall	e.g. Recipe instruction Factorial
Concerned with make-up of objects Simple repetition; no embedding No keeping track No long-distance dependencies Steps can be removed	Concerned with execution of action Simple repetition; no embedding No keeping track No long-distance dependencies Steps can be removed

Figure 5.5: Categories of iteration

- RECURSION
  - Structural
    - Tail
      - e.g. Right-branching
Left-branching
        - Make-up of object
Embedding at edge of object
Keeping track not necessary
No long-distance dependencies
Steps cannot be removed
    - Nested
      - e.g. Centre-embedding
Reflections in mirrors
        - Make-up of object
Embedding in centre of object;
material on both sides
Keeping track necessary
Long-distance dependencies
Steps cannot be removed
Output becomes next input
  - Procedural
    - Tail
      - e.g. Factorial
        - Execution of action
Embedding at edge of action
Keeping track not necessary
No long-distance dependencies
Steps cannot be removed
    - Nested
      - e.g. Cake cutting
        - Execution of action
Embedding in centre of action;
material on both sides
Keeping track necessary
Long-distance dependencies
Steps cannot be removed
Output becomes next input

Figure 5.6: Categories of recursion

5.3 Recursion as the Key to Human Language

The central claim of Hauser *et al.* (2002) implies that our interpretation of the term 'language' (in the narrow sense) should be restricted to a central syntactic operation which recursively combines lexical elements hierarchically. If this hypothesis holds, then the implication is that 'language' is highly scaled-down. It is atomic, in that it cannot be broken down into many interwoven parts. Consequently, it is easy to claim that its evolution need not have been complex or extended; instead, one small step could have given rise to the recursive component.

In this section, I will examine whether the thesis of recursion put forward by Hauser *et al.* is sound. To do this, I will survey the properties of language that set it apart from non-human communication systems, and from other cognitive systems. If all of these properties are the result of recursion in some way, then the claim of Hauser *et al.* may be on the right track. If, however, there are features of language that in no way fall out from recursion, or cannot be explained in terms of the recursive operation central to FLN, then recursion may not be the sole constituent of the narrow language faculty.

5.3.1 Minimalist Implications

The minimalist standpoint meshes with the claims of Hauser *et al.* quite obviously. Minimalism proposes a simple system based on one or few central elements, without the baroque complexity of earlier theories. Recursion in the thesis of Hauser *et al.* provides us with that one central element, all other elements which are required to generate the same set of grammatical sentences as all the modules of GB theory being assumed to be non-specific to human language. The simple system is thus based on a recursive computational component.

Seeing the system in this atomic way means that much of what we would normally have associated with the term 'language' must now be interpreted as belonging outside of the recursive computational component, in the wider conception of the language faculty (Hauser *et al*'s FLB). Examples of what must be placed outside the narrow language faculty but inside the broad language faculty include the lexicon, phonology and morphology. In the sections which follow, I will examine this division of the language faculty in more detail, and it will become clear that the partition is in the wrong place.

5.3.2 *What's Special about Language?*

In order to determine if the recursion-only hypothesis of Hauser *et al.* is plausible, we need to examine the features of language which make it 'special'; the features which set the human language faculty apart. This is a two-fold problem. We must investigate what it is that makes language uniquely human, and what it is that makes language uniquely linguistic. There are features of language that can be found in the communication systems of other animals; for example, semanticity or the ability to communicate about things distant in time or space. Similarly, there are features of language that can be found in other human cognitive systems; for example, the fact that it is learned by one generation from the preceding one. Any feature which falls into either of these two categories will not interest us here, as it will not determine the uniqueness of human language. Instead, what I will concentrate on in the following sections will be properties of the language faculty which are *both* uniquely human and uniquely linguistic.

Hauser *et al.* (2002:1569) define the faculty of language in the narrow sense as "...the only uniquely human component of the language faculty". If they believe that FLN is simply recursion, then they seem to be saying that the only feature of language that they consider 'special' is recursion. That is, recursion is the lone property of language that sets it apart from other human cognitive systems, and other non-human communication systems[18]. In what follows, I will analyse a number of features of language from a wide-ranging literature, and demonstrate that these features are both unique to language and unique to our species. I will then discuss the fact that such features surely belong in the realm of FLN, yet, importantly, that they cannot be argued to be the result of recursion in any sense.

5.3.2.1 *Berwick and 'Merge'*

Berwick (1998) offers a position which is wholly sympathetic to the claims of Hauser *et al*'s recursion-only hypothesis, and minimalism more generally. He asserts that the MP is compatible with a saltational evolutionary theory by virtue of the fact that the MP defines language as a simple atomic system, and such a system could have evolved in one step[19]. More specifically, he assumes that

[18] In fact, they later propose that recursion may exist in other cognitive systems, which, as Bever & Montalbetti (2002) argue, would then mean that language is not special at all.

[19] Recall the discussion of saltationism in section 4.7.

the fundamental property of language that fits into this evolutionary explanation is the operation Merge[20]. He states that: "...once the fundamental property of generativity has emerged, then Minimalism forces much of the rest of human syntax to follow" (Berwick 1998:322). By this he means that the central operation of minimalism that was discussed in chapter 2 – Merge – provides us with explanation for the many linguistic phenomena that require commentary. He further explains that: "[a]ll we need in addition is...a pre-existing substrate of words (a lexicon) *qua* conceptual relations and categorical perception"(*ibid*).

There is quite a lot that needs further examination here. Firstly, we need to investigate the operation of Merge. Is Berwick's claim that Merge provides us with everything we need the same as Hauser *et al*'s claim that recursion provides us with everything we need; is Merge equivalent to recursion? On top of this, we need to examine the features of language which Berwick specifically alleges fall out of Merge directly. Are these features explainable in terms of recursion, and if not, are they features which we can class as those which make language 'special'? Finally, we need to look at the additional functionality that Berwick merely glosses over. That is, is the lexicon a feature of language that is non-special, i.e. a feature which can be found either elsewhere in human cognition or in other animals' communication systems, and so deserves only to be part of the broader sense of 'language'?

Berwick places Merge at the centre of the evolutionary story for language, while Hauser *et al.* put recursion in this position. However, the operation of Merge and the property of recursion are not one and the same thing. Recursion is a characteristic while Merge is a procedure. Recursion is implemented through the application of Merge; that is, following the explication given in chapter 2, Merge applies to sets of lexical items repeatedly until all items have been organised hierarchically into a phrase or sentence. Merge takes two items, and joins them, projecting one as the head of the pair. The operation then applies once more to the output of that first pairing, and merges it with another item from the lexical resource pile. Following the definitions explored in section 5.2 above, we

[20] A similar proposal is put forward by Calvin & Bickerton (2000). They too assume that much of the complexity of language falls out of the interaction of only a few components, and that this makes accounting for the emergence of the system less problematic. Although their theory does not suffer from all of the issues which I will attribute to Berwick's, it does make problematic assumptions. For example, they claim that "[m]ovement is simply reattachment of an item at a higher level; no prearranged 'landing site' is required." (*ibid*:223), but as will be discussed below and in section 6.3, this account of movement is insufficient.

can see that the Merge operation applies in a recursive manner – the output of one application of Merge becomes input to the next application.

Recursion is useless without Merge. In other words, although Merge is not recursion, Merge is necessary for recursion to be implemented in language. In this way, Berwick's claim can be understood as essentially implying the claim of Hauser *et al.*[21]. While they claim that recursion is the core component of our language faculty, Berwick claims that Merge provides us with much of the syntactic machinery required for the faculty. The syntactic machinery is thus arguably the result of recursion, which is actualised by the operation of Merge.

So, we have established that the theses of Berwick and Hauser *et al.* are quite congruous. Now, we need to ascertain if the properties that Berwick argues to fall out of Merge are in fact features which are the result of recursion. The features which Berwick suggests fall into this category are enumerated in figure 5.7:

(i) Recursive Generative Capacity
(ii) Structure Dependence
(iii) Displacement
(iv) Syntactic Relations
(v) Locality Conditions

Figure 5.7: Berwick's features of language which are derived from Merge

Clearly, the first of these properties is a direct result of recursion. As we can recursively apply the operation of Merge over and over to the output of the previous application, we can generate structures which are infinite in size.

Structure dependence refers to the fact that sentences and phrases are not simply strings of words, but rather contain words and phrases which are related to each other or dependent on each other. Sentences can be broken down into smaller and smaller phrases, each of which is contained within a larger phrase. We do not apply grammatical rules, such as question formation, in terms of linearity, but rather in hierarchical terms. Berwick argues that structure dependence is a consequence of Merge due to the fact that it is an operation which applies to two units which are adjacent; it is unable to count units or to apply to less than or more than two units at a time. However, it is not so obvious that the recursive

[21]Note that in the next section we will see that Berwick's claim implies the existence of some features that Hauser *et al*'s claim cannot.

operation itself provides us with structure dependence, and even less so that recursion as defined in section 5.2 above does[22].

Take the example of question formation, and more specifically what is often referred to as *subject auxiliary inversion*, as an illustration. The question in (14b) is formed by inverting the subject *the reluctant candidate* and the auxiliary verb *should* of the corresponding declarative sentence (14a). The importance of structure dependence here is the fact that a rule for generating questions such as (14b) from declaratives such as (14a) in English cannot simply state that the auxiliary be moved one position to the left, as this would result in the ungrammatical (14c).

(14) a. The reluctant candidate should accept the position.
b. Should the reluctant candidate accept the position?
c. *The reluctant should candidate accept the position?

The recursive minimalist rule of Merge cannot alone account for these facts. Merge is understood as the process of attaching units together, and in the case of movement, more specifically attaching a unit which has been copied from some other point in the tree to an already existing unit (i.e. in (14b) attaching a copy of the auxiliary verb *should* to the NP *the reluctant candidate*). Merge cannot by itself rule out attachments which would result in the ungrammatical (14c) ; additional machinery is required. The subject auxiliary inversion rule cannot simply count lexical items but must be sensitive to phrasal boundaries, and this information cannot cannot come from the Merge operation. Berwick's suggestion that structure dependence falls directly out of Merge is thus questionable, and more importantly for the current discussion, recursion, defined as it has been at the end of section 5.2, can in no way engender structure dependence.

Displacement has been discussed in detail in sections 2.3.4.4 and 3.2.4. The Move operation selects an element in the course of a derivation that has already been merged, and for reasons of feature checking, moves it to a new position in the derivation where it is merged again. However, movement is not quite this simple. It is necessary that the original location of the moved item is marked in some way for reasons of semantics. Consider the wh-question in (15):

[22] It is further not obvious that Merge operates on *adjacent* items at all; the result of Merge is obviously an adjacency relation, but the input is simply two items from the unordered lexical array.

(15) Who$_i$ did John kiss e$_i$?

The wh-element 'who' has been moved from the position marked e_i (for empty category) to the position at the head of the sentence. Although the wh-element is now pronounced in this new position, we still understand it as being the object of the verb *kiss*, and as such belonging in some sense at the end of the sentence in the position here marked as an empty category. For this interpretation to be possible, movement must not consist just of a shifting process, but must involve a copying process of some sort in addition. This copying process will leave us with some (unpronounced) way of knowing the original position of the wh-element while pronouncing it in its new position.

Berwick (1998:331) assumes that: "...displacement is actually a subcase of Merge...". While it is true that movement involves the application of Merge, it must involve more than just this. Later work within minimalism (e.g. Hornstein (2001)) assumes what is known as the copy theory of movement, where copies of moved elements are sent to the conceptual-intentional system, while all copies except that pronounced are removed by the articulatory-phonetic system. Further, as chapter 2 indicated, movement also involves application of Agree and a pied-piping process. Consequently, Move cannot be a property of language which derives directly from the feature of recursion. The copying procedure, the Agree operation, and the pied-piping process that must all be intrinsic parts of movement are not related to, nor cannot be explained in terms of recursion. So, we have found a feature of language that does not fall out of recursion – movement. We must now ask if this feature is one which makes language 'special'. Do we find movement in the communication systems of other animals? Do we find movement in the other cognitive systems of humans?

These are not easy questions to answer. To begin to attempt answers, displacement must be characterised more generally so as to be able to apply it to non-linguistic systems. Displacement can be understood as the shifting of some sub-part of a unit of the system in question from the position of its intrinsic basis to a position elsewhere, while at the same time somehow retaining a pointer to its original position. Looking first to non-human communication systems, let us question what an analog to syntactic movement might look like. Firstly, movement in human language is forced by some property that is either semantic or syntactic. Thus, the reason we move the wh-element in (15) to the front of the sentence is to form an interrogative. Similarly, the reason we move an element to the front of a sentence in the process traditionally known as *topicalisation* is to place the semantic (or arguably perhaps pragmatic) focus on that element. On the other hand, raising or passive movements are syntactic in nature. Minimalism ensures that such movements are forced by assuming relevant uninterpretable features in the syntactic component. Non-human communication systems, however, lack the syntax of human language (Cheney & Seyfarth 1998). It is therefore difficult to imagine any direct analog of minimalist features forcing syntactic movement. Further, many animal communication systems lack compositionality (see sections 5.3.2.4 and 5.5.2 below for additional discussion). Without compositionality, picking out movement would prove troublesome; that is, in order to move a part of a call to a different position to express an alternative semantic emphasis, the call may not be holistic.

Possible exceptions to this generalisation regarding the lack of compositionality are honeybees and Campbell's monkeys. So, could we imagine what movement might look like in their systems? The dance of the honeybee is composed of three aspects, expressing, respectively, the distance of the food from the hive, the direction of the food from the hive, and the quality of the food. However, these three aspects of the dance are concurrent. We could only imagine movement if one aspect occurred before or after the others. Then, switching the canonical order might constitute something similar to movement in human language if the switch conveyed a more marked meaning. There is no attestation in the literature on honeybees of such a process, however. That is not to say that we can be certain that it does not occur, but would seem unlikely based on the simultaneity of the aspects of the dance.

The Campbell's monkey (about which more in section 5.5.2) emits alarm calls similar to the vervet's. However, they are sometimes preceeded by a boom call (Zuberbühler 2002) which has been interpreted as indicating a change in meaning. The linear order of this system makes it more amenable to imagining a movement process. In other words, we could conceive of the *boom-alarm* complex as the unmarked use of a boom call, and if the monkeys emitted an *alarm-boom* complex which could be interpreted as having a different semantics underlying it, we might want to posit an analog of syntactic movement. However, such a hypothesis would still lack any counterpart to the copying process involved in human language movement. An *alarm-boom* call has not been attributed to the Campbell's monkey at this point. Again, that does not tell us much, in that a lack of evidence does not necessarily mean a lack of existence.

However, it is important to realise that searching for such calls in species of this type may not be the right type of test, or more concerningly, may not be possible. The communication systems of other animals lack many of the features of human language which make direct comparisons near impossible. A lack of syntax, coupled with minimal (if any) semantics, and little compositionality, mean that the problem we are faced with is a great deal more complex than simply picking out comparable processes.

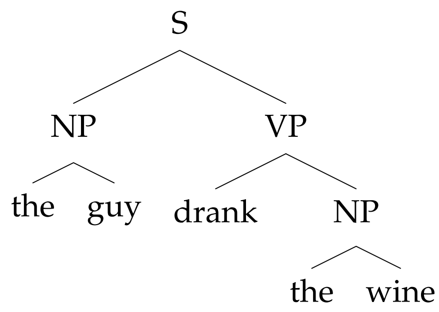
Let us turn now to think about human cognitive systems outside language; do analogs to movement exist here? We might, for instance, imagine that music could provide a parallel in the processes for altering the basic beat pattern of a piece of music. In other words, a piece of music consisting of bars each with four beats can be altered so that a certain bar marks only three of its four beats, with a longer beat falling in the previous or subsequent bar. In this way, we might see the alternation as movement of a beat from its canonical bar to another. However, the analogy can only go this far due to the lack of semantics underlying beat arrangement in music; that is, while syntactic movement in language expresses a change in semantics, musical bars don't have any underlying meaning which is altered by shifting beats.

It seems, thus, that it may also be extremely difficult to discern patterns in non-linguistic human cognition which mirror the property of syntactic displacement. Newmeyer (2004), in fact, notes that movement would not appear to have any accessible function outside communication: "...markers of clause boundaries such as complementizers serve no obvious role in cognition, nor does the 'displacement' of an element from another element with which it is associated semantically." Consequently, we must conclude that at present we have no evidence to support displacement in non-human communication systems or in human non-linguistic cognitive systems. Future work may turn up possible parallels, or we may never manage to overcome the issues standing in the way of such discoveries. For now, however, we might reasonably classify movement as a feature which appears to be uniquely human and uniquely linguistic, categorising it as a feature which sets language apart from these other systems.

The fourth feature which Berwick (1998) talks of is syntactic relations. He mentions a number of such relations which he assumes fall under this category, including subject-of, object-of, and c-command. He then questions why such syntactic relations must be defined in the way they are in other representational theories of grammar, and asserts that this is not required under minimalism, but that instead, the relations come for free. Concentrating on c-command, his specific argument is that the relation reduces to a 'visibility' criterion affecting elements at the time they are merged; that is, elements are only visible to each other if they enter the derivation at the same time. So, elements that have already been combined by an earlier application of Merge are said to have entered the derivation at that point, and cannot 'see' the units that are concatenated to them later on.

Berwick's example is shown (in a slightly adapted form) in (16). Here, when the elements *the* and *wine* are merged to give the NP *the wine* both elements enter the derivation at that point, and so are visible to each other (or c-command each other). A further merge concatenates the NP *the wine* with *drank*. In this case, *the wine* is visible to *drank* and so it c-commands it, but for each of the elements of the NP the case is different - they cannot see 'out of' their phrase; *drank* is not visible to either *the* or *wine* as the former element was not part of the derivation at the time the latter elements entered it:

(16)



In contrast to the previous three features central to Berwick's account, the syntactic relation of c-command, and its asymmetry, do appear to fall out from the recursive application of the Merge operation in an uncontroversial way[23].

Berwick's final feature is locality conditions. These are, in effect, the constraints placed on movement which prevent it from applying without limitation. For example, in (17) below, we cannot move the wh-element *what* further than

[23]This fact was already noted in section 2.3.4.2.

how, but we can do the opposite, as in (18):

(17) *What do you know how John ate?
(18) How do you know what John ate?

Berwick explains the difference in acceptability of these two sentences in terms of feature checking. That is, movement of *what* is blocked in (17) due to the fact that all features of the phrase *how John ate what* have already been checked off in the course of the derivation. The lexical items of this phrase are therefore opaque to movement operations; they have no need to move. However, features remain to be checked in (18) which allow for the movement of *how* that we see here. This explanation revolves around the feature-checking motivation of movement, which relates it to Merge in Berwick's eyes because he believes movement to be simply a subcase of Merge. However, I have shown above how movement is more than just Merge, and so cannot be reduced to recursion. As a result, locality conditions do not follow from recursion directly either.

The question of whether locality conditions are truly uniquely linguistic is again a tricky one. It is impossible to give a definitive answer at present. Broadly, for human non-linguistic cognition, we might cast locality conditions in terms of constraints on memory; that is, human memory places limits on the computations we can carry out. However, memory is far too broad a category to compare with the type of conditions Berwick has in mind. In fact, these conditions are directly related to movement, and so we cannot conceive of parallel conditions in either human cognition or animal communication without first envisaging analogs of movement itself in these domains.

As the quote at the beginning of this subsection suggests, Berwick is aware that there are features of language that are required on top of those that Merge provides. He notes that Merge could have evolved in addition to and subsequent to the emergence of a lexicon. The lexicon is a property that defines language. Without a lexicon, language would not function as it does. We understand a lexicon to be a repository of lexical items, where lexical items are associations of phonological, syntactic and semantic features that are used to build up phrases or sentences. The lexicon provides us with the elements which we use in deriving a sentence, and without it, there would be no sentence to derive. Lexical items are the core of language. As Berwick rightly claims, the lexicon falls outside the domain of recursion in language[24]. Lexical items are combined recursively by Merge, but they themselves are not recursive in any way.

However, Berwick's analysis does not stress the importance of the lexicon as a property of language which is uniquely human and uniquely linguistic. Although we could argue that in our non-linguistic cognitive make-up we find properties similar to the lexicon, there are significant differences. For example, it might be suggested that facts stored in memory are akin to lexical items stored in memory. However, there are two important features which distinguish lexical items from facts. Firstly, a lexical item consists of a form and a meaning, either of which can be used to look up the other. Facts, on the other hand, lack this bi-directionality. Further, as noted by Pinker & Jackendoff (2005), children learn lexical items in significantly different ways to facts. As Markman (1989) shows, childrens' mechanism for learning words relies on the mutual exclusivity bias (where a new word is assumed to have a different meaning to previously learned words), but this does not hold for fact learning.

Turning to non-human communication systems, it might be argued that animals such as vervet monkeys have a lexicon. Their alarm call system consists of calls each of which have an associated meaning. In terms of the human lexicon, the alarm calls possess both form and meaning (or phonological and semantic features). Their system therefore fits the delineation of a complex made of bidirectional units. However, two factors differentiate the vervet calls from human lexical items. For one, there are no syntactic features associated with vervet alarm calls. While the English word *eagle* has phonological features such as [begins with a vowel], semantic features such as [animate, non-human] and syntactic features such as [noun, singular], the alarm call for an eagle in the vervets' system has only features of the first two types[25]. A second distinguishing factor is the size of the human lexicon compared to the vervet 'lexicon'. The former is immensely larger (even for a young child) than the latter. A quantitative difference does not necessarily imply a qualitative difference. Nevertheless, equating the lexicon of a natural language with what we find in other species seems somewhat extravagant.

[24]See section 5.3.2.3 below for further discussion of this point.

[25]The exact nature of phonological and especially semantic features in a non-human communication system is obviously not clear, suffice to say that a reasonable parallel can be posited.

Thus, we would have to conclude that evidence for a comparative parallel to a human lexicon is not available in non-linguistic cognition, and although a lexicon might be posited in other systems of communication, a direct comparison is somewhat questionable. The lexicon (at least in its full human form) is therefore very special, and as such constitutes yet another feature of language which falls into the category of being unique yet not the result of recursion.

It appears at this point that the hypothesis put forward by Berwick is somewhat too simplistic. The properties of language which he discusses seem to be more complex than he suggests. The majority of them are not the result of Merge or recursion, yet they appear to be features that we would want to classify as defining human language; features which constitute a class which stands apart from our general cognitive abilities, and apart also from the general communicative adeptness of non-human animals. This would consequently suggest that the thesis of Hauser *et al.* is also too rudimentary. In what follows, additional features of language will be examined which back up this position. This will culminate in a re-thinking of the division of the language faculty to more clearly identify the factors that make language so unique.

5.3.2.2 Hockett's Design Features

Hockett's (1960) classic paper discussing the origin of speech evaluates human language as being composed of thirteen design features. Many of the features that are mentioned in the paper will not concern us here as they are features which also exist in other animal communication systems. These include the two mentioned at the beginning of this section (semanticity, and the ability to communicate about distant objects and events), and some more besides. However, Hockett also reviews features which are relevant to the discussion here. I will examine one of these in detail: duality of patterning.

Duality of patterning[26], in Hockett's words, refers to "...small arrangements of a relatively very small stock of distinguishable sounds which are in themselves wholly meaningless" (Hockett 1960:90). In other words, meaningful units (morphemes) can be broken down into smaller units (phonemes), which are meaningless in isolation; these meaningless units being able to be recombined in different

[26]See also Carstairs-McCarthy (1999) and Bickerton (1990) for discussion of duality of patterning as an unparalleled characteristic of human language.

ways to give different meaningful units. In this way, there are two levels of examining language – from the meaningful or the meaningless level. For example, the words *cat*, *tack*, and *act* all combine the meaningless units [k], [t] and [æ], but each of these are separate meaningful units themselves.

It appears that this feature of language is absent from any other system of communication. Although certain non-human systems may be able to combine meaningful units in different ways to express different meanings, there is no evidence that meaningless parts of the signal can be discriminated and recombined to form new messages. Taking the communication systems of the honeybee as an example again, a combination of dance shapes will be entirely meaningless[27]. Further, studies which have attempted to teach non-human primates to communicate using human sign language (see Gardner *et al.* (1989), Terrace (1979) among others) have failed to give evidence for duality of patterning in the primates' system. Although human sign language users exploit this universal feature of language in the same way that spoken language users do, the primates in these studies were not taught a full sign language, but rather a very basic version consisting of relatively few uninflected signs and very limited syntax. Duality of patterning was one of the properties that was, as a consequence, simplified out of the system taught to the primates.

It is also hard to imagine the property of duality of patterning being applicable elsewhere in human cognition. The defining feature of the property is its relation to meaning; combining the smallest units of language which on their own have no meaning to give larger units which express meaning. Without semantics, duality of patterning is vacuous. For this reason, there is no other human cognitive system to which we can apply the property; no other system of human cognition would seem to involve combining elements in a variety of manners in order to signify some underlying message.

As before, there is nothing to say that the property of duality of patterning will not be uncovered in some other species' communication system by future research. However, it currently looks like a uniquely human, uniquely linguistic property, making it one of the features that makes language 'special'. What does

[27]For example, the circle shaped dance is used to convey that the distance of food from the hive is minimal, while the waggle dance indicates that the food source is a long distance away. Combining the two to give a circle-waggle complex does not mean that the food is a medium distance away (or anything else for that matter).

seem clear is that there is no sense in which we can explain duality of patterning as being due to linguistic recursion. It is true that we combine meaningless units (phonemes) to give larger units (morphemes) in the same way that phrases are combined to give larger phrases or sentences, but there is neither self-embedding of phonemes within themselves or self-embedding of morphemes within themselves to create larger morphemes, nor is there any sense of having to keep track of a phoneme, while undertaking some other computation, and then returning to that phoneme.

Hockett has drawn our attention to an additional feature of human language which sets it apart from other communication systems and other cognitive systems. We have seen that this feature is not the result of recursion. So, it seems that the recursion-only hypothesis of Hauser *et al.* and, more generally, the claims of minimalism, are looking less convincing.

5.3.2.3 Pinker & Jackendoff and the Recursion-only Hypothesis

Pinker & Jackendoff (2005) present a critique of Hauser *et al*'s claims, and of minimalism more generally. Their problems with the recursion-only hypothesis revolve around the fact that minimalism appears to ignore many fundamental properties of language. The properties they discuss fall outside the domain of recursion, yet are plainly features that we would want to associate with the core capacity of language.

Phonology is examined in depth by the authors, and they conclude that the Minimalist Program simply disregards this aspect of language. As they conceive of Hauser *et al*'s thesis as being based on the thinking of minimalism, for them it follows that this thesis too fails to consider phonology. While it is questionable as to whether minimalism generally fails to account for phonology (it must have some place in the theory if the central idea is that syntax mediates between a conceptual-intentional system and an articulatory-phonetic system), it is clearer that Hauser *et al.* do not consider phonology as an aspect of language that falls into its narrow sense[28].

Under the heading of phonology, many more particular aspects are discussed by Pinker & Jackendoff. These include the separation of language into syllables,

[28]Responding to Pinker & Jackendoff's criticisms, Fitch *et al.* (2005) do, in fact, weaken their position slightly, stating that "...much of phonology is likely part of FLB...". Nevertheless, many of the points below remain.

metric feet and other phonological divisions. These types of categories, or mechanisms which could be classed as similar, do not appear to exist outside human language, in human cognition or in non-human communication. Moreover, although phonology can be thought of as organised in a hierarchical fashion, it cannot be conceived of as involving recursive self-embeddings in any of these categories.

Pinker & Jackendoff draw our attention to Hauser *et al*'s placement of the lexicon outside of the narrow language faculty. As pointed out in section 5.3.2.1 above, this seems ill-judged. Language without a lexicon is not conceivable. Furthermore, nothing in the sense of the human mental lexicon exists outside human language. The lexicon is therefore clearly an example of a property which makes language 'special'.

Looking at this point in more depth, we can find many features of the lexicon to back up this claim. Firstly, consider the size of the vocabulary of a human language, and the range of concepts which we can refer to. This vastly surpasses any other animal's communicative abilities.[29] Secondly, the lexicon is wholly learned by each and every generation using a particular language. None of it is already built into our brains when we are born, unlike the 'vocabulary' of some other species (e.g. honeybees or vervet monkeys (see Oliphant (2002), Seyfarth & Cheney (1986)). Thirdly, lexical items are completely arbitrary pairings of meaning and sound. There is no sense in which the phonetic realisation of a lexical item has the semantics of the concept or entity that it identifies built-in; [kæt] is not an animate, fluffy, feline sound.

None of these particular features of the lexicon indicate that it should be explained in terms of recursion, as we noted above. However, a final point that Pinker & Jackendoff make about the lexicon is that morphology, the domain of word composition, "...constitutes the classical domain of recursion à la HCF...". Morphemes can be combined recursively to generate words. However, although lexical items can be formed by recursive processes, there is much more to morphology than simply recursion. Non-recursive morphological processes that form words include the use of templates, affixation, and stem modifications including umlaut and ablaut. Pinker & Jackendoff's conceding of morphology to the scope of recursion is therefore unnecessary. Morphology is not only unique

[29]This property of language is also advanced by Carstairs-McCarthy (1999) and Bickerton (1990) as a defining character of our faculty.

to our communication system, and unique to language as a cognitive system, but much of it is independent of recursion. The lexicon is also clearly unique in the same manner. Therefore, we have established another principal property of language that designates it as a faculty *sui generis*.

In analysing syntax, Pinker & Jackendoff uncover a number of properties of language which the recursion-only hypothesis does not take heed of, yet are clearly highly important. They mention such syntactic devices as pronouns, articles, complementisers, auxiliaries, quantifiers, tense and aspect, all of which have significant roles to play in the syntax of human language. None of the animal communication systems surveyed so far (and later in this chapter) could be considered to exhibit such devices, for the simple reason already noted that such systems lack 'syntax' as it is defined for human language. In non-linguistic human cognitive domains, it is difficult to imagine what might constitute admissable parallel mechanisms.

Again, the features considered in this section have a number of things in common – they appear to be uniquely human and uniquely linguistic, and they (with the exception of the morphological component) are not a consequence of, nor can be analysed in terms of recursion, thus providing yet more issues for the thesis of Hauser *et al.*

5.3.3 Discussion

In the preceding subsections, many features of human language have been explored. The point has been made repeatedly that the majority of these features appear to be unique to our communication system, while at the same time being unrelated to recursion as it was defined in section 5.2. The caveat that has also been reiterated is that the current state of our knowledge about both non-human communication systems and human non-linguistic cognition curtails the parallels we can draw between these domains and human language, forcing the questions being asked here into the realm of the intractable. Future analysis and experimentation may allow these issues to become more pervious, and indeed may lead to the discovery of suggested analogies. For now, however, this enumeration of features implies that the proposal of Hauser *et al.* - that recursion as the sole defining property of language that makes up the faculty of language in the narrow sense - is flawed.

Hauser *et al*'s division of the language faculty into the broad and narrow senses has clear motivation, and even those who have criticised their precise claims (e.g. Pinker & Jackendoff (2005)) agree that it is smart from a conceptual point of view to divide the faculty into these two senses in order to be better able to tackle the questions of language evolution. However, what seems clear from the foregoing discussion is the fact that the dividing line that Hauser *et al.* draw is not in the right place. The faculty of language in the narrow sense is meant to refer to those properties of the human language faculty which are not shared with non-human animals, and which cannot be found in any of our other cognitive capacities. While Hauser *et al.* see recursion as being the lone feature which fits this categorisation, there are clearly others which must belong in the narrow language faculty too.

Figure 5.8 below schematises the features of the language faculty considered above. It displays seven features of language which fall into the class of features which, based on the preceding discussion, and taking the caveats there into account, would seem to belong in the narrow language faculty, and that are not linked directly to recursion. It further sets out two properties of language (discrete infinity and syntactic relations), which although related to recursion, should nevertheless be classified as separate from the property of recursion. We therefore need to extend the range covered by the language faculty in the narrow sense. We should keep the conceptual distinction drawn up by Hauser *et al.* of segregating those properties of language which are evident (albeit often in somewhat altered forms) in systems external to language from those properties which function singularly as idiosyncrasies of human language. However, we should allow the faculty of language in the narrow sense to include more than simply the property of recursion. Through the discussion above, it should have become evident that those features of language which belong in the narrow sense of the faculty do not just revolve around recursion, nor do they just revolve around syntax, but they encompass properties which fall into the domains of syntax, phonology, semantics and the lexicon.

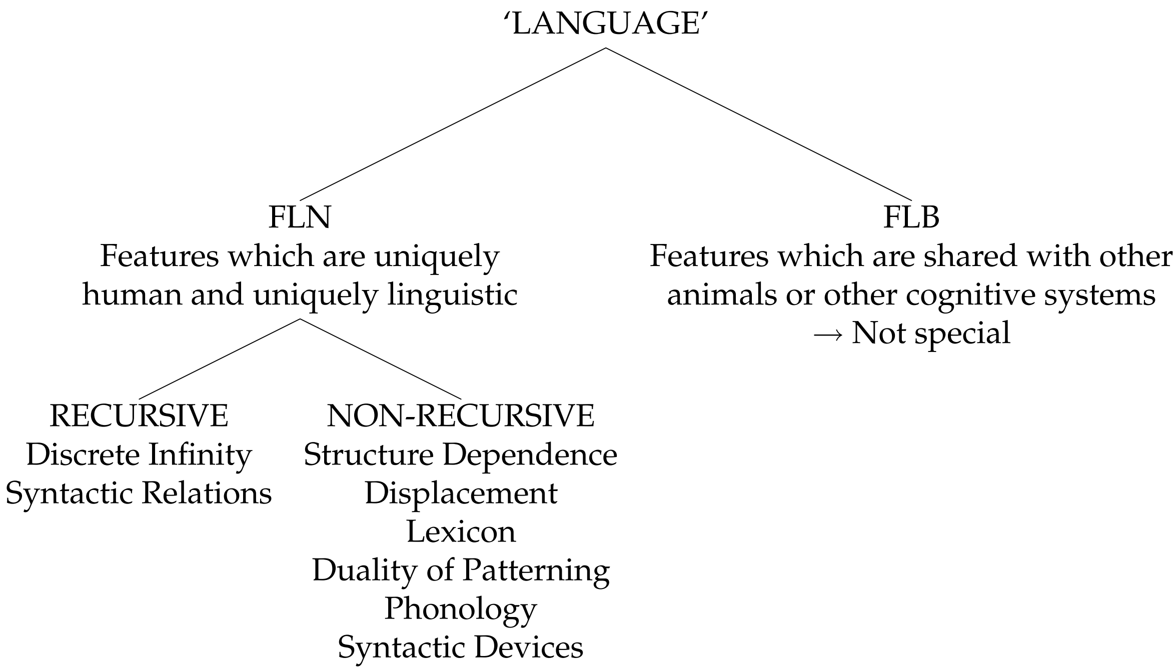


Figure 5.8: Features that make language 'special'

5.4 Phrase Structure and Recursion

In section 5.2 above, I introduced some definitions of recursion from the linguistics literature which referred to the concept in terms of *phrase structure*. I noted there that although the notion of phrase structure is important in discussions of recursion, the concepts are not synonymous. In this section I will examine the differences between phrase structure and recursion. In order to do this, I will firstly give an explanation of the term *phrase structure*, employing the historical details of its use in linguistics to aid comprehension. I will then determine what differentiates phrase structure from recursion in language, and will explicate this point in more depth by looking at the issue of semantics that was touched on in section 5.2.

5.4.1 What is Phrase Structure?

Chametzky (2000:3) defines phrase structure as "...[organising] sentence structure in terms of constituent hierarchies." What is meant by this is the well-known fact about language that it is made up of units which are combined into larger units. In other words, lexical items are combined to give phrases and phrases are combined to give still larger phrases or sentences. Phrases are understood to be constituents that act as single units in certain ways. So, while we can derive sentence (20) from (19), we cannot derive (21):

(19) John spoke to the professor.
(20) It was the professor that John spoke to.
(21) *It was professor that John spoke to the.

The reason for this is that only entire constituents can be moved; parts of constituents cannot be displaced on their own. Thus, *the* and *professor* together form a constituent or phrase.

Phrase structure refers to the manner in which the elements in a sentence are arranged. An important consequence of the manner in which sentences are put together is that they are not simply linear sequences of words or phrases, but are organised hierarchically. Thus, as Bickerton (1990:60) puts it "...phrases are not strung together serially, like beads on a string. Phrases are like Chinese boxes, stacked one inside another." Phrases are not simply concatenated, but one phrase can contain within it another phrase. This is illustrated in (22) where a sentence is broken down into a noun phrase and a verb phrase, and the verb phrase contains a noun phrase, which in turn contains a preposition phrase[30].

(22) $[_1\text{Jack } [_2\text{met } [_3\text{the man } [_4\text{from Cork.}_4]_3]_2]_1]$

5.4.1.1 *The History of Phrase Structure in Linguistics*

Phrase structure is a fundamental aspect of human language, and as such has played a central role in theories of language for almost a century. Bloomfield was one of the first to talk of sentences as being composed of what we generally refer to as *phrases*. He began with the Immediate Constituent Analysis of structuralism (Bloomfield (1917), Wells (1947)), which categorised the various structural parts into which a sentence can be factored. Subsequent work (Bloomfield 1930) further determined the anatomy of syntactic structures as consisting of constituents or phrases. Chomsky's *Syntactic Structures* later introduced phrase structure as one of three main components making up the system of language, manifested through the use of phrase structure rules similar to those seen earlier in section 5.2. The *Aspects* model refined the use of such rules by introducing the notion of Deep Structure as a base level at which the phrase structure rules could produce recursion[31].

The use of such rules came under question towards the end of the 1970's. The phrase structure rules of the earlier theories were problematic both because of their expressive power, and because they were redundant. The earlier model allowed for logically possible but non-occurring rules which would generate sentences that were not acceptable[32]. In other words, the phrase structure rules overgenerated, and only by adding complexity to the model in the form of restrictions on the phrase structure rules could this problem be overcome. Phrase structure rules became redundant once selectional and subcategorisation restrictions to deal with difficulties such as the one in footnote 31 were posited in the lexicon (Chomsky 1981). If the lexical entry for a verb encodes whether it is transitive and thus selects a NP complement or intransitive and thus doesn't, the role of phrase structure rules becomes less clear. As a result, in the subsequent generative model of GB theory, they were eliminated altogether. A consequent

[30] The numbered brackets indicate the hierarchical organisation of the phrases.

[31] Section 5.4.2 below discusses how phrase structure can produce recursion.

[32] For example, a rule such as $VP \rightarrow V\ (NP)$ does not encode which particular verbs take a NP complement and which don't, but suggests that both *Jim fell* and *Jim fell the ground* should be acceptable.

major reworking of the theory engendered what is now known as X-bar theory[33].

The success of X-bar theory came in large part from its importance for questions of acquirability and cross-linguistic variation. Phrase structure which is largely universal and generic across categories would be more easily acquired, while at the same time differences across languages can be captured by appealing to directionality parameters.

The recent development of minimalism has led to further revisions in the domain of phrase structure. Put simply, the economy and simplicity considerations of the MP judge the X-bar structure to be overly complex and baroque. Chomsky (1995a) introduced *Bare Phrase Structure* as an answer to this. Bare Phrase Structure is centred on the Inclusiveness Condition (see section 2.3.3.1), which says that the syntactic features of a non-terminal node can be fully recovered from the structure it dominates, while the syntactic features of a terminal node can be fully recovered from its entry in the lexicon. In other words, all details in a tree structure which exist purely to indicate the level of projection must be removed.

5.4.2 Phrase Structure versus Recursion

In much of the linguistics literature recursion is often either confused with, or subsumed under, the concept of phrase structure. This section will explain why these concepts are not one and the same, although they are closely linked.

As was discussed in section 5.2 , phrase structure rules can generate recursive phrases and sentences when phrases are allowed to be embedded either directly or indirectly within phrases of the same type. So, recursion occurs by allowing phrase structure rules to apply recursively. Christiansen (1994) distinguishes between three ways of deriving recursive structures from such rules: (i) left-embedding, (ii) right-embedding, and (iii) centre-embedding.

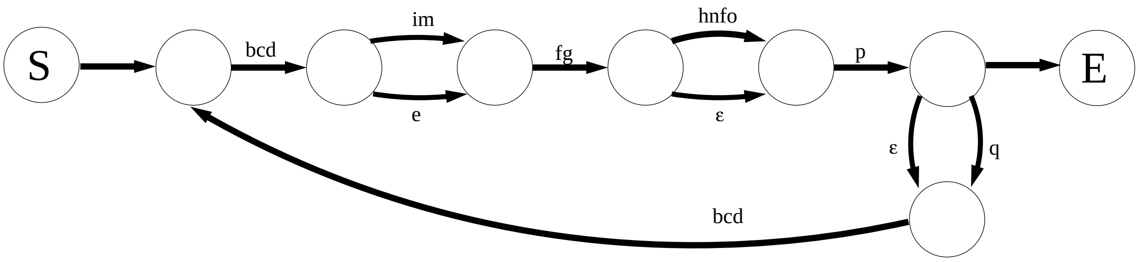
Abstracting away from such phrase structure rules, for the reasons discussed above, we can explain the difference between phrase structure and recursion as follows. Phrase structure is simply the architecture of the elements in a sentence; the hierarchical organisation of phrases. Recursion is not directly entailed by such hierarchical structuring however; a structure can be hierarchical without being recursive. It only arises when the specific phrases that are embedded

[33]See Jackendoff (1977) for detailed discussion.

inside each other are of the same type. Phrase structure is therefore required in order for recursion to be possible in language, in that we need the ability to structure hierarchically before we can embed recursively, but phrase structure alone does not guarantee recursion.

Let us consider what it might mean for a system to be organised hierarchically but not recursively. Okanoya (2002) discusses the communication system of the Bengalese finch (*Lonchura striata* var. *domestica*), a domesticated songbird with a particularly complex song. He claims that the song can be described using a finite state syntax, giving the example in (23):

(23)



Each letter in the diagram represents a different note in the song. It is clear to see that there are composites of notes that always occur together in a sequence, such as *bcd* or *hnfo*. Okanoya labels such groups of co-occurring notes *chunks*, asserting that chunks can further be combined to give *phrases*[34]. Using (23) we can determine some possible songs according to this organisational structure, as given in table 5.3.

[34]It is unclear from Okanoya's presentation exactly what in the above example should constitute a phrase. One might plausibly consider a phrase to begin at S and end at the final transition point. For this reason, I have omitted the phrasal level of analysis from what follows. This in no way affects the issue here.

	Song	*Chunks*	*Notes*
SIMPLE	bcdefghnfop	bcd, e, fg, hnfo, p	b,c,d,e,f,g, h,n,o,p
COMPLEX	bcdefgp bcdbcdimfgp	bcd, e, fg, p, im	b,c,d,e,f,g, p,i,m
COMPLEX	bcdimfghnfop qbcdbcdefghnfop bcdbcdefgp qbcdbcdimfghnfop	bcd, e, fg hnfo, p, q, im	b,c,d,e,f,g, h,n,o,p,q,i,m

Table 5.3: Some example songs of the Bengalese finch

Okanoya's analysis might suggest a non-recursive hierarchical structure such as that in figure 5.9[35].

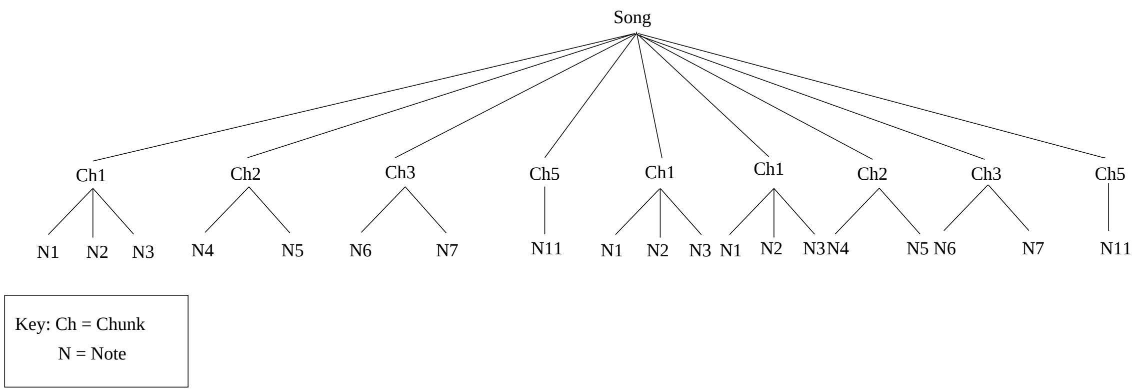


Figure 5.9: Non-recursive hierarchical structure for Bengalese finch song

Importantly, however, this is just one way of viewing how a structure might be derived from the finite state automaton in (23). The recursive hierarchical structure in figure 5.10 could also be generated from this machine.

[35]This structure illustrates just one possible song.

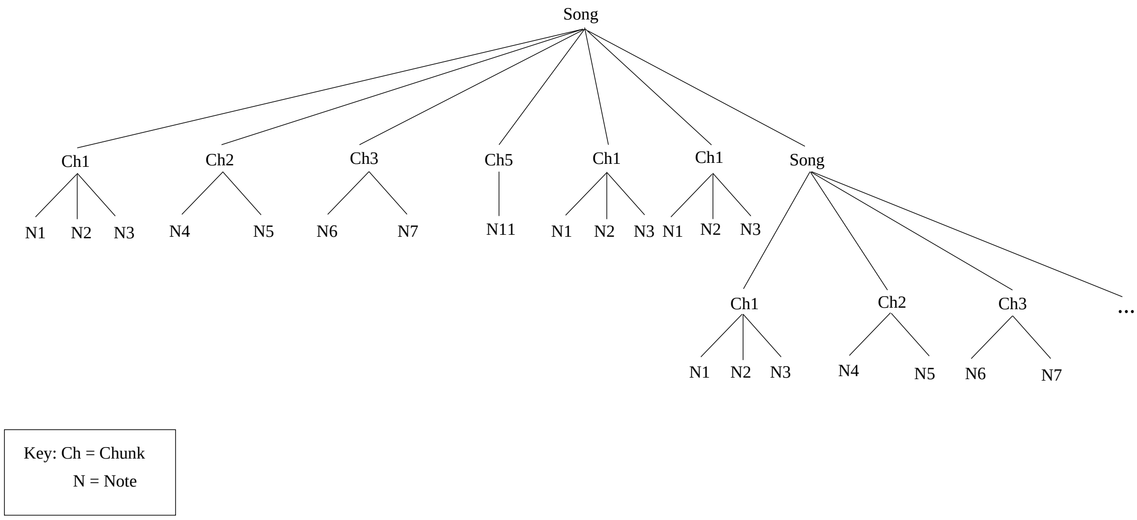


Figure 5.10: Recursive hierarchical structure for Bengalese finch song

In the case of the birdsong data, we are dealing only with strings of notes, there is no semantics to indicate the structure behind the strings. The finite state automaton can determine which strings can be generated, but cannot provide a way of determining which of the structures in figures 5.9 and 5.10 is the correct one; in other words, it is weakly adequate only[36]. Therefore, we cannot tell if this birdsong system is recursive. As we will see in section 5.5.3, this is a crucial issue in discussions of recursion. The difficulty in recognising recursion in non-human systems of communication often hinges on whether we can analyse the systems in question in terms of structure, or if we only have access to strings.

5.4.2.1 Semantics and Evolutionary Considerations

A further important distinction between phrase structure and recursion involves the extent to which they express meaning. We can begin the discussion of this issue by noting an idea alluded to by Fitch (2004). There, he suggests that phrase structure without semantics is possible. Indeed, he proposes that "...the ability to construct and process phrase structure, independent of meaning, is a crucial component of our ability to make "infinite use of finite means" in language...". How are we to interpret this statement, given our understanding that phrase structure is the hierarchical positioning of elements in a sentence, and as such

[36]One common way of generating trees from such a machine is to create the corresponding regular grammar, and use this to parse the sentence. This would give a recursive structure. However, this is merely a result of the translation of the machine into a restricted set of rewrite rules, rather than something intrinsic to the way in which a finite state automaton generates or parses a string.

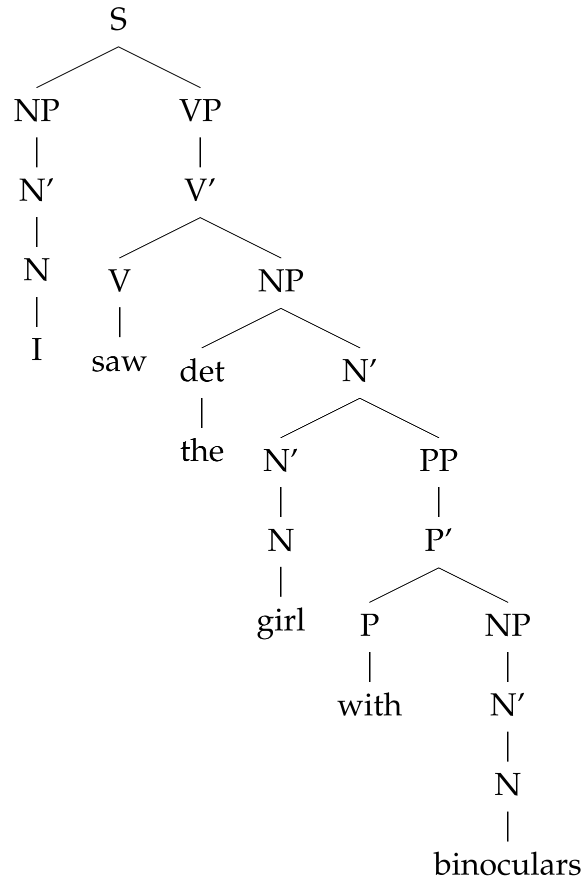
must reflect the semantic relations between these elements (Pinker & Jackendoff 2005)?

Fitch elaborates: "...embedding phonemes within syllables within words within sentences, we can use a small "alphabet" to generate an unlimited set of signals." Breaking this down slightly, we can draw a conceptual line after the point of syllables in this list of units, before we get to words. Words involve meaning, as do sentences; phonemes and syllables do not. So, we might understand the claim here to say that in combining the smallest elements of language – phonemes – into syllables, we use the same type of architecture as we do in combining the larger elements we have been discussing. Phrase structure, understood as hierarchical organisation, can equally be applied in phonology; phonemes are combined to give syllables, syllables are combined to give metrical feet. Consequently, we can say that phrase structure can exist independently of semantics. This point is backed up by arguments of the existence of phrase structure in music, which is devoid of the same type of meaning (Lerdahl & Jackendoff 1983).

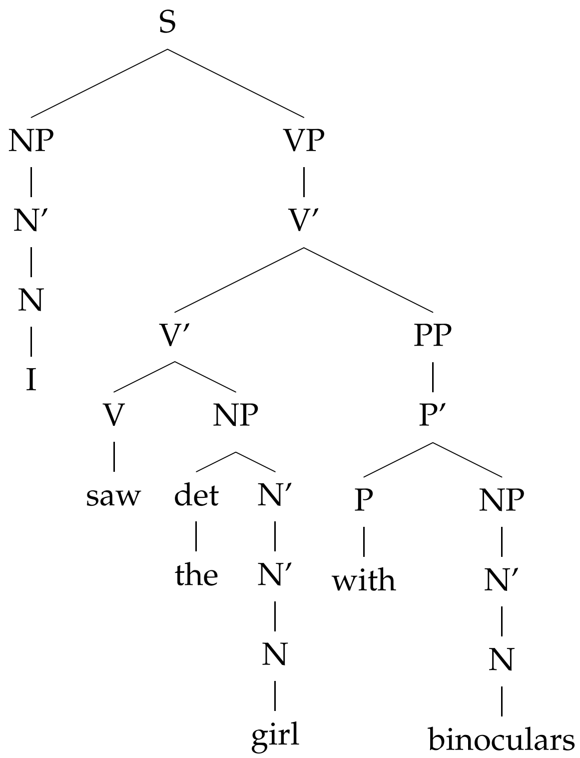
It is only once we reach morphology (the combination of morphemes to give words) and syntax (the combination of words to give sentences) that we need to worry about meaning. For example, although the sentence in (24) has only one linear order, it has more than one hierarchical organisation. These different structures, given in (25) and (26), indicate different interpretations of the sentence. In other words, the semantics associated with the structures are different.

(24) I saw the girl with binoculars.

(25)


S
NP
VP
N′
V′
N
V
NP
I
saw
det
N′
the
N′
PP
N
P′
girl
P
NP
with
N′
N
binoculars

(26)


S
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It is also only once we reach the domain of syntax that we invoke recursion as an explanatory tool. Recursion, as discussed earlier, has no place in phonology. Furthermore, as was touched on in section 5.2 above, and as will be examined further in section 5.5 below, in natural language semantics plays an important role in recursion. That is, linguistic recursion involves larger units containing smaller units, these smaller units semantically further defining the larger unit.

At this point, we have seen that phrase structure can exist independently of meaning, yet as the examples in (25) and (26) show, the exact hierarchical positioning of a particular element *can* affect the meaning of the sentence or phrase. Furthermore, phrase structure can also give rise to recursion, which in human language involves semantics[37]. We can now consider the situation from an evolutionary perspective.

Following Fitch (2004), let us assume that phrase structure independent of meaning is possible. It might be the case that such a hierarchical organising process evolved in our ancestors as a solution to problems of a non-linguistic kind, such as navigation, tool use, or social relations. In fact, work in animal cognition has produced hypotheses about the great apes that suggest the existence of hierarchical processing skills for food preparation (Byrne & Russon 1998), foraging (Whiten *et al.* 1996), (Whiten 2002) and social intelligence (Worden 1998) (see section 5.6.2 for more detail).

Later, this hierarchical processing capability could have come to be used in language as a procedure for building larger linguistic units out of smaller ones. In the case of phonology, the capacity was useful as it was with little modification required. However, in building multi-word phrases and sentences, the capacity was enhanced so that the position of units in the hierarchy mirrored the conceptual relations being communicated (what Jackendoff (2002) and Pinker & Jackendoff (2005) point to as our usual understanding of phrase structure). Once this was possible, phrase structure could then incorporate recursion in order to communicate recursive conceptual structures by allowing units to be located as hierarchical sub-units of units of the same type[38]. The emergence of recursive

[37]But see section 5.5 for detailed discussion of the interplay between semantics and recursion.

[38]That is, providing that the existing conceptual structure was already recursively specified. See section 5.6.1.5 for further discussion of this issue.

phrase structure would have accordingly increased the set of communicable conceptual relations many-fold[39].

To summarise the proposal, language was early on non-hierarchically organised, and only later was hierarchical organisation imposed on language through a process of exaptation from some non-linguistic cognitive domain. This ability to organise hierarchically would have remained essentially unaltered in the phonological domain, but would have been shaped in the syntactic domain to become semantically interpretable. The final step would have been to modify the semantically interpretable hierarchical organisation to allow elements of the hierarchy to be embedded inside elements of the same type, resulting in recursive syntax. This account accords with Simon's (1962) reminder that complex systems are likely to evolve in an incremental fashion where intermediate steps along the way represent stable *sub-assemblies*: "[t]he time required for the evolution of a complex form...depends critically on the numbers and distribution of potential intermediate stable forms" (*ibid*:471). Recursive semantically interpretable hierarchically organised syntax would have been preceded by three stable intermediate forms: (i) non-hierarchically organised syntax, (ii) non-semantically interpretable hierarchically organised syntax, and (iii) semantically interpretable hierarchically organised syntax.

In this section, I have examined the fundamental hallmark of language known as phrase structure, in a bid to distinguish it from the concept of recursion under investigation in this chapter. I have shown that although phrase structure is required in order that we can have linguistic recursion, it does not necessarily entail recursion. I have also drawn a distinction between phrase structure, which is simply a hierarchical architecture, independent of meaning, which exists in phonology, and the type of semantically-driven phrase structure associated with syntactic organisation. Finally, I sketched the outlines of a possible evolutionary

[39] It is worth noting here that an evolutionary proposal with some (superficial) similarity to the present one is offered by Carstairs-McCarthy (1999). His is a more restricted hypothesis about the evolution of syntactic structure from the prior existence of phonological structure. Specifically, he advances that the asymmetric relation between noun phrases and sentences mirrors the asymmetry of the syllable, and that this parallelism reflects an evolutionary development; that is, the structure of the syllable was exapted for sentence structure. However, there is a significant difference between Carstairs-McCarthy's syllabic model and what is being set out here. As Tallerman (2006) points out, the syllabic model assumes a very traditional view of sentence structure – the division into subject and predicate – while the majority of modern syntactic theories are based around the notion that a sentence is just one type of phrase with many of the same features as any other type of phrase (e.g. NP, VP, AP etc.). The hierarchical phrase structure of sentences being discussed in this section assumes this latter division of labour in syntax too.

scenario for the development of meaningless phrase structure into meaningful recursive phrase structure.

5.5 The Importance of Semantics

In sections 5.2 and 5.4 above we left open the question of the relation between recursion and semantics. Here we will return to this question by examining a number of issues which fall out from considering how recursion is affected by meaning. Specifically, I will look further at the distinction made in section 5.4 between phrase structure which exists independently of meaning and semantically-driven phrase structure. This will lead to an examination of semantics in the communication systems of other species. I will suggest that a lack of recursion in other animals' systems of communication may be related to the fact that other species do not possess semanticity to the same extent or at the same level that we do. Then I will further investigate the conclusion drawn in section 5.2 that iteration does not involve semantics, while all types of recursion (including those that have been suggested to be re-analysable in terms of iteration) do.

5.5.1 Phrase Structure revisited

Above, I sketched a possible evolutionary account of the development of phrase structure. It was suggested that phrase structure first arose in human language as an architectural possibility for constructing lexical items. This process was argued not to involve meaning, in that the units which make up syllables, metrical feet, and morphemes do not have a semantic representation. It was further proposed that what we normally understand by the term 'phrase structure', that is, the structure of lexical items which form phrases and sentences, does involve meaning.

So, we can draw a two-way distinction. On the one hand, there is structure which is meaningless. This is what Marler (1977) refers to as *phonological syntax*. On the other hand, there is structure which reflects meaning in some way. This is Marler's *lexical syntax*. Lexical syntax involves the assembling of phrases and sentences using lexical items as building blocks. As mentioned earlier, lexical items are constructs which embody an arbitrary connection between sound and meaning; each one is associated in the mind of a user with some representation of an entity or action in the world. When we combine lexical items, the resulting phrase or sentence also has a meaning; it picks out some situation in the world.

We further noted in section 5.4 that once we had meaningful phrase structure, we had the possibility of having recursive phrase structure. Meaningful phrase structure allows us to combine lexical items in such a way as to directly reflect the concepts we wish to convey. In other words, meaningful phrase structure allows us to select particular entities as being active in a situation; it allows us to convey who or what undertook some action and who or what was the recipient or target of that action. Now we might ask, why is it that recursion should only arise once we reach this point in the development of phrase structure? The answer is a claim that is not new (see e.g. Fitch (2004), Newmeyer (2004)) – recursive phrase structure reflects the recursive conceptual structure that we wish to communicate. If we want, for example, to communicate about a person who is unknown to our interlocutor, we may talk about the person in terms of who they are related to or who they know (e.g. *John's uncle's sister* or *The girl who works in John's office who lives next door to Bill*). In order to do that we use a recursive phrase to express the recursivity of the underlying thought[40].

So, recursion in natural language is plausibly a result of the need to communicate recursive thoughts. As recursive thought is arguably common, so is recursive phrase structure. What we now need to ask is, if other species lack the ability to communicate recursively (this question will be examined in more detail in section 5.6.3 below), is this due to the fact that they do not have recursive conceptual structure to express, or is it instead the case that although other species are capable of thinking in a recursive manner, they simply do not possess the equipment (or perhaps the motivation) to translate this thought into a recursive vocal signal?

At present, we cannot give a definitive answer. However, work which will shed light on this two-fold question is research which investigates whether other species have a theory of mind (see, for example, Povinelli (1996), Hare *et al.* (2001) and Premack & Premack (2002)). If other animals are capable of having thoughts about the thoughts and knowledge of others (i.e. if they are capable of such conceptual structures as *I know that Bill thinks that Jane knows that John knows that...*) then they have recursive conceptual structure. Worden (1998) proffers a proposal which suggests that human language has evolved directly from primate social intelligence. He claims that social intelligence, the ability to use past and present knowledge of social situations to be able to predict future events, grew into a theory of mind, the ability to know what others know, which then grew

[40]It is, of course, an assumption that our conceptual structure is organised in the same way as the language which conveys it, i.e. recursively. However, until we can prove otherwise, and based on the discussions to follow in section 5.6, this would seem to be the best null hypothesis to adopt on the matter, and it will be assumed throughout.

into human language as a direct application of these two mental faculties. Worden's hypothesis fits well with the approach outlined here; although it does not answer the questions posed in the previous paragraph, it suggests that they are the right questions to ask, and that future results in theory of mind studies in other species will indeed steer us towards unravelling the issues[41].

5.5.2 *Semantics in other Species*

Following on from these questions, this section will investigate the existence of semantically interpretable syntax in the communication systems of other species. The term 'semantically interpretable syntax' is just another way of referring to the property of human language discussed under the heading *lexical syntax* above; that is, the fact that human language phrases and sentences are structured in such a way as to reflect the meaning that they convey. The question to be addressed here is whether any other animals exhibit lexical syntax in their systems of communication.

In section 5.4.2 above we examined the song of the Bengalese finch (Okanoya 2002). We learned that the bird's song can be described using a finite state syntax; the song consists of units which are embedded inside other units. However, although this may at first appear to be an indication of semantically interpretable syntax, as was noted in section 5.4, the song has no semantics, and the low-level embedding does not reflect any semantically determined relations. It is worth noting that the song of the chaffinch (*Fringilla coelebs*), whose syntactic division into *trill* and *flourish* elements might also appear to hint at compositional semantics, similarly lacks lexical syntax. Although the length of these two elements affects male and female preferences (Leitão & Riebel (2003), Riebel & Slater (1998)), the song cannot be analysed as having semantically interpretable syntax.

In section 5.3.2.1, Zuberbühler's (2002) experiments involving Campbell's monkeys (*Cercopithecus campbelli*) were briefly alluded to. The experiments involve both the Campbell's monkey and the neighbouring Diana monkey (*Cercopithecus diana*). He claims that the calls of the former manifest lexical syntax. The Diana monkey has been shown to react to the alarm calls of the Campbell's monkey by issuing its own corresponding alarm call. In this paper, Zuberbühler proposes that an additional call, a *boom*, which the Campbell's monkey sometimes vocalises prior to the alarm call, in combination with the alarm call serves

[41] I will look further at theory of mind studies in sections 5.6.1 and 5.6.2 below.

to communicate a different meaning – for example, some other disturbance happening locally, like a falling tree. The paper indicates that the Diana monkey, on hearing the boom-introduced alarm call, does not have the same reaction as when it hears the alarm call on its own. The Diana monkey must therefore be interpreting this vocalisation differently. Consequently, Zuberbühler concludes that the combinatory rule of *boom + alarm call* is linked to a concurrent change in meaning; that is, the phrase structure of a Campbell's monkey is lexical, or semantically interpretable.

Narins & Capranica (1978) report experimental work suggesting that the coqui tree frog native to Puerto Rico (*Eleutherodactylus coqui*) also manifests a degree of lexical syntax in its song. Male frogs emit a two-note mating call which changes when another male is approaching. The usual call consisting of two different notes is replaced in these cases by a call consisting of a repetition of the first note only. The authors suggest that the first note may serve as a territory signal, whereas the second note serves as the female-attracting signal.

Work on the communication system of honeybees (*Apis mellifera*) (von Frisch 1966) indicates that they too may have a degree of lexical syntax. The honeybee dance combines three components to express three pieces of information in one signal.

At this point it may appear that we have found evidence of semantically interpretable syntax in other species, and we may want to move on to questioning why these species do not then appear to have recursive phrase structure. However, we should not be so quick to make assumptions of equivalence between these systems and human language. As Hurford (2004) has pointed out with regard to the Campbell's monkeys' boom-introduced alarm calls, these are not comparable to the complex syntax of human language in that these calls are not learned. The calls of the Campbell's monkey are innately determined. Moreover, the combinatory rule posited by Zuberbühler shows none of the complexity of human language syntactic rules, and as Hurford (2004:559) asserts: "[i]t would be extravagant to attribute any human-like meaning, such as negation, or modal operator (e.g. *maybe*), to the boom." A final issue with this example of lexical syntax is the fact that the 'speaker' and 'hearer' are of different species. It may be difficult to attribute compositional semantics to the Campbell's monkey simply on the reaction of the Diana monkey. Does the Diana monkey have the ability to interpret the calls of the Campbell's monkey, or is she merely reacting to a difference in acoustics only?

As for the coqui frog's song, although playback experiments did support the author's claim that only the first note of the song is directed towards other males, the degree of lexical syntax is again not comparable with human language. The important factors are again the learned-versus-innate variance, and the huge asymmetry in magnitude of signals.

Looking now to the honeybees' dance, we can similarly claim that it is not safe to make direct comparisons with human language. The reason in this case is that the honeybee communication system is again not learned, but is innate. Furthermore, the signals used by the honeybee are not symbolic, but are iconic. While human language signals bear no intrinsic feature of the entity they pick out in the world, the dance of the honeybee is fast and lively when food is of good quality, and even more obviously, the honeybee's body is directed to point towards the food. The point then, is that although the honeybee's communication system combines a number of semantically interpretable signals, the signals used are significantly different to the lexical items of human language. While human language combines arbitrary symbols in semantically interpretable ways, honeybees combine iconic signals. Differences such as these mean that we need to be careful about not comparing like with like.

A final possibility to consider is the 'language' of trained apes. A number of researchers (among others Terrace (1979), Savage-Rumbaugh & Lewin (1994), and Gardner *et al.* (1989)) have spent considerable time and effort over the last thirty or so years training chimpanzees and bonobos to learn human language. Due to apes' inability to vocalise in the way that humans can, these projects have used various devices including sign language and lexigram systems to investigate if these animals can learn something equivalent to human language. Although these studies have shown that both chimpanzees and bonobos are capable of learning to use symbols (although, in a manner quite limited when compared to even human children's abilities), there is little consensus as to whether the animals learn to combine these symbols in order to reflect an underlying meaning. A number of researchers have claimed that their subjects used word order in sentences (e.g. Gardner *et al.* (1989) for Washoe). Greenfield & Savage-Rumbaugh (1994) have further argued that Kanzi, a bonobo, not only managed to learn, but also invented productive grammatical rules, and could also understand the difference between such English sentences as *Put the water in the milk* and *Put the milk in the water*. On the basis of work with the chimpanzee Nim, Terrace *et al.* (1979), on the other hand, concluded that multi-symbol utterances may be the result of rote learning, or that the order used may be a result of the order used by the trainer.

Although Greenfield & Savage-Rumbaugh (1994) report that this is not the case for Kanzi, it is still unclear as to whether we can posit positive evidence of lexical syntax in such cases. For one, it has been claimed (Seidenberg & Petitto (1979), Kako (1999)) that such studies do not provide enough data to conclusively rule out non-linguistic interpretations. Moreover, in Kanzi's case, the categories that he applies ordering rules to appear to be non-syntactic, but rather reflect the modality of the symbol (Kako 1999)[42]. Another important argument that has been laid at the door of such research is that a regular ordering of a subset of symbols is not sufficient to determine true syntax (Seidenberg & Petitto 1979); while human language syntax involves combining single symbols, each with their own meaning, in many different ways in order to convey many different messages, the 'language' of the trained apes involves a much restricted set of symbols combined in often identical ways. Such evidence is not sufficient to back up some of the strong claims that have been made. Nevertheless, results from experiments of the language-trained apes' comprehension is somewhat less ambiguous. Here, it appears that Kanzi may understand the order of words based on their categories, and further may understand the link between syntactic position and thematic roles (see Kako (1999) for discussion). Thus, the conclusion at present for language-trained apes must be that while lexical syntax (perhaps in some weaker sense) is present in reception, it is absent in production.

In sum, the evidence of lexical syntax outside our species is weak. It is weaker still if we consider that lexical syntax doesn't just involve the semantically interpretable combination of units of communication, but more specifically that those units of communication must be arbitrary learned symbolic signals. While

[42]In other words, Kanzi always places the lexigram first in an utterance which combines a lexigram and a gesture.

other species may exhibit certain of these features, none exhibit all of them[43]. For example, vervets use arbitrary symbolic signals, but they are not learned, nor do they have lexical syntax. Honeybees combine units of communication to express changes in meaning, yet these units are innate and iconic. Campbell's monkeys and coqui frogs appear also to combine arbitrary symbolic units to signal changes in meaning, yet the units are innate and significantly few in number; there is no sense of the unlimited combinatory possibilities of human language. The Bengalese finch combines units in a hierarchical fashion but this produces only syntactic dependencies; the dependencies are not semantically interpretable.

Returning to the issue of recursion, there are two separate, yet connected questions which stem from the discussion here. The first is the question alluded to at the end of the previous section – do other species have recursive conceptual structure? The second is the question we have been addressing in the past few paragraphs – do other species have semantically interpretable syntax? The first question can be re-phrased as: do other species have a reason to have recursive phrase structure? The second: do other species have the mechanism to provide recursive phrase structure? In other words, without recursive thought there would seem to be no requirement for a species to have recursive lexical syntax[44]. However, even if a species does have an ability for constructing recursive thoughts, that does not mean that species will have recursive lexical syntax; it will firstly require semantically interpretable phrase structure which can then be manipulated to give it recursive semantically interpretable phrase structure.

5.5.3 *Recursion versus Iteration revisited*

At the end of section 5.2.3.1 it was suggested that the difference between iteration and tail recursion lies in the semantics of tail recursive sentences. We saw there that we cannot interpret the repeated phrases in (10) simply as separate propositions tacked onto each other as we can with those in (9), but that they must be understood as one embedded inside the other, modifying it in some way. As

[43]The question of the existence of lexical syntax in other species' communication systems is a difficult one. Although current research points to it not existing in species outside our own, there is nothing to say that the future will not bring experimental work which will discover its existence. As with many of the questions of homology and analogy in this and other chapters of this thesis, the conclusions we can draw at present are subject to future change, and so the claims made here cannot be firm assumptions, only plausible possibilities.

[44]Although see the next section for a possible evolutionary motivation.

Pinker & Bloom (1990:724) put it: "[g]iven such a capacity [the capacity for recursion], one can now specify reference to an object to an arbitrarily fine level of precision." Linguistic recursion inherently involves semantics in that embedded phrases further define or pick out the referent of the head of the phrase they are embedded inside. As discussed in section 5.4, sentences such as (10) have recursive phrase structures because they express an underlying recursive conceptual structure. An iterative description of the structure of the sentences is not true to the complex meaning they reflect. That is, in human language, semantics thus gives us the extra information required to identify the correct structure, where the string alone does not tell us if we are looking at iteration or tail recursion.

A weakly adequate machine such as the finite state automaton in (23) was argued to be incapable of distinguishing tail recursion from iteration; we need in addition some pointer to the structure[45]. What this means is that discovering tail recursion in non-human communication systems relies on their manifesting semantically interpretable syntactic structure. As the section above has shown, such systems have at best very weak lexical syntax. Specifically, any animal communication system which has structure which might lend itself to recursive manipulation does not appear to have the level of semantics that would be required to test if the configuration was truly tail recursive, or just iterative[46].

It might be argued that if a system has no semantics, recursion is not required. That is to say, with no meaning to express, iteration and non-recursive embedding would suffice for the syntax of the communication system. We might then ask why the system would have iteration or embedding of any sort if there is no meaning to communicate. What evolutionary reason might there be behind such structure? As suggested in Okanoya (2002), in the case of the Bengalese finches, the answer may lie in sexual selection. A member of the species who can vocalise longer and more complex signals is more attractive to the opposite sex, and gains more mates as a result. There is therefore a selective pressure for vocalisations that would incorporate iteration (a longer vocalisation would only

[45]The assumption throughout this chapter has been that semantics will provide the extra information required to make this evaluation. There is nothing to say, however, that the structure can only be derived from semantics. That is, we could imagine a system in which the structure was made transparent through intonation, pitch, or some psycholinguistic mechanism. The point is that strong generativity, however that is signified, is essential.

[46]We could imagine a playback experiment to test for tail recursion based on the ordering constraints discussed in section 5.2.3.1 that could be undertaken if such systems were to turn out to have the right level of semantics.

be possible through iteration if the number of single signals were few) and embedding (arguably, the complexity of the vocalisation would increase with the use of embedding[47]).

If sexual selection can drive a system towards greater complexity in this way, is there any reason why it might drive it still further to produce non-semantically interpretable recursion? As noted, we would not be able to identify this recursion for certain if it were of the tail variety. However, the same problem does not arise for nested recursion. It would, in principle, be relatively easy to spot nested recursion in a non-human communication system. Although there has not been any such structure reported in the animal communication literature, as was briefly mentioned in section 5.3.2.4 above, we could conceive of such a system. Thus, the birdsong system characterised by the rule in (27) would consist of such songs as in (28):

(27) $S \rightarrow \left\{ \begin{array}{ccc} a & S & b \\ c & S & d \\ 0 & & \end{array} \right\}$

(28) a. aabb
b. acdb
c. aacccabdddbb

While songs such as that in (28a) would not necessarily lead one to conclude that the system showed evidence of nested recursion (as it could perhaps be analysed as simply involving a counter[48]), the infinite set of songs that the grammar in (27) could generate, including those such as (28b-c), could only be produced by a nestedly recursive grammar. What remains then is to find ways of testing animal communication systems for such structures.

This section has examined the significance of considering not simply the linear arrangement, but also the underlying meaning of recursive structures. I have stressed that semantics is an intrinsic part of recursion in human language. Further, I have noted that semantics distinguishes iteration and tail recursion, which

[47] Although, recall from chapter 4 the problems of measuring complexity.
[48] Although Hurford (p.c.) maintains that a counter analysis may simply smuggle recursion in under another guise.

is why this type of recursion cannot be tested for in non-semantically interpretable animal communication systems. Nested recursion in animal communication systems was argued to be easy to spot in principle, with the open question being whether such structures can be found in actuality. Finally, it was suggested that although recursive semantics would seem to be the most likely motivation for recursive phrase structure in our communication system, if evidence were to be found of non-semantically interpretable nested recursion elsewhere, sexual selection might provide an evolutionary explanation.

5.6 The Uniqueness of Recursion

This section will examine how unique the existence of recursion is. As discussed in the introduction to this chapter, the recent proposal of Hauser *et al.* (2002) suggests that recursion may be the defining factor of the human language capacity. If this is the case, recursion would be a very special property of cognition. 'Uniqueness' here refers to this peculiarity. The challenge provided by this proposal is three-fold. Firstly, we should ask if the prominence of the concept of recursion is solely due to its place in human language; that is, do we find recursion in other human cognitive systems, or is it reserved for our communicative capacity? We should then question if the cognitive systems (external to communication) of other animals have a place for recursion. If the answer to this is positive, we then want to determine if recursion is found in any system of communication outside our own species.

Each of these questions will be addressed in turn in the sub-sections which follow. The conclusions we will come to for each puzzle will not be clear-cut; it will be suggested that we can find recursion outside communication in humans, but that current evidence fails to reveal conclusive evidence of recursion in the non-communicative cognition of other species, and further that the communicative systems of non-human species are difficult to test for recursion.

5.6.1 Recursion in other Human Cognitive Systems

The previous sections of this chapter have presented in detail manifestations of recursion in the human language capacity. In order to interpret exactly how special this feature is, we need to investigate whether it is to be found elsewhere in our cognition. Section 5.2 initiated this step by providing some informal examples of recursion from outside the domain of language. This section will consider the question in a more formal fashion by analysing a selection of human cognitive systems and complexes.

5.6.1.1 Number

In sections 5.2 and 5.3 above the idea that recursion in natural language gives rise to the property known as *discrete infinity* was discussed. Importantly, recursion is not equivalent to discrete infinity; it is merely the machinery which instantiates the property. Hauser *et al.* (2002) maintain that language and the natural numbers are analogous in terms of discrete infinity; that is, in the same way that a finite set of linguistic elements can be combined in an extraordinarily large number of ways to give infinitely many utterances, the natural numbers can be combined to give indefinitely many numerals. While there is "...no non-arbitrary upper bound to sentence length..." (Hauser *et al.* 2002:1571), there is no non-arbitrary upper bound to the magnitude expressed by a number.

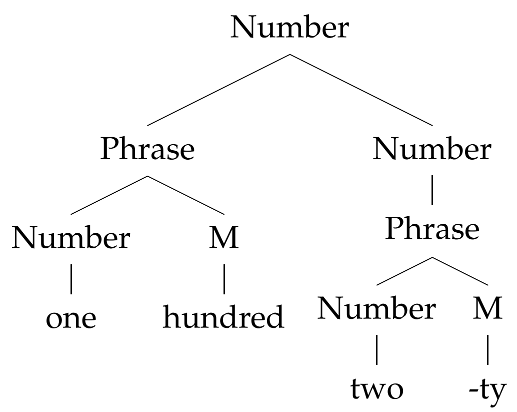
Understanding the property of discrete infinity to be pertinent in the number faculty does not directly entail that number cognition manifests the feature of recursion. However, consider how the discrete infinity of the number faculty is achieved. Simply adding 1 to any number allows us to express an even larger magnitude; the successor function can be applied unboundedly to produce larger and larger numbers. If we analyse the structure of a number we can then see how the successor function engenders recursion. As Peano's (1889) axioms show, a number is defined recursively using the successor function as its basis as follows: 1 is a number, 2 is 1 plus 1, 3 is 2 plus 1, etc. Following this, defining the number 5 tells us that 5 is a number which is equal to 4 plus 1. In order to fully understand this, we then need to find a definition for the number 4, which in turn requires us to find a definition for the number 3, and so on until we reach 0. Grinstead *et al.* (1997) offer the diagram reproduced in (29) to illustrate the point (where *s* stands for the successor function):

(29)

$$\begin{array}{c} \ldots \\ | \\ s(4)=5 \\ | \\ s(3)=4 \\ | \\ s(2)=3 \\ | \\ s(1)=2 \\ | \\ 1 \end{array}$$

A second aspect of the number system which clearly can be understood as recursive is outlined in Hurford (1987). He advances recursive rules for generating the structure of complex numerals. One of his examples is given in (30), and the rules given in figure 5.11 indicate the structural possibilities:

(30)



$$
\boxed{
\begin{array}{ll}
\text{NUMBER} \rightarrow & \left\{ \begin{array}{l} \quad\text{DIGIT} \\ \text{PHRASE} \quad (\text{NUMBER}) \end{array} \right\} \\
\text{PHRASE} \rightarrow & \text{NUMBER M} \\
\text{M} \rightarrow & \left\{ \begin{array}{c} \text{-ty} \\ \text{hundred} \\ \text{thousand} \\ \text{million} \\ \text{billion} \end{array} \right\}
\end{array}
}
$$

Figure 5.11: Recursive rules for generating complex numbers

The rules in figure 5.11 are recursive in the same sense that the phrase structure rules shown in earlier sections of this chapter were seen to be. That is, the structure of a complex number can be described recursively as a number embedded inside a phrase embedded inside a number, for example. However, it is important to note that the rules here were conceived to apply specifically to the structure of English numerals. Therefore, (as is Hurford's thesis) the recursion we see here is a direct result of language, and so cannot uncomplicatedly be argued to be the manifestation of the property in a separate cognitive system.

What the previous point indicates is crucial. It may be difficult to entirely separate the number capacity and the language capacity. It has been argued that number may have evolved as a by-product of language (Pinker & Jackendoff (2005), Chomsky (1988)), or indeed, that our knowledge of number may result from our language capacity (Hurford (1987), Bloom (1994)). In parallel fashion, it has been argued that language may have evolved out of the number capacity (Abler (1997), Hauser *et al.* (2002)). While it would seem that the most obvious direction is from language to number, given the fact that there are human cultures which operate without the latter (Gordon 2004) but none which operate without the former, either side of the argument highlights the fact that there is a crucial link. Species outside our own do not possess a language faculty. Neither do they, as we will see in section 5.6.2.1 below, possess a number faculty; their conception of number is not comparable to ours. It therefore may be hard to hold up any recursion that is argued to be present in our number faculty as a good example of recursion in a cognitive system outside the human language capacity.

5.6.1.2 Navigation

Hauser *et al.* (2002) suggest that recursion may not have evolved for linguistic purposes, and its initial evolution may have been a response to some other problem that our ancestors faced. One possibility they propose is navigation. Although it has been argued (Pinker & Jackendoff 2005) that navigation is unsuccessful in illustrating recursion, and indeed, many aspects of it are[49], there are two sub-tasks involved in navigation which may provide evidence of recursive abstraction.

Path creation (often referred to as wayfinding) is one such task. We can easily conceive of wayfinding as a recursive operation, along the lines of the algorithmic divide-and-conquer method often used in solving searching and sorting problems in computer science. Given a wayfinding task where the environmental representation is known to the subject, to create a path from source (S) to destination (D), the task is divided in two; first create a path from S to some midpoint, marked by a landmark, and then create a path from the midpoint to D. In turn, the task of creating a path from S to the midpoint can be broken into two - first create a path from S to some point that is halfway between S and the midpoint of the entire path, and then create a path from that halfway point to the midpoint. The entire path creation task will be recursively defined into smaller and smaller tasks until each sub-task is of manageable proportions. In the terms delineated in section 5.2, this is a case of nested recursion. There is a requirement to keep track of where we are in the process, otherwise the path may not be correctly created. In addition, there are long-distance dependencies formed between certain steps in the process (as will be seen below). Further, we cannot

[49]For example, the process of landmark recognition does not involve recursion; there is no sense in which comparing some object in the environment with some mentally stored and subsequently retrieved model (or analysing the object for adherence to some set of rules that it should observe) involves embedding of objects inside identical ones, or embedding of properties of the object inside other properties, or any equivalent interpretation.

continue to add more and more sub-paths in a repetitive fashion, as we will surpass the terminating condition (that is, we will go beyond the destination point), so this cannot be an example of pure iteration or even tail recursion. Finally, we cannot remove any of the steps in the process and still expect to arrive at the same result; doing so may result in our path not reaching its proper end-point.

Figure 5.12 outlines an environment in which a path must be created from source (S) to destination (D). In the same environment there are a number of landmarks - a river (R), a bridge (B), a house (H), a mountain (M), a park (P), woods (W), a gate (G), and a castle (C) - some of which will form points in the most direct path. Figure 5.13 steps through the recursive solution to creating this path:

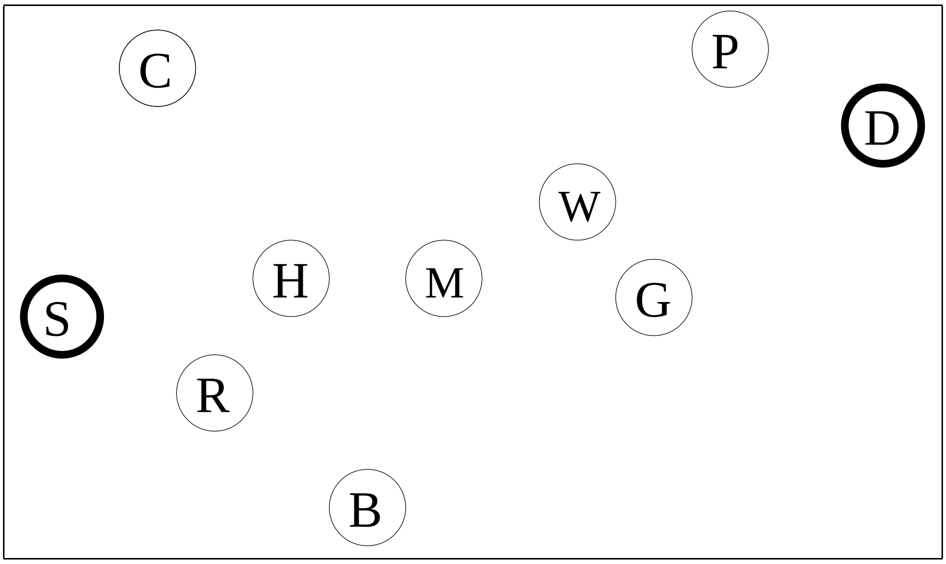


Figure 5.12: Environmental representation with landmarks used for path creation

```
FUNCTION CreatePath (S, D):
  CreatePath (S, M):
    CreatePath (S, H):
      CreatePath (S, R)
      CreatePath (R, H)
    CreatePath (H, M)
  CreatePath (M, D):
    CreatePath (M, W)
    CreatePath (W, D):
      CreatePath (W, G)
      CreatePath (G, D)
```

Figure 5.13: Recursive solution to path creation problem

We could, of course, equally maintain that humans, in solving path creation tasks, use an alternative non-recursive strategy. An iterative solution to the path creation problem just discussed would be to create a path to the nearest landmark to the source, and once that landmark has been reached, create a path to the next nearest landmark, and so on, until the destination has been reached. At each point along the way, the previous step can be forgotten; all that is needed to be retained in memory is the destination point, and so a stack type memory is not required. In order to determine whether path creation tasks provide an instance of *necessary* recursion in human cognition, we would need to investigate what strategies are used by humans solving such tasks in actuality. Thus, wayfinding provides us with a sensible and useful domain in which to seek out recursion in human non-communicative cognition, but it must be left for future experimentation to determine whether recursion is a necessity in this case.

A further aspect of navigation that may have recursive underpinnings is environmental representation. This can be seen as an over-arching principle which specifies the backdrop against which landmark recognition and path creation can proceed. In order to be able to create a path using landmarks as placeholders along the way, the environment in which the landmarks and path exist needs to be represented in the subject's mind in some way. The environment is hence represented as a complex arena composed of objects or landmarks, spatial measures between these, and relations among them. This is what Gallistel (1990) has termed the *cognitive map*.

For example, to specify a particular instance of some type of landmark, it might be represented in the subject's head as *the house next to the river* or *the house* *next to the river by the mountain* or *the house in the woods next to the river by the mountain*. Although it is here represented in linguistic terms, the conceptual system of human beings allows such representations to exist in our heads in other terms which do not presuppose a language capacity. Such representations would appear to be recursive. Note, however, that this is not a case where recursion *must* be invoked[50]. It is equally plausible that the conceptual system simply differentiates between similar landmarks in some non-recursive way, such as *the big house* versus *the small house*. Further, it is arguable whether a recursive environmental representation is specific to navigation. The sections below will draw on other cognitive complexes for manifestations of recursion, and it will be seen that the recursive representation of environments used in navigation shares intrinsic features with the recursive constructs seen in these systems; it is a recursive conceptual structure that is at issue here rather than a specialised recursive navigational capacity.

Our conclusion on the recursivity of navigation must then be that (i) path creation suggests an opportunity where operating in a recursive fashion is viable, and might offer certain advantages, and (ii) while the ability to construct mental representations in a recursive fashion may be desirable to navigate well, navigation is only one area in which this particular recursive ability manifests itself; structural recursion is thus not an elementary feature of navigation, but an elementary feature of a more basic cognitive technique which is used in navigation (Pinker & Jackendoff 2005).

5.6.1.3 Games and Music

Social activities that humans engage in, such as playing games or creating music, provide us with another area of human cognition in which to search for recursion. Bever & Montalbetti's (2002) commentary on Hauser *et al.* (2002) uses the children's game of tag as an example to illustrate recursion. The game revolves around one person, usually known simply as 'it', who chases all other participants. Once a person has been caught, they become 'it'. While the procedure of tracking the person who is 'it' throughout the life of a game is an iterative process (each time the person who is 'it' changes, the players can simply shift some pointer to that person and forget who the previous 'it' was; at each stage, the

[50] I will return at the end of section 5.6.1 to the question of cognitive processes that are necessarily recursive.

players can forget how the current 'it' came to be so), defining 'it' leads to recursion. The concept of 'it' can be (tail) recursively defined as the person who was caught by 'it'. Again, a non-recursive definition of 'it' is possible; for example: 'it' is the person who chases everyone else, 'it' changes throughout the game by catching other people, and when a person is caught, they become 'it'. Note however, that the recursive definition is clearly more succinct and more economical; a point to which we will return in section 5.7.

Another example of a game that involves recursion is the Towers of Hanoi puzzle that we met in section 5.2. There it was shown how the puzzle is best solved using a recursive strategy. Here we can add that such a strategy has no linguistic basis, so is another example of recursion elsewhere in cognition.

Hauser *et al.* (2002) and critiques thereof (Pinker & Jackendoff 2005) agree that music may provide insights into recursion in human cognition. We mentioned in section 5.4.2.1 above that music can be shown to exhibit the type of phrase structure known as *phonological syntax*, but there we did not discuss the possibility of recursive music. Let us examine this in a little more depth now. Music consists of a number of hierarchical levels of representation[51] (metrical, tonal etc.), each made up of combinations of elements. For example, beats combine to give bars which combine to give phrases which combine to give pieces. If music were to be recursive, we would need to say that such units can be embedded inside identical ones; we would need to be able to have bars within bars, or phrases within phrases. We can think of notes as being analogous to phonemes; they are atomic units and there is no way to embed one inside another. What about musical phrases; are these analogous to linguistic phrases where self-embedding is a possibility? The answer to this is that it may be very difficult to tell. Ascertaining if a musical piece consists of musical phrases of the same type embedded inside others will be problematic, as musical phrases lack semantic content. As with determining recursion in non-semantically interpretable animal communication systems, we will not be able to tell if phrases that are repeated in a musical piece constitute simple iteration or tail recursion. We might imagine though that nested recursion could be identified more easily.

Lerdahl & Jackendoff (1983) introduce the property of recursivity in their discussion of the architecture of music in relation to its grouping structure. They

[51] Although see Lerdahl & Jackendoff (1983) on the question of *strict* hierarchy in music.

argue that the grouping structure of music is recursive in that "...it can be elaborated indefinitely by the same rules". It seems that what they mean by this is that the listener segments a musical piece into progressively larger units. So, larger units contain smaller units, and the listener is perceptive to these different levels. However, this does not fit the salient criteria of recursion established in this chapter; it involves hierarchy and embedding, but not self-embedding. This type of recursivity will not serve as a manifestation in our non-linguistic cognitive abilities.

A more creditable suggestion of recursion in music is made by Hofstadter (1980). In this case, recursion is posited in the key change modulation in music. In relatively simple pieces of music, the listener is suggested to require a shallow stack onto which he can push key changes and pop them off once they are resolved. Thus a piece of music may begin in one key, and part way through modulate to a different key. At this point, the listener must store the tonic key in memory for the duration of the section of the piece in the new key. Once the tonic key is resolved, that is, once the piece of music returns to the original key, the stack item is popped. So, recursion here is the nesting of a musical key within another, in a similar way to the nesting of a linguistic phrase inside another. Based on the delineation in section 5.2, it is an example of nested structural recursion.

In more complex musical pieces, such as Bach's *Little Harmonic Labyrinth*, key modulations are quick and abundant, leaving the listener confused as to where they are in relation to the tonic key. Hofstadter suggests that this indicates that in processing music there is a limit to the level of recursive embedding we can handle. This parallels the difficulties we have in processing linguistic nested recursion beyond a certain depth.

It would thus seem that of the type of human social activities involving higher levels of cognition, recursion is attested in the playing of games, the solving of puzzles, and the processing of music. Moreover, although certain of these involve recursive processes and structures which could be alternatively interpreted, the complex key modulations of Bach appear to be necessarily recursive.

5.6.1.4 Vision

Vision is an archetypal cognitive system. Work in the field of vision (e.g. Marr (1982)) has done much to further our appreciation for the complex workings of the mind. Vision involves very many processes, such as depth perception, stereoscopy, motion analysis, and edge detection. Of such processes, Pinker & Jackendoff (2005) and Jackendoff & Pinker (2005) suggest that the manner in which we visually compose objects into groups, and decompose objects into parts may provide some evidence for recursion outside language. Let us explore this proposal more precisely.

Object recognition is a perceptual process which involves comparison of some object to a representation stored in memory. Decomposition of the object into component parts is one process assumed to be involved in this aspect of human perception (Marr & Nishihara (1978), Biederman (1987))[52]. Involving lower-level perceptual processes such as determining colour, edges, and depth, it takes place every time we look at a scene and figure out what it is that we see. On encountering a scene, our visual processing system assigns a meaning to the scene (in other words, it allows us to understand what we see) by recognising each object that is part of the scene. This is accomplished by decomposing the objects in the scene into smaller parts. Visually processing, or recognising, each of these objects involves a bottom-up process which is achieved by further decomposing the objects into their aggregate parts. This process is applied repeatedly until the parts cannot be further broken down. We then mentally reconstruct all sub-parts of an object and a meaning is assigned to each one. Once all objects have been recognised in this way the scene is also assigned a meaning.

The process of object recognition by way of decomposition can be understood algorithmically as similar to the cake cutting example of section 5.2 or the path creation example of section 5.6.1.2. That is, we apply the decomposition function recursively. The first input to the function is the entire scene. The first application will decompose the scene into the larger objects (say a person, or a building), and these objects will form the input to the subsequent applications of the function, where they are further decomposed into their subparts (head, torso, legs, or roof, walls, door, etc.). Although here we are not dealing with such a simple case of dividing something (be it a cake or a path) into just two parts on each recursive

[52] See also Edelman (1997) for discussion of other object recognition processes.

call, there is no doubt that the procedure is recursive, and more specifically, nestedly so.

A similar aspect of visual processing that lends itself to a recursive analysis is the difference between global and local processing (Treisman (2004), cited in Hurford (forthcoming)). Initial visual processing is global; the superficial gist of the scene is taken in. Only after this does local processing occur, where the individual features of the scene are identified, and bound to the relevant objects. Recursion comes in when we consider that on a second pass through the scene, the elements that were local in the first pass become the global elements, in turn giving rise to even more localised elements which will be subject to further processing on the next pass. Once more, this is analogous to the cake cutting and path creation examples.

5.6.1.5 Social Cognition and Theory of Mind

Human social cognition affords another contender for non-linguistic recursive processes. By social cognition, we mean the ability to understand and interpret social situations. This can be broken down into a number of different areas and capacities. It includes being able to recognise the self and others as individuals, knowing about the kin relations and alliances of others, the capacity to infer causal-result patterns based on social situations, the capacity to know what other individuals see, know or think. Social intelligence is understanding the behaviour and the psychological states of others.

Within social cognition, we can distinguish between simply knowing about the behaviour of others and knowing about what they themselves know. This latter capacity is known as our theory of mind (mentioned briefly in section 5.5.1 above). Much recent work on theory of mind has carried out experimental research on non-human primates to determine the level of similarity between their and our social cognition. In section 5.6.2.5 below this work will be discussed in more detail, focussing on how such experiments have shown non-human animals to have certain social cognition, if not necessarily a full theory of mind. For the moment, we are concerned only with human abilities. As human possession of a theory of mind is uncontroversial, we will concentrate on this higher order social capacity of embedding minds within minds to help illustrate that recursion is available in our non-linguistic cognitive apparatus.

Imagine the following situation: Bill is throwing a party next Thursday. He has invited a number of people, including John and Mary. Bill really wants Mary to be at the party. John, however, doesn't want Mary to be there. Mary believes (incorrectly) that the party is on Friday. John knows this, but Bill does not. John also knows that Bill is unaware of Mary's misinterpretation of the invite. In other words, John knows that Bill does not know that Mary believes that the party is on Friday.

John's theory of mind allows him to not simply know something about another person, but to know also what that person knows or thinks. What that person knows could be something that another person knows or thinks. In this example, John's theory of mind allows him to embed the knowledge and beliefs of Bill and Mary inside his own. With this ability, he can then choose to deceive the other parties to aid his own interests by not telling Bill that Mary has the day wrong, or not telling Mary that she should come on Thursday instead, or alternatively he could choose to do the honest thing and let them know.

Apart altogether from the obvious advantages that such a capacity would afford in out-competing conspecifics[53], the ability to have such knowledge requires a mental aptitude that works recursively. Knowing that Bill is throwing a party involves a simple conceptual structure, able to represent flat propositions, while knowing that Mary knows that Bill is throwing a party involves self-embedding of propositions to give hierarchically recursive structures, and knowing further that Jane knows that Mary knows that Bill is throwing a party (and so on) would show that the self-embedding of such propositions can be limitless (at least up to the point where memory lets us down).

Some (e.g. Fitch (2004), Gray & Russell (1998)) have argued that a theory of mind is intimately linked to language. As was noted in section 5.5.1 above, a theory of mind is evidence of a recursive conceptual structure, and a recursive conceptual structure signifies a tenable motivation for recursive language. However, this coupling does not entail that a theory of mind can be understood as part of the language capacity, and thus it provides yet another example of how recursion is used elsewhere in human cognition.

[53]See work on deception and theory of mind by e.g. Byrne & Whiten (1991) and Newton & Reddy (1997).

5.6.1.6 *Necessarily Recursive Human Cognition*

In a number of places in the previous subsections it was noted that recursive interpretations of certain cognitive processes may not be the only possible interpretations. That is to say, recursion is available in domains outside language, but it may not be the only solution available, and thus it cannot be considered a necessity in such cases. The issue being unravelled in this section of the chapter is how unique recursion is; this importantly depends on discerning not simply optional recursion outside of language, but processes which are only possible through recursive means. If a cognitive domain gives rise to processes which can be tackled both recursively and non-recursively, from an evolutionary point of view this may mean that the recursive strategy was a later addition, made possible by the co-opting of recursive capacities which previously evolved in another domain (e.g. language). That is, optional recursion outside of language does not deny the uniqueness of linguistic recursion posited by Hauser *et al.* (2002). Examples of recursion which fall into the category of optional recursion are wayfinding, landmark recognition, the Towers of Hanoi puzzle, and 'it' in the game of tag. Nevertheless, there are clear cases of necessary non-linguistic recursion in the following areas of human cognition: music (the embedded key changes of Bach), visual perception, social cognition and theory of mind[54].

5.6.2 *Recursion in other Non-Human Cognitive Systems*

The second question to be addressed in order to determine how unique recursion is in its manifestation in cognitive systems is whether we find recursion in the non-linguistic cognition of non-human species. In order to do this, we will follow the pattern of the previous section and examine some cognitive processes manifested outside our species which might require recursion.

5.6.2.1 *Number*

Studies have shown (Brannon & Terrace (1998), Kawai & Matsuzawa (2000)) that non-human primates can be trained to understand certain facts about numerosity. However, what is obvious from such studies is the vast difference in number capability between us and even our closest living relatives. Non-human animals have a rudimentary numerical system only (Dehaene 1997). They are able to distinguish only small magnitudes, and any ability they possess to deal with

[54] Number also provided examples of recursion that are necessarily so, but recall that the number system and the system of language are difficult to tease apart.

numerals above three or four is the result of intensive training. Human children never receive such training, and pick up the fact that the number system is based on the successor function very quickly. For non-humans, there is no understanding of the successor function; although they can compare magnitudes, each number is treated as a separate representation of magnitude to be learned uniquely.

The recursive definition of numbers discussed in section 5.6.1.1 above is based directly on an understanding of the successor function. As a result, non-human species will lack this type of recursion. The second type of numerical recursion discussed for humans will also be absent in animals due to their lack of linguistic abilities. Thus the domain of number offers no evidence of recursion in non-human cognition.

5.6.2.2 Navigation - The Travelling Salesman Problem

Problems of the well-known travelling salesman class provide an arena in which to test the use of recursion and iteration. Basically, the problem can be described as follows: given a number of cities on a plane, find the shortest path between them such that each city is visited only once. The problem can be solved in a number of ways, including either iteratively or recursively searching through all possible solutions. That is, each possible path is analysed and compared against all others. The iterative method compares each path with the next, choosing the shortest of the two to be compared on the next iteration. The recursive method, in contrast, is constructed much like the navigation problem discussed in section 5.6.1.2; that is, a divide-and-conquer principle is used to recursively constrain the set of paths to be compared.

Menzel (1973) reports experiments carried out on juvenile chimpanzees using this paradigm. The chimpanzees witnessed pieces of fruit being hidden at various points in a field, and were subsequently released to find the fruit. Although the chimpanzees succeeded in finding all pieces of fruit, and in fact did this in such a way that they did not revisit any hiding place, and that distance was minimised, as Premack (1983) observes, the chimpanzees' behaviour could be generated by a simple iterative nearest neighbour rule.

A more recent re-working of Menzel's experiment using vervet monkey subjects is reported by Cramer & Gallistel (1997). Again, the vervets succeeded in solving the travelling salesman problem. In the initial cases, again, an algorithm designed to choose the next nearest location did as well as the vervets. However, additional experiments showed that the vervets were taking into consideration the location of at least the next two hiding points on the plane. This work does not examine whether the monkeys might have been making these calculations iteratively or recursively, but it does point to an area of research which may be a very useful place to further investigate the occurence of recursion in non-human cognition.

5.6.2.3 Complex Action Sequences

One obvious place to look for recursion in the cognitive capacities of non-humans is in their ability to undertake complex actions. By complex actions we understand actions that are composed of ordered sequences of less complex actions. For example, hunting prey might be understood as a complex motor sequence which is composed of such lower level actions as stalking the prey, catching the prey, and killing the prey. Each of these actions in turn could be similarly analysed and further anatomised. Complex actions can thus be understood as hierarchical, and perhaps involve embedding. The question is, can such actions be understood recursively, and if so, do we find reliable examples of recursive complex action sequences in non-human species?

A number of studies report experimental work examining hierarchical behavioural patterns in other species (Whiten (2002), Byrne (2002), Byrne & Russon (1998)). We have already noted that hierarchy does not necessarily entail recursion (section 5.4.2), but that recursion requires hierarchy. Consequently, hierarchically organised actions constitute a reasonable place to look for support for the hypothesis that recursion may exist in non-communicative cognition in such species. Whiten and colleagues (e.g. Whiten (2002), Whiten *et al.* (1996)) have carried out a series of experiments, where a subject is required to open an artificial fruit in order to obtain a reward, analogously to opening a fruit in the natural habitat to retrieve the edible contents. Opening the fruit involves a reasonably intricate system of removing bolts and pins, removing handles, and opening lids. The capacity of chimpanzees to structure actions sequentially is evidenced by their ability to imitate a sequential action pattern leading to the opening of the fruit. However, the artificial fruit experiments test for hierarchical imitative capacities in humans only. Without evidence for hierarchical behaviour in chimpanzees we have no starting point to check for recursion. While such experimental research is headed in the right direction for gaining results which will help to solve the question of recursion in such species' cognitive systems, the current state of play leaves us no closer to an answer. It is relevant to note, however, that others (e.g. Gibson (1990), McGrew (1990)) have argued that investigation of tool use in non-human primates indicates that hierarchical organisation of complex action sequences may be beyond their grasp.

The mountain gorilla food preparation techniques discussed by Byrne & Russon (1998) appear at first glance to provide a clearer domain in which to find recursive behaviour. In order to make safe for eating the leaves and stalks of nettles and other plants, gorillas (*Gorilla g. beringei*) that live in the mountains of Rwanda, Zaire, and Uganda exploit a complex procedure. The procedure consists of steps such as gathering the plants, gripping the stems while folding and tearing the leaves in a particular fashion, and then picking out the unwanted parts before finally consuming what is left. Byrne and Russon provide the diagram in figure 5.14 to highlight the hierarchical nature of the process:

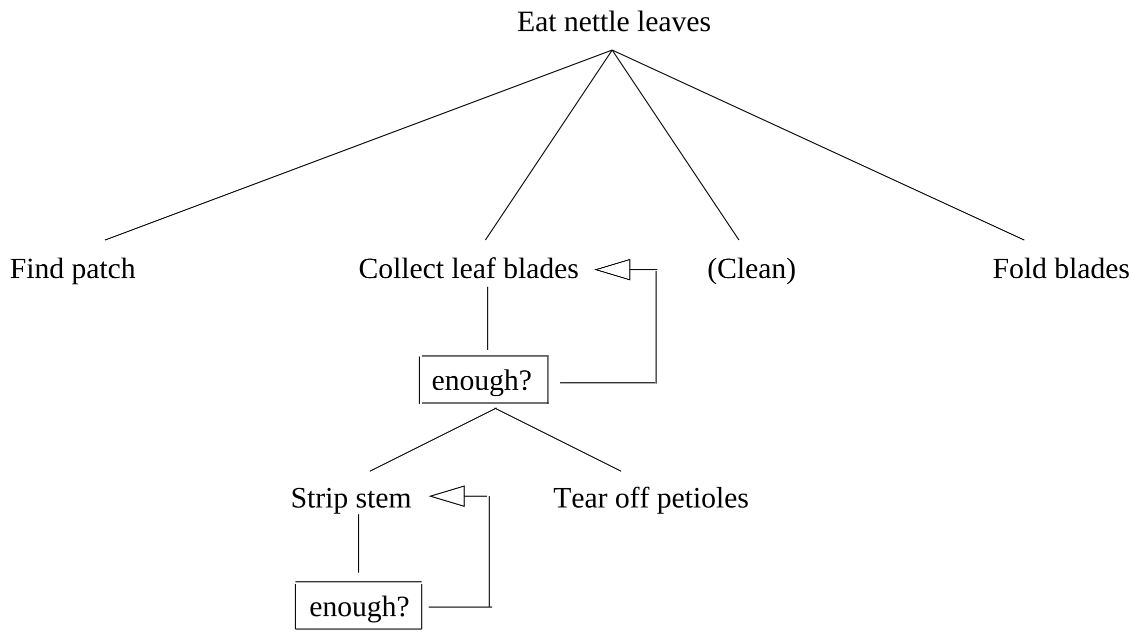


Figure 5.14: Hierarchical structure of mountain gorilla food preparation technique

The question of whether this complex hierarchically organised behaviour exhibits recursion is somewhat trickier. Byrne and Russon offer the following phrase structure inspired rules for the sub-tasks:

nettle → find + collect + (clean) + fold
collect → strip + tearoff + (collect)
strip → strip + (strip)

Figure 5.15: Phrase structure rules for mountain gorilla food preparation

They claim that the structure they have assigned to the actions indicate its recursivity. Let us now examine this claim in more detail based on the delineation of recursion given in earlier sections of this chapter.

The second two rules given above exhibit self-embedding. That is, in the *collect* and *strip* rules, we see the same action on both the left and right of the arrow. In both cases, the embedding is at the edge of the action sequence, so it appears that we should interpret it as tail recursion[55].

However, section 5.2 detailed the requirement that we cannot remove steps in a tail recursive process in the same way we can an iterative process, and still expect to reach the right end result. The nature of the rules that Byrne and Russon give suggests that the very steps that they characterise as recursive can be omitted in certain circumstances. The bracketed actions represent optional actions, but two of them (*collect* and *strip*) also correspond in the diagram in figure 5.14 to the actions that are repeated in a loop until some terminating condition is met (here, that is when the gorilla has enough). If the gorilla has enough leaves on loop one of the *strip* or *collect* action, then there will be no self-embedding in the hierarchical behaviour, yet the end result will still be that the gorilla has gathered and prepared nettle leaves for consumption.

A classification of the mountain gorillas food preparation technique as an example of recursion in the non-communicative cognition of non-human animals consequently becomes rather dubious. Future work might, of course, establish a valid correspondence, but it looks at this point as though the effect is merely superficial.

[55]Note that in the *strip* rule, there are two instances of self-embedding. However, this is simply a case of iteration within the tail recursion; it does not deny the interpretation of tail recursion since both instances of the embedded strip action occur at either edge of the sequence.

5.6.2.4 Social Cognition and Theory of Mind

The existence of a human-like theory of mind in non-human species is highly controversial. In most species, it is accepted that there is no evidence of a theory of mind. However, in chimpanzees, there may be indications of some aspects of this cognitive complex, although consensus is limited here too (for example, Heyes (1998), Fitch (2004) and Gray & Russell (1998) are among those who argue against non-human theory of mind, with Hurford (2004) and Seyfarth & Cheney (1992) among those who believe that there may be some degree of it in other species; for instance, perhaps we can attribute to chimpanzees desire but not belief of conspecifics (Gomez (1996), Gomez (1998), Whiten (1996))). What seems less controversial is that other species possess some level of social cognition. In section 5.6.1.5 we discussed human social cognition and the place of recursion in terms of the higher order social complex of theory of mind. Here we will have to broaden our horizons in order to assess the capabilities of other species. The question will then be, do lower level aspects of social cognition exhibit recursive structures or processes, and more specifically, do we find examples of recursion in the social cognition of species outside our own?

It seems reasonable to attribute to (at least certain) non-human primates[56] abilities such as recognising conspecifics as individuals, recognising and understanding the behaviour of other individuals, identifying alliances and kin relations among conspecifics. There is much work which suggests these assumptions to have some basis. I will briefly review some examples here.

Tomasello & Call (1997) maintain that chimpanzees have the ability to learn about the behaviour of others in the group without understanding the psychological reasoning behind such behaviour. They use the example of a chimpanzee knowing that a nearby noise will make their conspecifics flee, but that they do not understand the reasoning that makes them flee; in other words, they cannot attribute to their conspecifics the same type of mentality that they themselves have.

Povinelli & Eddy (1996) also contend that understanding in chimpanzees of others' mental states is very weak. The experiment they use involves a chimpanzee begging for food from a human experimenter. It was shown that chimpanzees begged equally from experimenters who had visual access to food and

[56] In fact, certain such abilities have been argued to be manifest in other animals, such as dogs (see Hare *et al.* (2002)).

those who didn't. (Those who didn't were blindfolded or had their heads in a bucket or had their backs to the food.)

Later work (Tomasello *et al.* 2003) indicates that chimpanzees may in fact have some access to the psychological states of others. In an experiment where a dominant and subordinate chimpanzee were in a competitive situation for food, it was shown that the subordinate chimpanzee would only advance towards food that the dominant could not see. If a barrier was erected in such a way that the dominant's view of the food was blocked, then the subordinate would pursue that food rather than any that was in the dominant's line of vision. Such experimental results hint at a capacity to understand that barriers block visual access, and that which cannot be seen is not known about.

Further experiments (Tomasello *et al.* 2003) highlight the fact that chimpanzees may also be able to attribute intention to others. In this case, a human experimenter in possession of food does not give the food to the chimpanzee for one of two reasons; either he cannot (for example, if the experimenter cannot reach the food), or he will not (for example, the experimenter teases the chimpanzee with the food but declines to pass it to him). The results show a more prolonged interaction time on behalf of the chimpanzee in the *cannot* cases, suggesting that the chimpanzee knows that it is more likely that the experimenter will eventually reach the food than it is that he will stop teasing with the food and give it over. The combination of these two abilities is posited by the authors to reveal a greater social intelligence than previously assumed for chimpanzees.

However, such levels of social cognition do not entail a fully formed (human-like) theory of mind in such animals. Tomasello *et al.* (2003) argue that chimpanzees show no concept of attention or perspective in visual perception experiments, exhibit no notion of the prior intentions of others or understand intentions signified in a communicative fashion, nor do they demonstrate any ability to know what others know and believe. In terms of recursion we can put it like this: chimpanzees may be able to form reasonably complex propositions about themselves and other members of their group, but they do not possess the capacity to embed minds within minds in the way illustrated in section 5.6.1.5.

Seyfarth and Cheney (Cheney & Seyfarth (1990), Seyfarth & Cheney (1992)) are among those who suggest that studies in this vein indicate that theory of mind may not be an all-or-nothing concept. We can thus attribute aspects of a theory of mind without having to posit a fully functional complex. Bergman *et al.* (2003) provoke interesting questions in this area. They report experimental evidence showing that baboons classify themselves and their conspecifics into both a linear hierarchy of dominance and matrilineal kin groups simultaneously. Playback experiments were used to investigate the reaction of the baboons to both intra- and inter-familial rank re-ordering. The baboons reacted more strongly to call sequences where dominance ranks between families were reversed, indicating that they understand both linear dominance hierarchies within families, and within the group as a whole. If this is indeed correct, it would suggest that although chimpanzees cannot embed minds within minds, they are capable of another type of embedding that is recursive. That is to say, the proposal here would entail that the chimpanzee can form conceptual structures which we might represent as in (31) and (32)[57]:

(31) [X is mother of Y [who is mother of Z [who is mother of me]]]
(32) [X is more dominant than Y [who is more dominant than Z [who is more dominant than me]]]

Such conceptual structures express associations which follow the rules of tail recursion outlined in the course of this chapter[58]. For example, we cannot remove a 'phrase' without affecting the whole structure. Similarly, we cannot reorder phrases and maintain the correct relations. While definitive answers to the question of whether chimpanzees can master such conceptual structures have yet to be pinpointed, the current evidence intimates that it is a strong possibility. As far as the issue at stake here is concerned, it seems that full-blown theory of mind is not required in order to posit recursive conceptual structure; a lower level of (although still complex) social cognition will suffice.

So, although the present accepted view of animal social cognition is far from clear-cut, and such contention precludes us from incontestably positing evidence of recursion in this faculty, experimental research in the field points to a promising domain in which to situate our current question. Future work in this area

[57]Of course, for a troop as large as the baboon's - up to 80 individuals - it is likely that he uses transitive inference to come to such conceptual structures, rather than storing internally the thousands of separate structures required to reflect the different relational possibilities (Hurford forthcoming).

[58]That is, if we assume that the conceptual structures of other animals are similar to our own. We think about our conceptual structures in linguistic terms, but other species do not. Thus, we cannot be indisputably sure that their conceptual structures are correspondingly recursive.

will undoubtedly lead to more conclusive responses.

To sum up, the cognitive complexes of other species that we have examined here seem like the most obvious places to look for attestation of recursion in other animals' non-communicative cognition. However, as the discussion has shown, we cannot posit unambiguous positive evidence in any of these cases. Nevertheless, as is well known, absence of evidence is not evidence of absence. The proposal of Hauser *et al.* (2002) that recursion is only evident in human linguistic cognition will be proved wrong only with substantial corroboration of recursion elsewhere; vindicating a theory of negative evidence is a lot more difficult. Consequently, future work needs to concentrate on assessing and ameliorating the findings in the domains discussed here if we are to disprove the supposition that other species do not exhibit recursion in their non-communicative cognition.

5.6.3 Recursion in Non-Human Communication Systems

The final question to be addressed in this section is whether recursion is found in the communicative systems of species outside our own. Given that we have not found definitive manifestation in the general cognition of non-humans, it might seem unlikely that recursion will be revealed in their communication. Logically, however, it is not impossible that this is the domain in which we will find the confirming evidence that the previous section has merely hinted at. That said, deliberation of animal communications systems such as that of the Campbell's monkey, the honeybee and the Bengalese finch in section 5.5.2 suggested that finding recursion in such communication systems may be far more difficult than an initial impression might suggest. This section will review some of these arguments again, and look in particular at what properties animal communication systems would need to have if they were recursive, and whether we can viably test for such properties.

5.6.3.1 Semantics Revisited

Earlier in the chapter the place of semantics in a recursive interpretation of communication systems was investigated. Summing up the findings, we can distinguish between two types of animal communication systems. A number of animal communication systems appear at some level to exhibit (weak) semantically interpretable syntax (lexical syntax). Among these were the combinatory alarm calls of the Campbell's monkey and the dance of the honeybee[59]. Although such

[59]Ujhelyi (1998) puts a similar case forward for the long calls of apes.

systems appear to manifest semantics, it does not seem quite reasonable to put this on the same level as the semantics of human language. For one, it has been argued (Seyfarth & Cheney 2003), based on work on the alarm and contact calls of a number of monkey species, that there is no intentionality inherent in the call system; although listeners may interpret the calls, the caller does not intend that interpretation to be made. This means that such communication is not referential in the way that human communication is, but as audience effects show, neither is the communication simply a stimulus response system. If such communication systems sit somewhere in the middle of the often presupposed dichotomy of emotional/stimulus-driven versus referential communication, then there may be a degree of semantics, but nothing which we can meaningfully match with human language semantics.

A second type of animal communication system is illustrated by the song of the Bengalese finch. Such a system exhibits no semantics in any sense, yet is clearly organised in a hierarchical fashion which permits embedding; it has *phonological syntax*. Again, we cannot draw direct comparisons between phonologically syntactic systems and human language due to the lack of semantics.

Some very recent work (Suzuki *et al.* 2006) offers a further example of a communication system fitting this latter classification. The song of the humpback whale (*Megaptera novaeangliae*) is analysed as showing hierarchical structural organisation. The authors suggest that recursion is an efficient way of representing such a hierarchical grammar. Although they are careful to issue the same caveat as section 5.4.2 did, that "...recursion is not necessarily implied by hierarchy." (*ibid*:1863), their proposal opens up the possibility of a non-human communicative system where recursion might be found.

The first of these two types of system exhibits a limited degree of semantics, but the very restrictive combination of elements means that there is little, if any, chance of the systems being structured in a hierarchical embedded fashion. Without this complex architecture, recursion of any type is not possible. With regard to the latter type of system, we seem to be dealing with a total lack of semantics[60], but with a good deal of hierarchical structure, admitting the possibility of

[60]Suzuki *et al.* (2006) make no claim either way as to the semantic content of the humpback whale's song; it may be, therefore, that future research on this animal might provide the evidence of semantically interpretable syntax that would allow us to delve much further into this problem.

embedding. In this case, the semantic deficiency prohibits testing for tail recursion. Nested recursion could nevertheless be uncovered should it exist. It thus remains for future work to use these realisations to narrow the research scope, and aim towards designing experiments to diagnose the type of recursion in the type of systems that is possible.

5.6.3.2 *Requirements for a Recursive Communication System*

So, it seems that in attempting to locate recursion in the communicative cognition of other species we may be faced with a greater problem than we might have imagined. Nevertheless, let us persevere a little longer. This section will consider what we might look for in a communication system that is organised hierarchically that might indicate that it is nestedly recursive.

One of the main features of recursion discussed in terms of both human language and other cognitive structures and processes is its support of long-distance dependencies. We observed that nested recursion must involve an association between elements which are distant (in linguistic or procedural space), while tail recursion does not. (7) is repeated here (as (33)) to aid recollection:

(33) The mouse the cat the dog the fox attacked chased bit ran.

Here, there are dependencies which are non-local, such as between *the mouse* and *ran* or between *the dog* and *chased*. These dependencies are a direct result of the nestedly recursive self-embedding possible in human language. In a similar fashion, when we consider again the steps of the path creation solution given in figure 5.13 we can see that there is a dependency between steps 1 and 6 and between steps 2 and 5; that is, for example, on completion of all the sub-steps that make up step 1, we need to continue the procedure by beginning step 6.

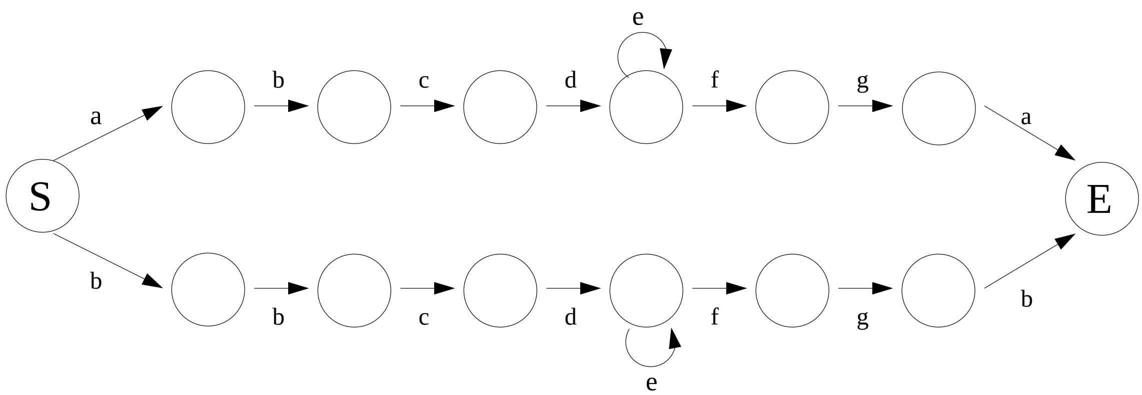
Long-distance dependencies are an automatic consequence of nested recursion in natural language[61]. For tail recursion, such dependencies are not an issue. Returning to non-human cognition, and specifically non-human communication,

[61] It is logically possible to conceive of a language that could be described as nestedly recursive, but that does not have long-distance dependencies. An example is the a* language, where all strings are composed of any number of a's. However, it is only under weak generativity that we can posit a nestedly recursive grammar for this language, while such a grammar strongly generates cases such as (33). That is, for the a* language, an iterative grammar and a nestedly recursive grammar are weakly equivalent, but once we consider the structure of a language, long-distance dependencies are forced by nested recursion.

the question being addressed is if we can tell if such systems are recursive. As noted, the lack of semantics in many non-human communication systems means that we cannot test for tail recursion, but that it is in principle possible to tell if a communication system which lacks the semantics associated with human language exhibits nested recursion. Nested recursion can be seen quite simply by just examining sets of strings. If a system was to involve nested recursion it would then have to also support long-distance dependencies. The question now is whether we find such relations in any animal communication system.

Although there is no clear evidence of long-distance dependencies akin to those in (33) reported in the literature on animal communication[62], and although it may be difficult to imagine what form such dependencies might take in certain communication systems that have been surveyed in this chapter, birdsong is one system that might plausibly provide examples. Imagine a system characterised in the following way:

(34)



If a long-distance dependency is understood as defined in section 5.2, this song can be analysed as follows. If the song begins with an *a* note, it must end with a *a* note, no matter how many notes intervene. Similarly, if the song begins on a *b* note, it must end on a *b* note. A song cannot begin with an *a* note, followed by the notes *bcdefg* and then end with a *b* note. In other words, the form of the first note determines the form of the last note.

Importantly, this example, although clearly exhibiting a long-distance dependency, does not manifest nested recursion. There is no embedding of notes

[62]One possibility is Suzuki *et al.*'s (2006) suggestion of humpback whale song, although their presentation makes it somewhat unclear what form these dependencies take.

within notes or chunks of notes within chunks of notes. Human language also indicates that long-distance dependencies can exist independently of nested recursion:

(35) Which tickets do you have for the concert?

Here, the dependency between *which tickets* and *for the concert* is the result of a wh-movement process. Thus, long-distance dependencies do not necessarily entail nested recursion. Finding such dependencies in non-human communication systems might very well hint at the possibility of nested recursion, in that there is some correlation between the two properties, but it will not definitively designate the system as recursive. In other words, long-distance dependencies cannot be used as a diagnostic of nested recursion, making the problem of determining whether a hierarchically organised non-human communication system is nestedly recursive even more difficult than we might have initially imagined.

In sum, the lack of phonological syntax in certain other species' communication systems (e.g. honeybee dance) will prevent the existence of recursion there, while the lack of semantically interpretable syntax in systems that do have phonological syntax (e.g. bird song) will prevent our testing for tail recursive structures. The only possibility for discerning recursion in non-human communication systems therefore lies in the discovery of nested recursion in systems which manifest a reasonable degree of phonological syntax, allowing for hierarchical self-embedding. Further work in this area may very well in the future uncover such architectures; for now we can only note that given the difference in the actualisation of recursion in non-human as opposed to human cognition, the likelihood of discovering recursion in non-human communication would not seem too high.

5.6.3.3 Recent Work

In this final subsection I will look at some recent ideas on the communicative abilities of non-human species that might bring us somewhat closer to placing recursion inside or outside of such systems.

Fitch & Hauser (2004) report recent experimental results that they claim show that tamarin monkeys (*Saguinus oedipus*) are unable to master a context-free grammar[63], while they are able to master a finite state grammar. From this they adduce that these monkeys are incapable of dealing with hierarchical organisation of the sort that humans can.

The study involves a familiarisation/discrimination paradigm where both human and tamarin subjects were exposed to strings generated by one of two grammars (a finite state grammar, $(ab)^n$, or a context-free grammar, $a^n b^n$), and were later tested on their differential reactions to new strings consistent with both the grammar they learned from, and the other grammar. The strings consisted of syllables of two types - the *a* type, a high-pitched syllable uttered by a female, taken from the set {ba di yo tu la mi no wu}, the *b* type, a low-pitched syllable, uttered by a male, taken from the set {pa li mo nu ka bi do gu}. (36) gives examples of strings generated by the finite state and the context-free grammars respectively, where the *a* syllables are marked in bold, and the *b* syllables are not:

(36) a. **la** pa **wu** mo **no** li
b. **ba la tu** li pa ka

On the basis that humans substantially discriminated between strings consistent with and inconsistent with their training grammar, whether trained on a finite state or a context-free grammar, it is concluded that humans can learn both grammars. Conversely, due to the fact that the tamarins trained on a context-free grammar showed little differentiation in their looking times when faced with an inconsistent finite state generated string (compared to the considerable difference in looking time showed by tamarins trained on the finite state grammar when faced with an inconsistent context-free grammar generated string), it is claimed that they cannot learn the more complex phrase structure grammar.

Despite claims of methodological flaws (Perruchet & Rey 2005) in Fitch & Hauser's experiments (see below), there may be an interesting alternative interpretation of the findings. Consider the nature of the strings that the context-free

[63] Fitch & Hauser use the term *phrase structure grammar* for this class, but their claims refer only to type 2 grammars on the Chomsky Hierarchy, and not to the more powerful type 1 context-sensitive grammars or type 0 unrestricted grammars which also fall within the class of phrase structure grammars.

grammar generates. These strings all follow the a^nb^n pattern, having a certain number of *a* syllables followed by the same number of *b* syllables. Such strings might reasonably be described as nestedly recursive. On the other hand, the finite state strings follow a pattern that cannot be described as nestedly recursive; $(ab)^n$ is either iterative or tail recursive (which it is cannot be determined for the meaningless strings used in the experiments - see below).

In that case, the interesting thing about the difference in processing abilities of humans and tamarins could be re-cast in terms of recursion, or more interestingly, keeping track. The hypothesis would then be that although tamarins are capable of handling iterative/tail recursive strings, they cannot handle nestedly recursive strings which require a stack type memory. This would align the processing abilities of tamarins more closely to that of humans; while human languages exhibit a great deal of tail recursion (both right- and left-branching), nested recursion, in the form of centre-embedding, is both less frequent, and subject to more significant processing difficulties. The hypothesis could by no means equate human and tamarin processing abilities however; while humans clearly can process centre-embedding (even if only to a limited level of embedding), tamarins cannot. If we could show that the $(ab)^n$ language was tail recursive rather than simply iterative, the difference in processing abilities of humans and tamarins would then not lie in recursion, but in the difference between tail and nested recursion. As has been discussed previously, while nested recursion requires a stack type memory, tail recursion does not. Thus, perhaps the crucial step in the evolution of human language was not recursion, but an enhanced memory with the ability to store and retrieve in a stack fashion.

Implicit in Fitch & Hauser's results is the claim that tamarins cannot deal with a recursive language, while humans can, thus confirming Hauser *et al.*'s (2002) claim that recursion is what makes humans unique, and moreover formalising this uniqueness as stepping one level up the Chomsky Hierarchy. However, the 'non-recursive' $(ab)^n$ language could, in fact, be tail recursive, showing that a language that sits lower on the Chomsky Hierarchy than the context-free a^nb^n language can also be recursive, and thus eliminating this (albeit intuitively elegant) evolutionary explanation of human language.

The hypothesis that human uniqueness derives not from recursion, nor from the move from regular to context-free languages, but from an enhanced stack memory finds certain support in the simulation work carried out by Christiansen

& Devlin (1997). They show that nested recursive structures are harder to learn than tail recursive structures, due to the fact that tail recursive structures maintain word order consistency while nested recursion gives structures with inconsistent directionality patterns[64]. The reason that Christiansen and Devlin propose that learning nested recursion is thus more difficult is that it requires greater memory: "[c]enter-embeddings are difficult to process because constituents cannot be completed immediately, forcing the language processor to keep lexical material in memory until it can be discharged" (Christiansen & Devlin 1997:114). Accordingly, a language like (ab)^n should therefore be easier to learn than a language like a^{n}b^n because of the increased memory requirements that the latter language requires. While Christiansen & Devlin's proposal is that the difference between tail recursive and nested recursive structures is a matter of degree, the current approach suggests that the difference is one of category; Christiansen & Devlin require more memory, the current proposal requires a different organisational possibility for memory. Nonetheless, the point remains that what seems to be crucial here is memory, not hierarchy or phrase structure or recursion.

The preceding argument relies on two assumptions: firstly, that the a^{n}b^n language is nestedly recursive, and that the (ab)^n language is tail recursive. Given only a string, with no available structure, it may not be possible to tell if the string is recursive or not. We would need additional information which points to the structure in order to be able to choose between recursive and non-recursive options. In the case of (36a), the meaningless syllables make it impossible to determine if the structure is flat and iterative or if it is hierarchical and tail recursive. For (36b), we could claim that the string is processed either nestedly recursively, or simply by counting the number of *a* syllables and the number of *b* syllables and comparing them. Given only strings, as we are in the Fitch & Hauser experiment, there is no way to decide. Therefore, the hypothesis above remains simply that for now; a conjecture as to what one important difference between human and non-human communication systems may be. The difficulty is that proving or disproving this hypothesis is only a possibility if such experiments can be redesigned to incorporate a pointer to the structure of the strings in question (e.g. semantics).

[64]The examples in (a) and (b) are used by Christiansen & Devlin to illustrate this:
(a) [$_{NP}$ buildings [$_{PP}$ from [$_{NP}$ cities [$_{PP}$ with [$_{NP}$ smog]]]]]
(b) [$_{NP}$ buildings [$_{PP}$[$_{NP}$ cities [$_{PP}$[$_{NP}$ smog] with]] from]]

The second, more basic, assumption is that Fitch & Hauser are asking the right questions. That is to say, are the differences between humans and tamarins correlated with differences in syntactic processing abilities, or with something else? Perruchet & Rey (2005) suggest, based on a modified version of Fitch & Hauser's experiment, that human subjects do not process strings such as (36b) as centre-embedded, but rather undertake the task as a simple perceptual discrimination task, distinguishing between $(ab)^n$ and a^nb^n strings dependent on whether they involve one or more than one acoustic transition. If human subjects are not processing a^nb^n strings by learning the context-free grammar which generates them, Perruchet & Rey maintain that tamarins inability to distinguish between the two sets of strings cannot be assumed to be due to their inability to learn a context-free grammar. If this is a correct interpretation of what is going on, while Perruchet & Rey's work would not nullify the proposal that the difference between the processing abilities of humans and tamarins is the type of memory structures available to them, it would mean that alternative experimental means still would be required in order to substantiate the hypothesis.

5.6.4 Some Conclusions

The findings of this section can be summed up by table 5.4. In human non-communicative cognition clear examples of recursive structures and procedures are manifested in number cognition, games and music, visual decomposition of objects, and social cognition and theory of mind. More specifically, those that are *necessarily* recursive are found in the domains of music, vision, social cognition and theory of mind[65]. In other species, however, there is far less evidence for recursion in their non-communicative cognitive complexes, and any apparent evidence must be classed as speculative at this point. Such conjectures include the areas of kinship and dominance relations, and even more precariously, complex action sequences. Finally, non-human communication systems have proved to cause a number of difficulties when assessed for recursive properties. The claim at present must be that there is no hint of recursion here. Although we must remain open-minded about its discovery in the future, lack of phonological syntax and semantically interpretable syntax will clearly limit the progress that can be made.

[65]Those marked in table 5.4 with an asterisk.

More detailed and interesting conclusions can be drawn from table 5.5. Here, a comparison is drawn, based on the evidence in this and earlier sections, between the existence of recursion and the requirement for keeping track. As noted above, enhanced memory in the form of a stack is only required in cases of nested recursion; thus, the recursion part of the table has been broken down into tail and nested recursion. What this table shows is that the important generalisation with respect to the differences between humans and other species may in fact not be in recursive capabilities, but may in fact be in the ability to keep track in a stack fashion. While human language and cognition displays both tail and nested recursion, and consequently the ability to keep track, the suggested instances of recursion in animal non-communicative cognition are cases of tail recursion (kinship and dominance hierarchies). No hints of nested recursion, and thus no hints of devices for keeping track, have been found in the cognition of other species. With regard to animal communication, we noted that tail recursion would be near impossible to distinguish from iteration. Nested recursion, although logically possible, has not been attested in the communication systems of non-humans either. To repeat a point made a number of times already, absence of evidence is not evidence of absence, but based on the split seen in table 5.5, a possibility which we should not instantly disregard is that although non-human species may have (limited) recursive capacities, they have no means for keeping track of the sorts of dependencies that nested recursion gives rise to.

Human Non-Communicative Cognition		Animal Non-Communicative Cognition		Animal Communication	
Number	√	Number	X	Campbell's Monkey Alarm Calls	X
Navigation	?	Navigation	?	Honeybee Dance	X
Games/Music	√*	Complex Action Sequences	?	Bengalese Finch Song	X
Vision	√*	Social Cognition/Theory of Mind	?*	Tamarin Grammar Processing	X
Social Cognition/Theory of Mind	√*				

Key: √ = recursion exhibited
X = recursion not exhibited
? = unclear if recursion is exhibited
* = necessarily analysed as recursive

Table 5.4: Recursion in the communicative and cognitive systems of humans and animals

	Tail Recursion	**Nested Recursion**	**Keeping Track**
Human Language	Left-branching Right-branching	Centre embedding	Centre embedding
Human Cognition	Game of tag Towers of Hanoi	Object decomposition Path creation Key modulation	Object decomposition Path creation Key modulation
Animal Cognition	Kinship hierarchies Dominance hierarchies		
Animal Communication			

Table 5.5: Recursion versus keeping track in animal and human cognition and communication

5.7 Language without Recursion

In this section, I will examine the question of what a recursion-less language would look like. The claim of Hauser *et al.* (2002) implies that a lack of recursion in our communicative abilities might reduce our system of language to something a lot closer to a system found elsewhere in the animal kingdom. Here I will examine whether this is indeed the case. Would a language that did not in any way incorporate recursion function in a useful way? That is, would such a language faculty give rise to the same level of expressivity as we consider to hold of human language as it is? More importantly, would a language without recursion still look like a human language, or would we wish to class it as closer to a non-human communication system?

Answers to these questions call for re-analysis of the data in previous sections. What sort of constructions have we seen to be recursively generated? Can the semantics of such constructions be expressed in non-recursive ways? Alternatively, without recursion, is it impossible to communicate the meanings associated with such recursive structures? These questions will be investigated in the following manner: first, a review of the data from this chapter will allow us to succinctly characterise the constructions that recursion furnishes. We will then consider if recursion-less language would prevent us from being able to accommodate the meanings underlying such structures. A negative answer will be given, based on evidence from a particular case of such a language. The issue of protolanguage will then be investigated from the point of view of recursion; that is, evidence from a protolanguage theory will back up the argument that recursion-less human communication is possible and viable. Finally, an evolutionary scenario predicated on the issue of conceptual structure will be offered for the emergence of recursion in human language.

5.7.1 Recursive Structures

Earlier sections of this chapter have provided many examples of linguistic recursion. Let us now review these examples, and develop a typology of recursive structures and their corresponding communicative functions, which can be used to assess the requirement for recursion in our communication system.

All instances of recursion in natural language seen in sections 5.2 and 5.3 can be boiled down to two categories of construction: possessives and subordinate clauses[66], with the latter category subsuming quite a range of sub-categories. Possessives are illustrated by examples such as those in (37), subordinates by those in (38)[67]:

(37) a. [$_{NP}$ [$_{NP}$ [$_{NP}$ John]'s mother]'s cake].
b. [$_{NP}$ [$_{NP}$ [$_{NP}$ [$_{NP}$ Jane]'s uncle]'s dog]'s bone].
c. [$_{NP}$ [$_{NP}$ [$_{NP}$ [$_{NP}$ [$_{NP}$ The boy]'s sister]'s teacher]'s daughter]'s book].

(38) a. [$_S$ Bill knows [$_{NP}$the man [$_{CP}$ that [$_S$ I saw yesterday]]]].
b. [$_S$ My sister studies with [$_{NP}$the girl [$_{CP}$ that [$_S$ I met at the party [$_{CP}$ that [$_S$ John hosted in the bar [$_{CP}$ that [$_S$Bill recommended]]]]]]]].
c. [$_S$ The mouse [$_S$ the cat [$_S$ the dog chased] bit] ran].
d. [$_S$ The professor said [$_{CP}$ that [$_S$ the students all failed the exam]]].
e. [$_S$ The students thought [$_{CP}$ that [$_S$ they had passed the exam]]].
f. [$_S$ The child learned [$_{AdvP}$ how [$_S$ to ride a bicycle]]].
g. [$_S$ [$_{CondP}$If [$_S$ it doesn't rain]], I'll go].
h. [$_S$ He ate the cake [$_{CauseP}$ because he was hungry]].
i. [$_S$ The teacher wants [$_S$ Kate to do her homework]].
j. [$_S$ Jane, [$_{NRRelC}$ who [$_S$ lives in France now]], studied with Lisa.]

The function that the majority of the recursive structures here play has previously been noted as allowing us to further describe or pinpoint a particular entity or action salient in the discourse. The possessive examples in (37) and the subordinates in (38) illustrate a range of ways in which recursion is used to generate natural language which permits essentially two communicative functions to be realised. It is used to (i) make reference to a finer level of precision, and (ii) to provide additional modifying information. The question we should logically ask next is whether a lack of recursion would prevent us from expressing such concepts and relations. In other words, are there alternative ways in which we can express these concepts? Hurford (2004:562) notes that "[i]t is possible to imagine a quasi-human language which only had main clauses (i.e. no subordinate clauses) and no embedded possessive or self-embedded constructions of

[66]A further class of recursive structures are embedded Preposition Phrases, such as:
[$_{NP}$ The house [$_{PP}$ on [$_{NP}$ the hill [$_{PP}$ by [$_{NP}$ the river [$_{PP}$ over the mountain]]]]]]
However, it is arguable as to whether such examples do form a separate class; they may simply be reduced relative clauses, and thus a sub-set of the subordinate class.

[67]The phrase types assumed here include Adverbial Phrase (AdvP), Cause Phrase (CauseP), Conditional Phrase (CondP), and Non-Restrictive Relative Clause (NRRelC); this terminology is used simply to be as transparent as possible; alternative terminology would not change the pertinent point.

any kind." Continuing with this intuition, we could imagine that subordinates such as those above might equally well be expressed using simple juxtaposition; something along the lines of (38′)[68]:

(38′) a. Bill knows the man. The man, I saw him yesterday.
b. My sister studies with the girl. The girl, I met her at the party. The party, John hosted it in a bar. The bar, Bill recommended it.
c. The mouse ran. The mouse, it was chased by the cat. And the cat, the dog bit it.
d. The students all failed the exam. The professor says so.
e. The students passed the exam. This they thought.
f. The child learned the bicycle-riding.
g. No rain. Then I will go.
h. He was hungry. He ate the cake for this reason.
i. The teacher wants Kate's homework-doing.
j. Jane studied with Lisa. Jane lives in France now.

Similarly, we might imagine that an alternative non-recursive structure for possessives such as those in (37) might be to use juxtaposition and some type of identity-marker (IDEN.)[69] which is used to link noun phrases in juxtaposed clauses/sentences, as in (37′):

(37′) a. The cake belongs to the mother. John is the son-IDEN.
b. The bone belongs to the dog. The owner-IDEN is the uncle. Jane is the niece-IDEN.
c. The book belongs to the daughter. The mother-IDEN is the teacher. She teaches the sister. The boy is the brother-IDEN.

This thus suggests that recursion-less language is indeed possible. This has implications for the hypothesis of Hauser *et al.* (2002) that recursion is the sole feature that distinguishes human from non-human communication, in that it

[68] Admittedly, it becomes harder and harder to conceive of non-recursive ways to structure such expressions as we move from single embeddings to multiple embeddings. However, as noted earlier, it becomes similarly difficult to deal with the recursive counterparts beyond a certain level of embedding.

[69] We might in fact argue that non-recursive possessives do not even require such a marker, but that coreferring pronouns would suffice. However, this would require assuming that a possessive phrase such as *her son* does not have the recursive structure [$_{NP}$ [$_{NP}$ her] son]. This may be the case if a pronoun is not considered to constitute a NP, but is rather some sort of possessive determiner.

seems clear that the expressions in (37′) and (38′) go far beyond non-human communication systems, yet they do not use recursion. The sentences in (37′) and (38′) illustrate what Hurford (2004:563) means when he says: "...recursion can actually be seen as a simplifying device, allowing more efficient storage of possible sentence patterns compatible with their meanings." As the examples show, a non-recursive expression of a recursive concept is reasonably more structurally complex than its recursive counterpart. The alternative to recursion is parataxis; the juxtaposing of phrases and clauses in a non-subordinating and non-modifying manner. Parataxis leads to repetition and/or numerous anaphora, which from both the speaker's and hearer's points of view is relatively costly. Thus, we might say that recursion furnishes the most efficient or optimal solution to the problem of expressing a recursive concept. However, although we might argue that the addition of recursion to the suite of principles and tools of human language admits more efficient structures in certain cases, we would not want to say that the non-recursive structures in (37′) and (38′) are less expressive.

An interesting point which certain of the examples above raise relates back to the issue discussed at the end of section 5.6 regarding recursion versus keeping track. The nested recursive example in (38c) and its non-recursive counterpart in (38′c) show that there seems to be a trade-off between structural efficiency and memory requirements. That is, (38′c) involves parataxis, but no subordination or recursion, and hence no requirement for an enhanced stack type memory. However, it is reasonably complex from a structural point of view. On the other hand, the nestedly recursive (38c) requires augmented memory, but also exhibits more efficient structure. Thus, a reasonable evolutionary conjecture is that recursive language is a response to the requirement for an optimal solution to expressing recursive thought, but that this evolutionary step would only be possible given sufficient memory. For those concepts that are expressible in tail recursive terms, no complex memory would be required, but for nested recursive structures, the ability to keep track in a stack fashion would be a prerequisite, but would in turn lead to significant reductions in communicative effort.

5.7.2 Language without Recursion: the Case of Pirahã

Recent work by Daniel Everett (Everett (2005), Everett (1986)) on the Amazonian language Pirahã provides fascinating evidence suggesting that there may indeed exist a language lacking the very feature under consideration here. That is, Pirahã appears to be a language which does not use recursion. That is not to say that Pirahã is a quasi-human language (in the same way as our imagined example above). Further, Pirahã does not provide evidence for assuming an underlying faculty different to that attributed to the English speaker, the French speaker, or the speaker of any other human language. As Culicover & Jackendoff's (2005) *Toolkit Hypothesis* suggests, the human language faculty provides us with a large set of devices and properties which different languages exploit in different ways. If it is the case that Pirahã truly does not have any self-embedding, this is simply one example of how the toolset of human language can be employed in varying fashions. In other words, recursion is available to the Pirahã speaker just as it is to the English speaker, and if a Pirahã had been brought up instead in an English-speaking environment, they would not have been unable to master the recursive possessive and subordinate structures of (37) and (38). What is important in these findings, however, is the fact that the Pirahã people can communicate without recursion as was just speculated to be possible. Pirahã is a full human language[70]; that is, it cannot be equated with any non-human communication system, it is a system that exhibits uniquely human, uniquely linguistic features, a system that can only be acquired by the possessor of a human Language Acquisition Device, yet it lacks the feature that Hauser *et al.* (2002) argue is the defining characteristic of human language. Some more detailed examination of the Pirahã language will now follow.

5.7.2.1 Lack of Subordination

One of the many striking absences that Everett (2005) reports in Pirahã is the fact that it does not make use of CP-embedding. Thus, there is no subordination of the type exhibited in (38). Subordination which serves to further specify a referent (38a-c) is achieved with juxtaposition, often with the use of a morpheme meaning 'same', as illustrated in (39)[71]. Indirect speech (38d) is syntactically equivalent to direct speech, the difference being pragmatically determined. Thus, (40) is interpreted as direct speech when the context forces the referent of *ti* to be *Xahóápáti*, and as indirect speech if the context forces one to interpret *ti* as

[70]The argument might be made that Pirahã is in fact not a full human language, but something more akin to a pidgin, and thus that its apparent lack of recursion causes no difficulty for HCF's hypothesis. However, it is clear that Pirahã does not sit in the same class as a pidgin. For one, Pirahã is the first language of its speakers, while a pidgin speaker generally is in possession of another first language. Secondly, where language learners do acquire a pidgin as their first language, their Language Acquisition Device forces them to imbue it with the grammatical complexities of UG, thus leading to a creole. If Pirahã were to be understood as parallel to a pidgin, then why does the child acquiring Pirahã not impose recursion on it, in a creolisation type of process?

[71]Example (39) is taken from Everett (2005), example (40) from Everett (1986).

referring to the person reporting the speech. Subordination of the type in (38e) - that which reports the thought of another - is realised in Pirahã again by means of juxtaposition, the complement of the verb understood as the content of what was thought[72]. In these cases, nominalisation of the verb achieves the subordination, and there is no pre-clausal complementiser (equivalent to English *that*).

(39) ti baósa -ápisí 7ogabagaí. Chico hi goó bag -áoba.
I cloth -arm want. name 3 what sell -completive
'I want the hammock. Chico what sold.'

(40) hi gái- sai xahóápáti ti xi aagá-hóág- a
3 say-NOMLZR Xahóápáti 1 hunger have-INGR-REMOTE
(i) 'Xahóápáti said, "I am hungry." or
(ii) 'Xahóápáti said (that) I am hungry.'

Equivalents to (38f-i) are generated using juxtaposition, nominalisation or morphological marking (Everett 1986). Importantly, Everett (2005) notes that the Pirahã have the communicative resources to express everything which embedding expresses in other languages. Therefore, we can't attribute to the lack of recursion a lack of certain expressivity. The Pirahã data would therefore appear to buttress the arguments made above that a recursion-less language is not any closer to a non-human communication system; human language is possible without the property of recursion. There is obviously more that sets human language apart from other systems of communication, as section 5.3 advocated.

5.7.2.2 Limited Possessors

Looking now to the recursion of possessives (as in (37)), it is observed that recursive possession is not possible in Pirahã, although one possessor is permitted:

(41) *kó7oí hoagí kai gáihií 7íga[73]
name son daughter that true
'That is Kó7oí's son's daughter'.

[72]Note that there is no verb for *think* in Pirahã; the verb *say* is used to denote intentions too.
[73]Everett's (2005) example (47).

(42) kó7oí kai gáihií 7íga
name daughter that true
'That is Kó7oí's daughter'.

Everett (2005) claims that the lack of recursive possession is one of the features that can be directly related to the culture of the Pirahã people. He notes that their knowledge of others in their and neighbouring villages is extensive, and as a result, one level of embedding will usually suffice to pinpoint any person they wish to communicate about. However, arguing that Pirahã is no worse off than languages which do allow recursive embedding of possessors because it does not have a requirement for such constructions raises the same issues as arguing that human language is no better than mouse 'language' for the reason that mice have no need to communicate about the vast array of things that we do. Once the need for broader communicative contexts arises, mouse 'language' is no longer equal to human language. In the same way, should the need arise for the Pirahã to express recursive possessive concepts, their language could no longer be considered equal to languages which allow structures analogous to (37). Yet, (43) shows that Pirahã can express such concepts using alternative means (i.e. parataxis).

(43) 7ísaabi kai gáihií 7íga. kó7oí hoagí 7aisigí -ai
name daughter that true. name son the same -be
'That is 7ísaabi's daughter. kó7oí's son being the same'.

Pirahã has to then be considered equally expressive. Thus, the implication of Hauser *et al.* (2002) that language with recursion is somehow better - "[i]n particular, animal communication systems lack the rich expressive and open-ended power of human language (based on humans' capacity for recursion)." (Hauser *et al.* 2002:1570) - fails if 'better' is interpreted as meaning 'more expressive'. One way in which 'better' could be understood (which is clearly not the meaning Hauser *et al.* wish to convey) is with regard to the efficiency discussed above that recursion provides. Thus, although expressively, Pirahã equals languages with pervasive recursion, from the perspective of efficient encoding it might be considered less effective.

Although recursive possession cannot be expressed by syntactic recursion in Pirahã, and is instead conveyed using juxtaposed phrases as in (43), (42) shows that a single possessor causes no difficulties. However, (42) cannot be analysed as recursion. If such cases were assumed to be generated by a rule such as (44), what would prevent the recursion from being (in principle) infinite? In other words, what would then rule out cases like (41)? A non-recursive rule such as (45) eliminates this problem.

(44) NP $\rightarrow$ NP & N

(45) NP $\rightarrow \left\{ \begin{array}{ll} \text{det} & \text{(AP)} \\ \text{N} & \text{poss} \end{array} \right\}$ N

In any case, this is not as crucial a finding for the issues here as it first appears, given that we are in no way positing an alternative language faculty with no recursion built in for speakers of Pirahã. Whether Pirahã has no recursion or just this one instance of (very limited) recursive phrase structure still demonstrates that human language can work equally well without recursion from an expressive point of view.

Fitch *et al.*'s (2005) claim that the status of Pirahã is entirely independent of the recursion-only hypothesis misses a crucial point. What the Pirahã data tell us is the following: (i) if the criteria for assuming syntactic recursion in a language is that there must be embedded inside a phrase one of the same type, Pirahã appears to lack syntactic recursion, (ii) Pirahã is a full human language, and (iii) "...Pirahã most certainly has the communicative resources to express clauses that in other languages are embedded..." (Everett 2005:631). The recursion-only hypothesis says that recursion is the only feature of the narrow language faculty. This entails that recursion is the one property which sets human language apart from other communication systems; it is the one property which makes language what it is. However, faced with a full human language that can use alternate means to express recursive conceptual structures highlights the fact that recursion must be just one of a number of tools in the set which serves to make language unique; it cannot be the single defining feature of language.

5.7.3 Recursion in Protolanguage

The evidence thus far appears to indicate that recursion-less language is both possible, and that its expressivity would not be compromised in such a way as to make it an unviable language (although we have noted, following Hurford (2004), that it might not be as structurally efficient as recursive language). A question which now arises is whether it is possible that the human language faculty passed through a stage in its evolution in which it had many of the features which we attribute to its current state but without the ability for recursive phrase structure. Such earlier stages of the human language faculty are suggested in theories of language evolution that we might broadly term *protolanguage theories*. This section will examine the question of where recursion fits into protolanguage.

5.7.3.1 Jackendoff's Protolanguage Theory

One particular protolanguage theory will be examined in this section: Jackendoff's stages in the evolution of the language faculty. The question to be borne in mind is whether this theory is compatible with the view that a communication system which does not use recursion in any way is possible, and at the same time is substantially different from systems of communication seen in other species, such as those analysed in earlier sections of this chapter. Although all protolanguage theories are just that - theories without any fossil evidence to confirm or disprove them - if they bear out this hypothesis, the case for the recursion-only proposal will appear weakened even further.

The model of Jackendoff (2002) conforms obviously to a gradual adaptationist view of the evolution of language, with a number of ordered and parallel stages of development set forth to explain how the progression from an ancestral species with no language to the current human language faculty might have proceeded. The model clearly indicates the point in the path where the group of features already acquired might reasonably be referred to as protolanguage. The overall generalisation with respect to recursion is that protolanguage did not afford the use of phrase structure to its users. Presumably then, based on the discussions of the order of emergence of phrase structure and recursion in section 5.4, without phrase structure, protolanguage users would not have had recursive syntax.

Jackendoff's stages are reproduced in figure 5.16. Looking more closely at the discussion of the stages in the model, we see that recursion is not explicitly mentioned at any point. However, we might ask the following two questions of the stages mentioned in order to establish at what point recursive syntax enters the picture: (1) which of these stages (if any) are required before syntactic recursion can exist? and (2) which of these stages (if any) need recursion to be in place before they can emerge? Table 5.6 indicates the answers.

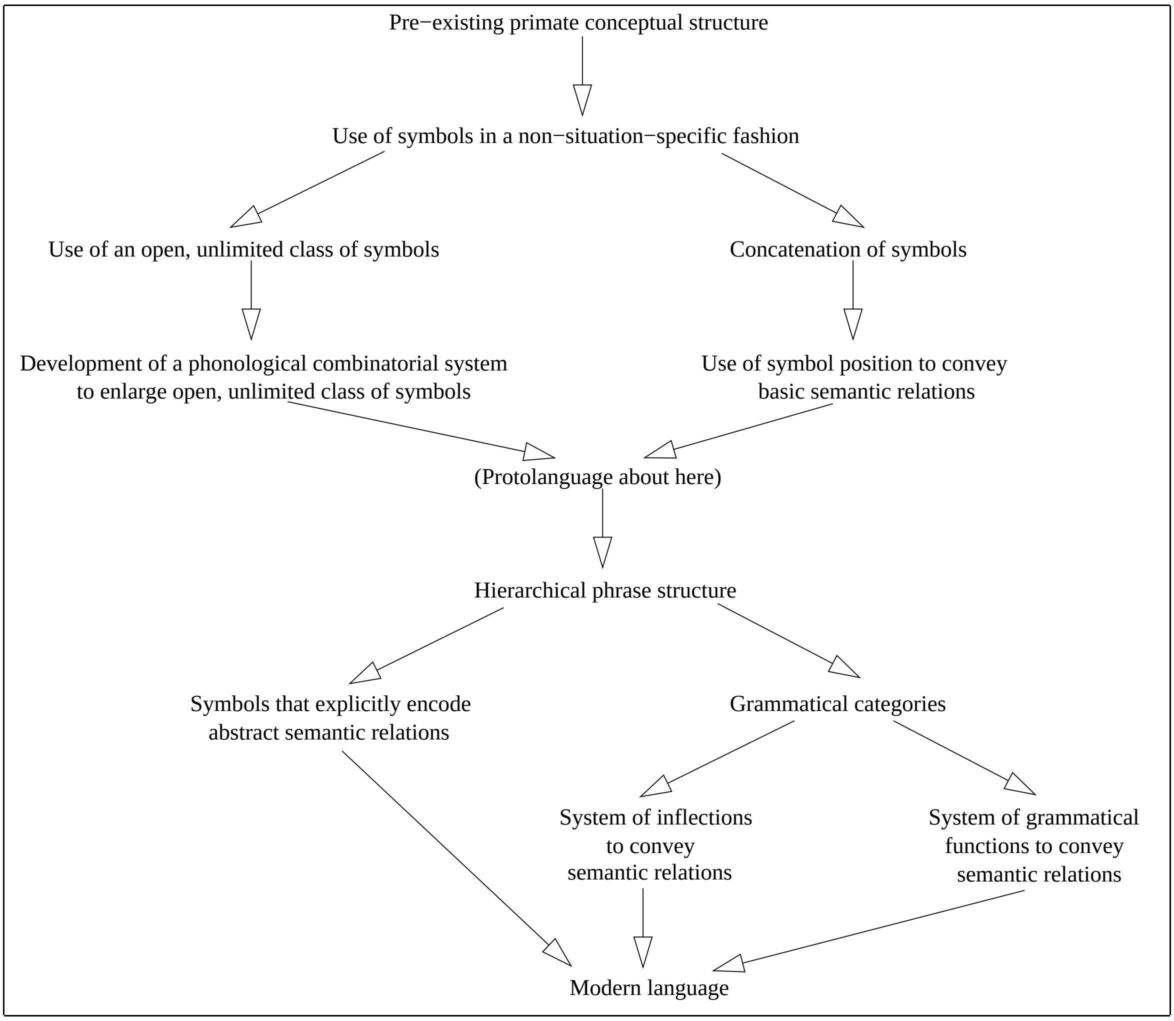


Figure 5.16: Jackendoff's stages in the evolution of language

Stage	Required for recursion?	Recursion required for it?
Non-situation-specific symbols	YES*	NO
Open class of symbols	NO	NO
Concatenated symbols	YES*	NO
Phonological combinatorial system	NO	NO
Symbol position indicating semantic relations	YES*	NO
Protolanguage		
Hierarchical phrase structure	YES	NO
Symbols indicating abstract semantic relations	NO	NO
Grammatical relations indicating semantic relations	NO	NO
Inflections indicating semantic relations	NO	NO
Modern language		

* A weaker correlate of this feature would be sufficient as a pre-requisite for recursion.

Table 5.6: The place of recursion in Jackendoff's stages

The one clear prior requirement for recursive syntax among the features which Jackendoff asserts to identify the main stages in the evolution of the language faculty is hierarchical phrase structure. As was discussed in section 5.4, hierarchical phrase structure is needed in order to recursively embed phrases. Other pre-requisites have been marked in the above table with an asterisk. This indicates that the feature posited by Jackendoff is reasonably strong, and that a weaker correlate would suffice for recursion to get off the ground. With regard to non-situation-specific symbols, clearly there is a requirement for some type of signal parts which will be recursively embedded. However, there is no necessary requirement that these parts be symbolic, nor situation-specific. Concatenation of signal parts would also be required before we could have recursive syntactic structures in that we need multiple-element utterances before we can embed. Again, however, the elements in question would not have to be symbols. In such a non-semantically interpretable protolanguage, only nested recursion would be distinguishable. As has been discussed in previous sections of the chapter, tail recursion requires semantics in order to distinguish it from simple iteration. So, for protolanguage to manifest tail recursion, the above pre-requisites would indeed have to take the stronger forms outlined by Jackendoff. On top of this, a further pre-requisite would be the need to indicate semantic relations in some way. Jackendoff assumes that the syntactic position of elements is what is required here. However, free word order languages presumably also exhibit recursion, so a weaker formulation might simply require *some* means of indicating semantic relations (be it position, inflection, or something else)[74]. However, this requirement is not necessary for the system to show nested recursion. As we saw above, strings alone force a recursive interpretation in such cases, and so the identification of semantic relations (by whatever means) is not necessary. Although picking pre-requisites out of Jackendoff's schema calls for certain qualification, the choice of these stages seems relatively straightforward. The other stages of the model do not embody necessary conditions for recursion; for example, a small set of symbols/elements can be combined into phrases, which can be recursively structured, in the same way as a large set, and phonological combinatoriality is independent of syntactic combinatoriality.

As to the second question posed, none of the featural stages require recursion as a prerequisite. That is, we could interpret recursive syntax as being at the top of a complexity hierarchy of these features. This fits well with the hypothesis developed thus far; recursion could be added to the set of properties or devices that the language faculty offers and thus provide additional structural possibilities (economy, for example), yet a system lacking recursion (but, for instance, accommodating non-recursive hierarchical phrase structure[75]) would still be reasonably expressive. Certainly, such a system would be more expressive than any non-human communication system; it would be vastly more productive, it would convey thoughts and ideas about the here-and-now as well as the distant-in-time-and-space, it would be compositionally semantic, and more besides. Therefore, we might posit that recursion enters the evolutionary path outlined in figure 5.16 somewhere after the introduction of hierarchical phrase structure, although whether it emerged before or after the stages following this is not clear (nor is it critical for the story sketched here).

5.7.4 Conceptual Structure Revisited, and an Evolutionary Scenario

The foregoing section has suggested that recursion-less language is indeed possible and useful. Thus, the hypothesis is that the human language faculty evolved gradually and incrementally, recursion being a fairly late addition to the suite of

[74]In other words, the requirement might be one of the later stages Jackendoff posits, rather than his fifth stage.

[75]Note that the stages of Jackendoff's model make no distinction between recursive and non-recursive phrase structure. Section 5.4 however, drew attention to the important separation between these.

features we now boast[76]. Certain properties (such as symbol usage and concatenation, and phrase structure) must have preceded the emergence of recursion, and certain properties (such as the combinatoriality of phonology, constraints on null elements, or the existence of grammatical inflection) are independent of the emergence of recursion, and might have emerged before it, after it, or even concurrently. In developing this evolutionary scenario, we have so far discussed only other features of language. But what about non-linguistic pre-requisites for the emergence of recursive phrase structure? In this final subsection, I will revisit the relation between recursive conceptual structure and recursive phrase structure, in an attempt to put the time of emergence of recursion on a firmer footing.

Throughout the later stages of this chapter it has been assumed that recursive phrase structure expresses recursive conceptual structure, and that although not impossible, without the latter, the former seems evolutionarily less likely. The question to be addressed now is whether recursion emerged in the conceptual structure and the communication system of our ancestors in parallel, or whether recursive conceptual structure emerged first and forced the emergence of recursive phrase structure. I will argue that the more likely scenario is the latter. The reasoning for this goes as follows.

Evidence and examples from this section have shown that recursion-less language is expressive, and therefore useful. Furthermore, we noted cases where recursion-less language can express underlying recursive conceptual structure, such as subordinate clauses and recursive possessives, without difficulty. We might then be tempted to ask the question: if recursion-less language works just fine, why did recursive language evolve? Is it not the case that evolution is a meliorizing agent; that is, it will make do with a good enough solution to a problem, and won't worry about finding the best solution? In this case, non-recursive structures, such as those seen earlier in this section, seem to be a good enough solution to the problem of expressing recursive conceptual structure. The answer may reside in a point hinted at earlier; being able to structure not just thoughts, but also language, recursively would have given our ancestors an advantage in terms of energy. It was alluded to above that recursion is a compressing device; representing the relations between events or entities in a recursive fashion

[76]Recall that the argument there does not assume that speakers of a recursion-less language, such as the Pirahã, have a different language faculty to speakers of languages that emply recursion. Thus, claiming that recursion was a late addition to the language faculty is *not* claiming that the Pirahã have a more primitive version of the language faculty.

is more concise - compare again (37c) and (37′c) (repeated here as (46a-b)). A more concise expression involves less articulatory effort on behalf of the speaker, and saves both time and energy.

(46) a. The boy's sister's teacher's daughter's book.

b. The book belongs to the daughter. The mother-IDEN is the teacher. She teaches the sister. The boy is the brother-IDEN.

Thus, without a recursive conceptual structure there would be no driving force for recursive syntactic structure. Yet, as examples such as (37') and (38') show, recursive conceptual structure can be expressed without recursive phrase structure, so recursion is most likely to have emerged first in conceptual structure and later in syntactic structure, rather than a parallel emergence. Indeed, it has been claimed (Kalmár (1985), Mithun (1984)) that certain preliterate languages lack subordination (or at least manifest significantly less subordination than do literate languages), although alternative means of expressing subordination imply that there is no correlate lack of subordinate conceptual structure[77]. This observation would also support a non-parallel evolutionary account.

In conclusion, this section has provided evidence from protolanguage, and a case study of Pirahã that recursion-less language is possible. More importantly, a system of communication which incorporated many of the design features of human language but lacked recursive phrase structure would be functionally more advantageous to its users than a system with the equivalent capabilities of non-human communication systems. In evolutionary terms, recursive phrase structure arose as a response to expressing recursive thought in a more efficient way. Therefore, recursive conceptual structure was one pre-requisite for recursive language. In terms of the evolutionary progression of the linguistic system itself, recursion had to arise after the emergence of hierarchical phrase structure, but the order of emergence of recursion in relation to many other features of language is not crucial.

[77]Deutscher (2000) makes the weaker suggestion that certain subordinate structures may have evolved as an adaptive response to more complex communicative patterns. That is, the evolution of such subordinate linguistic structures may have been driven by a need to communicate subordinate conceptual structures.

5.8 Conclusions

The take-home message of this chapter is that the concept of recursion must be studied much more carefully than it has been up to this point. This chapter can be seen as a type of warning, illustrating the confusion that can arise, and the ill-judged assumptions that can be made, when care is not taken. What the preceding discussion has shown is that intuitions are not enough, and precise formulation should be demanded. Clearly, even with such conscientious analysis, there are many issues that remain; however, the type of vague allusion that is evident in Hauser *et al.* (2002), and the ensuing rejoinders (Pinker & Jackendoff (2005), Fitch *et al.* (2005), Jackendoff & Pinker (2005)), will only hamper progress in the field.

What this chapter has also shown is that Hauser *et al.* (2002:1572) are right in stating that "[a] powerful approach to problems of language evolution is provided by the comparative method, which uses empirical data from living species to draw detailed inferences about extinct ancestors." The data in section 5.6, drawn from many domains within animal cognition and communication, helps to more clearly delineate that which we should understand as uniquely human and uniquely linguistic. In the field of evolutionary linguistics, we need to be very clear about what it is that emerged before we can suggest answers to how and why questions.

On a more empirical level, what has this chapter achieved? The answer to this is a clear two-way disinction between types of recursion, leading to a claim about the difference between human and animal cognition which may inform theories of the evolution of language. The two types of recursion are tail and nested. The former looks like iteration, and semantics is required to distinguish it from iteration. It was shown to be evidenced in human language, but not in non-human communication, and moreover that any evidence of it there will be very difficult to uncover. In cognition more generally, tail recursion was shown to be evident both in humans and in other species. Nested recursion, on the other hand, was argued to be evident in human language and cognition, and although theoretically detectable in non-human communication and cognition, currently not attested there.

The difference between tail and nested recursion was shown to boil down to the memory requirements the latter imposes - a push-down stack type of memory capacity. The claim was then made that the lack of nested recursion, but yet the existence of tail recursion, in non-human domains suggests that the difference between human and animal cognition is not to do with recursion, but is one of memory. That is, like Christiansen (1994), I propose that recursion is a red herring, blinding our view of the greater importance of memory to the uniqueness question.

Finally, in terms of the MP, what have we learned in this chapter? As section 5.3.1 outlined, the recursion-only hypothesis is clearly amenable to minimalist thinking. Although Fitch *et al.* (2005) deny the direct link between their evolutionary proposal and the MP, it is obvious that the simplicity and atomicity which underpins the recursion-only hypothesis have been directly inspired by the development of minimalism within generative grammar; it is hard to see a GB-oriented Chomsky coming to the same evolutionary conclusions. For the thesis as a whole then, this chapter highlights once more that the human narrow language faculty is not that minimal; that considering language at a level up from the nitty gritty of the minimalist syntactic architecture, and a level down from the general theoretical and methodological premises of the MP does not alter the view developed in chapter 4 that FLN is complex and intricate, and that an evolutionary account which denies this is mistaken. In the chapter which follows, I will consider the evolutionary implication of the MP from the deepest level - the particularities of the minimalist architecture itself.

CHAPTER 6

Perfection Revisited - The Empirical Facts

6.1 Introduction

The preceding chapters have sketched a picture of a theoretical viewpoint which stands in opposition to what we know of evolution. The minimalist language faculty has been argued to be implausible from an evolutionary perspective for a number of reasons. Motivated by the primary concern of developing a system which conforms to conditions of economy, the system of language that emerges from minimalist theorising is reduced, atomic, and simple. In turn, this simplicity forms the backbone of the perfection argument; as the system consists only of what is strictly necessary, it is the optimal solution to the problem of mapping between sound and meaning. However, perfection directly contradicts the evolutionary bias for redundant, uneconomical systems; the preference of evolution to meliorize. The simple minimalist system is furthermore evolutionarily improbable by virtue of it permitting only a saltational account; the usual gradual adaptive processes of evolution leading to greater complexity than minimalism admits. In other words, the minimalist language faculty is not evolvable.

In the last chapter, the focus of investigation changed slightly. There, it was shown that an evolutionary scenario advocated recently (Hauser *et al.* 2002), and entirely sympathetic to the tenets of minimalism, suffers from both empirical and theoretical troubles. The recursion-only proposal has been shown to be flawed for a number of independent reasons. The implication in that chapter is that the human language faculty must be more complex than a minimalist (or recursion-only) view suggests. The question to be addressed in this chapter is how minimal the minimalist language faculty actually is. That is, are there reasons to believe that the conceptual basis of the MP cannot be borne out empirically? In what follows, I will suggest that the program fails to convincingly delineate a system which is truly reduced, economic, non-redundant, or perfect. There remain in the system hidden complexities, extraneous operations, unmotivated stipulations, and phenomena whose current lack of explanation hints at further requisite complexification[1]. It is important to keep in mind the distinction drawn between the levels of description at which the claim of minimalism can hold. While certain of the charges against minimalism laid out in this chapter highlight complexity in the description of the system (contravening methodological minimalism), certain others highlight complexity in the workings of the system (contravening substantive minimalism). The former show only that the MP is flawed in its descriptive pursuit. As a result of the latter, however, the claim that language is a highly complex system, whose evolution is likely to have been gradual and piecemeal rather than abrupt and outright, becomes further reinforced.

[1]Importantly, as was stated in section 2.3.4, it is a particular variety of the MP that is facing criticism here. While certain minimalist models may not face all of the difficulties enumerated below, Chomsky's particular brand of minimalism (Chomsky (1995b), Chomsky (2001), Chomsky (2002a)) does.

6.2 Degeneracy and Imperfection in the System

The previous chapters of this thesis have spoken in a number of places of linguistic redundancy and degeneracy. However, in all cases, the discussion pertained to redundancies and degeneracies that are a feature of the linguistic system independent of a minimalist reading of it. The first section of this chapter will deal with redundancy and degeneracy of a different kind - that which exists in the minimalist system itself. That is, the system of language that minimalist theories advocate is not in actuality as efficient or non-redundant as supposed. Consequently, if redundancy and degeneracy are to be equated with sub-optimality, the minimalist vision of language begins to collapse.

A first example of degeneracy in the minimalist system is seen in the general type of architecture assumed. Following the generative tradition, the MP would typically be placed on the derivational side of the derivational-representational dichotomy. However, the theories derived from the program appear, in fact, to straddle the divide, unsure of which side they want to belong to. The minimalist conception of language involves both derivational operations and representational conditions, making it neither purely derivational nor purely representational (Brody (1998), Johnson & Lappin (1997)). Derivation comes in the form of the core computational operations of Merge, Move and Agree; overt processes which apply to the contents of the lexical array, developing the sentence in a step-by-step manner. Representation, in contrast, comes in the form of the two remaining levels of representation - PF and LF - and the well-formedness conditions which hold at these levels (such as the principle of Full Interpretation, stating that every symbol must be interpretable at the interfaces)[2].

A theory which mixes derivations and representations is problematic for minimalism in that it results in a system which is governed in two overlapping, and plausibly interchangeable manners. In other words, there are derivational and representational aspects of the system which essentially do the same jobs. Brody (1995) argues, for example, that the derivational Move operation and the representational chain that holds between moved-from and moved-to positions are not both required in the system, as they signal the same information. The system

[2] It is impossible, of course, for a derivational system to exclude representational levels; the system derives representations. However, it is possible for a derivational system to exclude conditions on representations, the work of such conditions being carried out instead by restrictions on the manner in which the derivation can proceed (what Brody (2002) refers to as a weakly representational derivational system).

could work equally well with only one or other, indicating an obvious degeneracy.

In a copy theory of movement, the copy of the moved item is a further redundancy in the system[3]. Although the copy does have the specific job of indicating the original position, and thus the 'deep' semantic (see section 2.2.4) role of the moved item, there does not seem to be any reason why this must be indicated by a full copy, which is then subject to the deletion processes in the PF component required to ensure that only one copy is pronounced. Assuming movement to involve copying of this manner thus entails not simply redundant representational information, but also superfluous operations.

A crucial question is why it is the case that leaving a full copy of the moved element is the most computationally minimal choice. Why is it that applying the PF deletion rule to this copy is cheaper or simpler than, say, leaving behind only the semantic features of the moved element, thus obviating the need for PF deletion? Presumably, this alternative would have to involve some process which deletes all but the semantic features of the moved element in the narrow syntax, a process which, as it has not been taken up, must be computationally more expensive than the PF deletion of the full copy. But what makes it so? We will return to questions of this nature in the next section.

A further imperfection (although not a degeneracy) in the minimalist system is the generation of a number of derivations which must be compared using global economy conditions in order for the correct derivation to be arrived at. The idea is this: a lexical array may be manipulated in a number of ways using the available operations of Merge, Move, and Agree to produce a number of alternative derivations. The alternative derivations would then need to be assessed in order that the best, or most optimal one, could be selected. The assessment involves the use of global economy conditions. For example, Procrastinate states that operations should be applied as late as possible, and Last Resort states that operations should be applied only if they result in elimination of uninterpretable features, while Shortest Move states that shorter moves are preferred over longer ones[4]. The optimal derivation is then that which violates the least number of such conditions. Imperfection arises with the possibility of

[3]Note that this is a case of redundancy, rather than degeneracy, given that it is an identical item doing the same job as another - see section 4.8.1.

[4]See e.g. Chomsky (1995b) or Hornstein *et al.* (2005) for details.

being able to generate more than one (indeed large numbers of) derivational alternatives from just one lexical array.

Of course, a more detrimental anti-minimalist problem arises from the computational complexity that this approach entails. Comparing the derivations that a lexical array may generate becomes a huge task once the number of items in the lexical array grows above a very small number. As Johnson & Lappin (1997:11) note, "...there are, for a numeration N with k lexical items, each occurring exactly once, k! (k factorial) different sequences of lexical selections from N of length k, exhausting N. This causes the number of possible derivations, in the worst case, to increase sharply in relation to the number of lexical items."

It is true that in later versions of minimalism (those following the derivation by phase approach), global economy conditions no longer play this significant role. Instead, comparisons are limited to the derivational sub-sets computable from the portion of lexical material visible at that point. Here, local rather than global economy conditions are exercised to determine the most optimal sub-derivation. So, for example, the assumption that Merge is cheaper than Move is enough to rule out derivations involving unnecessary movement. While phase-driven comparison addresses the problem of computational explosion to a certain extent[5], it does not altogether rule out the imperfection of multiple derivations for one lexical sub-array (as section 2.3.4.5 showed). Thus, despite certain mitigation, even later MP theories suffer from this sub-optimality.

[5]It does not completely deal with the complexity, of course; a full elimination of the computational expansion would require that no comparative process whatsoever take place.

6.3 'Extra' Operations and Competing Motivations

The minimalist equates optimality and perfection not simply with non-redundancy, but also with a type of bareness that derives from admitting only that which is strictly necessary - the virtual conceptual necessities of the system. In other words, nothing superfluous should exist in the minimalist system of language. The question to be addressed in this section is whether this is indeed the case; does the architectural organisation and the computational operation of the minimalist language faculty truly adhere to the bare-essentials protocol? Newmeyer (2003:588) suspects not: "...no paper has ever been published within the general rubric of the minimalist program that does not propose some new UG principle or make some new stipulation about grammatical operations that does not follow from the bare structure of the MP." The following will show that Newmeyer's suspicion is not ill-founded.

The first obvious violation of the rule of conceptual necessity is the operation Move. The motivation for movement was explained in section 3.2.4, as the means by which the conceptual-intentional system can retrieve from the linguistic object both the deep semantics associated with selectional roles, and the surface semantics of discourse structure. As such, the MP argues Move to be only an apparent imperfection, and hence an operation that the system cannot do without. But is this really the case?

The answer must be no; it is not difficult to imagine alternatives to movement which could just as clearly distinguish deep and surface semantics. It is well-known that in English the surface semantics of topic/comment, or focus, are signalled by movement only infrequently. More often than not, it is intonation that takes on the role of revealing such discourse aspects of the semantics of the linguistic representation. Another alternative is the use of morphological markers to indicate the surface semantics (as in Japanese). While these are examples of how particular languages work, there is no reason that we cannot generalise to the language faculty. If specific languages can use non-movement means to distinguish deep and surface semantics, then there is no reason for the language faculty to include the operation of movement at all.

The high-level question of why we must assume a movement operation differs from the question of how that operation is implemented according to the detailed workings of the minimalist system. Many (e.g. Berwick (1998), Chomsky (1995b)) assume that Move is simply a slightly different application of Merge; that is, applying the movement operation simply involves merging in a new position an item that has previously been merged[6]. However, as was discussed briefly in the previous chapter, this take on the operation cannot be correct; if a copy theory of movement is assumed, then Move involves more than Merge does. As a result, Move must be considered a separate, and thus additional, operation in the architecture. An alternative is a theory which does away with Move entirely, arguing that copies are not required, and so "...a term that moves is simply the input to more than one structure-building rule [Merge]..." (Epstein *et al.* 1998:108 fn.3). The point is that Move is anti-minimalist in copy theories as it cannot be re-analysed as Merge.

The Move operation in later versions of the MP is forced by the existence of [EPP] features, and satisfies the removal of these uninterpretable features through its application. This is circular reasoning however. That is, in order that movement be legitimate, it must carry out some job necessary in the feature-checking process. So, movement is required because it checks and removes [EPP] features. However, as all other features can be checked and removed at a distance via Agree, [EPP] features are specifically added to the architecture to drive movement. Without [EPP] features, there would be no requirement for movement, but without movement, there would be no requirement for [EPP] features. Neither [EPP] features (about which more in the next sections) nor movement are therefore conceptually necessary. Move is then a true (rather than an apparent) imperfection. As such, a minimalist system should be able to do without it.

Seuren (2004) questions the number of levels of representation that minimalist theories assume. That is, he wonders why the conceptual necessity is to assume two levels of representation - PF and LF - when just one would suffice. Although Seuren's reasoning here is fallacious[7], his general point stands. In chapter 2, the levels of representation were explained as feeding the interfaces to the external systems. In other words, PF delivers phonological information to the articulatory-phonetic interface. This interface then converts the information

[6]See section 5.3.2.1 for discussion of Berwick's position.

[7]He wrongly suggests that the minimalist claims the Move operation to link the levels of representation, and so without a Move operation, PF and LF would not both be required. However, as chapters 2 and 3 outlined, the Move operation links surface and deep level semantics, not phonological and semantic levels of representation.

that it receives into terms that the external articulatory-phonetic system will understand. LF, on the other hand, delivers semantic information to the conceptual-intentional interface. This, in turn, converts the information into a form that the external conceptual-intentional system will be able to process[8].

So, two separate levels of representation support two separate interfaces to two separate external systems. It is to this organisational structure that Seuren has an objection. While two separate interfaces have a clear motivation, it is less obvious that we need a level of representation corresponding to each interface. Seuren (2004:139) notes that "[o]ne can easily imagine one and the same level of representation, some of whose features are legible to the one and others to the other interface." Indeed, Brody's (1995) *Lexico-Logical form* model is articulated in this very manner. Of course, such a reduction would necessarily result in complexity elsewhere in the system. That is, there would be fewer levels of representation, but the one remaining one would be distinctly more elaborate[9].

A further contradiction to the conceptual necessity criterion is Spell-Out, or more specifically, the cyclic nature of Spell-Out that the derivation by phase architecture presumes. As discussed in chapter 2, Spell-Out is the point in the derivation at which phonological and semantic information are shipped to PF and LF respectively. In the later derivation by phase system, Spell-Out is not one, but a number of repeated points in the derivation. At the end of each phase, the relevant information is spelled-out to the interfaces. The reasoning, presumably, is that in a system where Spell-Out is cyclic, the amount of linguistic material that has to be segregated into phonological and semantic matter, and that has to be dealt with at the interfaces at any one Spell-Out point, is considerably less than if the entire linguistic representation were to be spelled out in one go.

However, if the system is to be truly minimalist, opting for the simplest and barest manner of derivation, then cyclic Spell-Out becomes somewhat less obvious. The question is whether it is computationally simpler to execute Spell-Out just once in each derivation, or each time an appropriate sub-set of the derivation has been completed. At first blush, the former of these two options might appear to have the edge in terms of bare necessity. However, the argument that multiple Spell-Out entails limited memory requirements also holds water from a simplicity perspective. This highlights a type of conflict never acknowledged in

[8]See Jackendoff (1998) for one suggestion of the form this conversion may take.
[9]See below for more discussion of this general point.

the minimalist literature - the notion of competing motivations.

The idea of competing motivations, or naturalness principles in conflict (see Dressler (1977)), has long been a concern in linguistics[10]. Martinet (1955) explains that a speaker will only reduce his physical effort by as much as will still allow successful communication to take place. Haiman (1983) adds that the desire for economy may also conflict with the requirement to maintain iconicity of structures. Gabelentz (1901) talks of the tension between *Bequemlichkeitsstreben* - striving for ease - and *Deutlichkeitsstreben* - striving for clarity. Linguists with a functionalist bent frequently appeal to conflicting pressures to explain the existence of very many grammatical phenomena (see, among others, Du Bois (1987), Croft (1990), Langacker (1977), Dik (1989), and Kirby (1997)), while Optimality Theory has shown that there is a way to formalise the conflicting constraints in language.

Newmeyer (2003) observes that already in the first half of the twentieth century the Prague School had concluded that the conflicting pressures of phonetic and semantic requirements on the grammar would prevent it from being optimal. Johnson & Lappin (1999:127) focus specifically on minimalist theorising by noting that, for example, a Shortest Move condition "...appears economical from one perspective, in that it limits the domain of syntactic relations by movement. However, it is uneconomical in another sense, as it requires a greater number of moves in a derivation than a "fewest moves" principle, which would produce larger movement domains." The point is this: efficiency, or bareness, from one point of view, may be inefficiency, or elaborateness, when alternately considered. If the criteria for defining optimality in the system are not clearly and unambiguously set out by those working within the program, then we cannot definitively measure the bareness of the system. In the case of cyclic Spell-Out, should it be memory requirements or the number of applications of the operation that gauges the conceptual necessity[11]? As the next section will show, the MP is too cavalier with its employment of terminology to be practicable.

[10]Outside linguistics, in domains such as biology too, explanations frequently reflect the influence of multiple conflicting pressures on a system.

[11]Sternberg's (1966) work on short-term memory retrieval shows that people prefer to do a simple task a number of times rather than doing a more complex task just once, suggesting that multiple Spell-Out might be preferable (although this does not necessarily entail that it is more economical). The point remains that the minimalist literature lacks any such discussion.

6.4 What is Meant by 'Perfection' Anyhow?

The preceding discussion brings us neatly on to the next question of this chapter - what is meant by 'perfection' in any case? Although this issue was dealt with in depth in chapter 3, a brief, and more critical, re-consideration here will highlight another problem with the minimalist take on the language faculty. That is, the paragraphs which follow will stress the little value which the terms 'optimal' and 'perfect' bring to discussions of the system of language; they suggest an ideal which is both conceptually problematic and formally imprecise[12].

The conceptual issue has already been hinted at above; in very many, if not all, cases where an attempt is made to offer explicit evidence of perfection, the measure by which this is determined appears somewhat arbitrary, in that it has not been designated anywhere as a specific criterion of optimality. The cases of Shortest Move and cyclic Spell-Out have been examined above. Other examples which suffer from similar difficulties are the locality constraints on Agree, the notion of phases, and the idea of a sub-array.

The operation of Agree in early minimalist theories was constrained in such a way that it could only hold between elements in a particular local relation to each other - a Specifier-Head relation (Chomsky 1995b). Later, this stipulation was relaxed, to let Agree hold over longer distances. However, the theory still required that the goal of the probe be in its local c-commanding domain (Chomsky 2001). Thus, the system was again forced to incorporate a restriction on the application of Agree. The most computationally simple (and hence the most optimal) option would surely be to allow Agree to apply freely[13]. That is, allowing Agree to hold between two elements over any distance would permit the grammatical machinery to consist of fewer rules. On the other hand, allowing Agree to apply in this free manner would entail a complexity to somehow rule out illicit Agree relations[14]. The question is what makes this particular locality condition the most optimal option. This, then, is another case of conflicting interests. Two options - restrict Agree from the start to local domains, or apply Agree freely,

[12]Note that in this section, the terms 'perfection', 'optimality', and 'economy' will again be used interchangeably as they are in the minimalist literature, the reason being that what is at issue here is whether the minimalist argument is internally sound. The caveats from chapter 3 should, however, be borne in mind.

[13]In fact, Chomsky (2001:27) himself notes that "[o]ptimally, the operations Agree/Move, like others, should apply freely." However, in the same paper, and elsewhere too, the suggestion appears to be that optimality equals strictly cyclic.

[14]In fact, one way of thinking of the job that the locality requirement of c-command does is precisely this - to act as the complexity which rules out illicit Agree relations.

and then eliminate the problem cases using some additional rule - each have reasonable optimality motivations; why should one be chosen over the other? More importantly, if we have to compromise at all, then the resulting system cannot be perfect; a perfect system would incorporate fewer stipulations *and* a lack of any adjustment operation. The question is, would such a system be possible?

Presumably, the minimalist would butt in here to argue that the derivation by phase framework renders the preceding point void. The phase-based system forces Agree to operate over a limited distance without having to strictly stipulate that it apply locally. However, there are two difficulties worth pointing out here. One is that the phase is not enough to account for all illegal Agree relations. For example, in a double object construction, where the dative object intervenes between the verb and the accusative object, Agree between the latter two is blocked. Yet, if the dative object were to move out of this position, an Agree relation could be established between the verb and the accusative object. The point, of course, is that in both cases, the accusative object and the verb are within the same phase, so something more than this is required in the system to rule out Agree in the former, but not the latter case. There is also an optimality issue with the notion of phases themselves, which is this. The phase was introduced to limit the complexity of a computation by requiring a smaller amount of material to be dealt with at any one time. While this is undoubtedly a legitimate concern from the perspective of minimising the system, so too would be the option of working with the entire derivation's material at once in order to avoid multiple overlapping[15] computations. In other words, the phasal derivation involves multiple computations but less material in each one, while the non-phasal derivation involves only one computation but more material to deal with. Which is more economic, or optimal? Again, there is no independent criterion to promote one over the other, suggesting that as a result of competing motivations, a perfect system is not possible.

A final example to consider is the subarray. As a result of the introduction of phases, the lexical array is divided into subsets, each of which is associated to a particular phase. Here again, there is a conflict in economy measures. While the subarray means that material is reduced (in the same way that the phase does), at a high level, surely an equally appropriate criterion for economy would be to

[15]Each sub-computation, if you will, overlaps slightly with the next by virtue of the fact that at each phase, the edge of the previous one must be retained to allow phases to be correctly connected - see section 2.3.4.5.

have only one array per derivation rather than a multitude of them. Once more, there is a choice as to how economy should be gauged. Once more, competing motivations result in a compromise. And once more, the system that results cannot be perfect[16].

The second issue referred to above is the lack of formalisation inherent in the minimalist's notion of perfection. The terms 'perfect' and 'optimal' are used in the literature in a way which implies that the measures and definitions thereof are obvious. Nothing could be further from the truth however. In the few places where any explication is offered, there is little consistency in the principal themes.

In the early nineties, perfection is equated with a lack of redundancy: "...the system is elegant, but badly designed for use. Typically, biological systems are not like that at all. They are highly redundant..." (Chomsky 1991a:49). Only a few years later, however, it is adherence to economy conditions which drives the optimality of the system: "[t]he linguistic expressions are the optimal realizations of the interface conditions, where "optimality" is determined by the economy conditions of UG." (Chomsky 1995b:171). Here, the economy conditions mentioned which determine how perfect the system is include those constraining movement: "...its [the linguistic expression's] derivation must be *optimal*, satisfying certain natural economy conditions: locality of movement, no "superfluous steps" in derivations, and so on." (Chomsky 1995b:220). But of course, movement is frequently (in this and other publications) cited as an imperfection, so this measure of optimality seems a little counter-intuitive.

Some years later, Chomsky (2000:12) notes that "[i]n a perfectly designed language, each feature would be semantic or phonetic, not merely a device to create a position or to facilitate computation." Immediately, we would then question how such entities as [EPP] features or phases could be part of the system, as these are just that - devices which create positions ([EPP] features) and facilitate computation (both [EPP] features and phases). In his *Derivation by Phase* paper, Chomsky cites both uninterpretable features: "...uninterpretable formal

[16]Optimality, in contrast to perfection, can arise in a system where competing motivations result in such compromises. However, it is the stronger claim of minimalism that language is perfect that is under scrutiny here.

features...appear, prima facie, to violate conditions of optimal design." (Chomsky 2001:11), and more curiously, cross-linguistic variation, as contrary to the optimality criterion: "[t]hese considerations bear directly on parametric variation, in this case yielding conclusions that are familiar features of linguistic inquiry. Any such variation is a prima facie imperfection: one seeks to restrict the variety for this reason alone." (*ibid*: 2). In a later paper, this imperfection is stated even more strongly: "...even the fact that there is more than one language is a kind of imperfection" (Chomsky 2002b:109).

A clearer explanation of perfection suggests that non-natural languages, such as those used in computer programming, constitute perfect systems, and anything found in human language which does not exist in these systems must be classed as an imperfection: "[a] good guiding intuition about imperfection is to compare natural languages with invented 'languages', invented symbolic systems. When you see differences, you have a suspicion that you are looking at something that is a prima facie imperfection" (*ibid*: 109). However, as Newmeyer (2003) correctly points out, there are very many reasons why natural and non-natural languages should differ, perfection and optimality considerations aside.

Others also offer equally differing perspectives on the character of perfection. Uriagereka (1998:533) suggests that apart from movement, uninterpretable features, and cross-linguistic variation, also lexical items are non-optimal in the derivational processes which form them: "[t]o some extent, words present a departure from optimality in the syntactic system, as do linguistic variation, strong and uninterpretable features, and the very existence of movement processes." Perhaps his strangest assertion, however, is that "...there can be perfectly convergent and even optimal derivations that have no interpretation whatsoever..." (*ibid*: 153). In other words, the optimality of a derivation is entirely independent of whether the derivation can be interpreted. Now, if the job of the grammar is to create a mapping between sound and meaning, then it is very difficult to see how the optimal way of doing this would be to ignore the processes which decode the phonological and semantic material in the sound and meaning components.

The above selection of quotations highlights the inconsistency of explanation that is to be found in the literature. Clearly, perfection is to be equated with economy and simplicity, but in exactly what sense, or along exactly which dimensions, is highly puzzling. As Seuren (2004:134) puts it: "...Chomsky's "conceptual necessity" is nothing but the vague idea that it is difficult to imagine that things could be different.” Indeed, even minimalists themselves are acutely aware that perfection is an as yet opaque concept: “ ...the nature of optimal design that is instantiated in FL (if any) is a matter of discovery...” (Chomsky 2001:11).

To sum up this section, the term ‘perfection’, used as an explanatory and evaluating device in the minimalist literature, is far from rigorously circumscribed. This leads to a problematic situation when problems of conflicting interests are considered. Knowing that Optimality Theory has found a way to deal with such conflicts, the question must be, how less minimal would the MP have to become in order to deal with the competing motivations which exist?

6.5 An Imperfection in the Mapping Process

One overwhelming problem that the minimalist conception of language cannot deal with is structural ambiguity. The MP views the narrow language faculty as a computational system whose function is to create a mapping between signals and meanings. Moreover, this computational system is hypothesised to be perfect. However, it is precisely in the mapping process that syntactic ambiguity marks a sub-optimality or imperfection.

Structural ambiguity is best looked at as upsetting the one-to-one mappings we might intuitively expect the syntax to generate. Ambiguous sentences such as (1) show that one-to-n mappings are possible:

(1) I saw the girl with green binoculars.

This raises a further question of competing motivations. Should it be the case that the more optimal manner of mapping between sound and meaning is to allow only simple one-to-one mappings, or should the mappings not be constrained in this way? If the former, then structural ambiguity is an imperfection in the computational system just by virtue of not being a one-to-one mapping. However, should we argue that the more economic solution would be to have one-to-n mappings apply freely, then structural ambiguity would not be so transparently imperfect.

Yet, if one-to-n mappings were to be more optimal than one-to-one mappings, the ideal situation would surely be to allow such mappings in all situations. Consider the sentence in (2):

(2) I saw the girl with green eyes.

Just like (1), the adjunct phrase in (2) could equally semantically modify either the verb *saw* or the noun *girl*. There is presumably not anything in the computational system that rules out such structural ambiguity. However, under a normal reading, for most people, it is not the case that (2) exhibits the same type of ambiguity that (1) does; the usual reading is taken to involve the modification of the noun, not the verb, by the adjunct phrase. Therefore, if the computational system can generate two structures for (2), something in our processing system must be ruling one of these out. So, if one-to-n mappings are the optimal choice, then imperfection doesn't arise in the syntax, but there must be a complexity in the system more generally to account for the structures that the parser makes available. This explanation promotes once more the modular view of the language faculty argued for in chapter 4. The computational module and the parsing module work independently - the former allows syntactic ambiguity in the case of (2), while the latter excludes it. Thus, if unconstrained one-to-n mappings are optimal, complexity is forced in another module of the system.

In sum, ambiguity in language which arises as a result of the manner of attachment of adjuncts causes a significant difficulty for the minimalist claim that the computational system is perfect. Minimalist literature nimbly avoids getting into this tangled issue; however, it is clear that any account minimalist theories were to offer would have to posit a system with added complexity in some component.

6.6 Stipulations without Independent Motivation

A further problem faced by minimalism is the plethora of explicit unmotivated stipulations that the literature is home to. This section of the chapter will examine those assumptions made which, although offering additional empirical coverage, do not fall out from the general principles, operations, or architecture of the theory, and can be classed as nothing other than stipulative.

In early versions of minimalist theory (Chomsky 1995b), the most obvious stipulation concerns the manner in which cross-linguistic variation was accounted for. Section 2.3.4.4 made brief reference to weak and strong uninterpretable formal features; the details were these. In order to explain why certain languages admit movement processes that other languages don't (e.g. main verb movement in French versus non-movement in English (Pollock 1989), wh-movement versus wh-in-situ languages), analyses within the GB framework posited a distinction between overt and covert movement processes. In the MP, movement processes were all to be motivated by feature checking. Thus, it must be some character of the features which check which decides if movement will be overt or covert.

As the features in question have no obvious differences across languages (i.e. both overt and covert wh-movement involve checking of a [wh] feature), an additional attribute was added to the feature - its strength. Strong features were proposed to induce overt movement as the result of needing to be checked early in the derivation, with weak features allowing covert movement to be a possibility[17]. This is a clear stipulation in the workings of the system; nothing in the over-arching laws governing the minimalist language faculty can generate this dichotomy. Neither can the dimension of feature strength fall out from any of the 'conceptually necessary' derivational operations, or representational levels of the architecture.

Again in chapter 2, the later re-analysis of overt versus covert movement was explained. Although this got rid of one stipulation, it simply replaced it with another - the [EPP] feature. While the [EPP] feature again serves to offer empirical coverage that the system could not otherwise provide, there is no independent motivation or conceptually necessary justification for it. The [EPP] feature is

[17]Note that the strength of a feature has is in no way correlated to any morphological properties which might differ in the languages in question.

added to a position (C or I) simply to induce movement to its specifier. There is no sense in which the [EPP] feature (or indeed the Extended Projection Principle from which the name derives) has motivation apart from the need to account for the empirical data in question. Moreover, a problem arises if the feature is located on a C or I head which is otherwise feature-less and empty; a minimal structure surely should not allow such heads to be created just to hold an [EPP] feature.

In *Derivation by Phase* (Chomsky 2001), [EPP] features are further drawn on in the formulation of a stipulative principle - what Johnson & Lappin (1997) refer to as the *Have an Effect on Output Condition* (HEOC):

(3) α enters the numeration only if it has an effect on output.
(Chomsky 1995b:294)

The principle is stated in Chomsky (1995b) as a manner of limiting the form of a numeration; that is, only if α's existence in the numeration results in a convergent derivation with an interpretation that an α-less numeration could not generate, is it licensed. Later (Chomsky 2001), this principle is invoked to constrain optional movement operations, such as Object Shift. Here, its application states that "...the optional rule in these constructions assigns an [EPP] feature to v*, thus allowing (and requiring) OS." (Chomsky 2001:34). Not only is the HEOC a stipulative principle which cannot be motivated through alternate already existant means, it also leads to the type of derivation comparison process discussed in section 6.2 above (Johnson & Lappin 1997). Derivations with and without the additional α must be compared in order to determine if the outcome will be effected by its insertion in the numeration/addition to the relevant head.

Chomsky (2001:6) states that "[c]ase itself is not matched, but deletes under matching of ϕ-features." A fourth stipulation then is that Case features work differently to other uninterpretable formal features on the lexical item. Other features can only be checked and removed through application of the Agree operation, which locates a probe and goal with matching features (e.g. a [wh] feature on the C head, and a [wh] feature on a lower wh-phrase in *John saw who*), these features checking and deleting. Case features, however, exist only on the goal. Thus, there is no agreement between the Case features of the probe and goal, as only one Case feature obtains in the relation.

The question then is how Case features are to be removed before reaching the interfaces, as they too are uninterpretable there. The answer is to stipulate that Case features are allowed to delete without checking. That is, when a probe and goal agree for other uninterpretable features, the Case feature on the goal will also delete[18]. Having two classes of uninterpretable formal feature - those that are subject to Agree in order to delete, and those that are not (Case features only) - is not only stipulative, but also contravenes minimalist economy guidelines (one class being more minimal than two).

The derivation by phase realisation of minimalism brings with it a host of further stipulations. The first is whether the phase itself has independent motivation, or is stipulated. The answer appears to be the latter. Chomsky talks of the phase as motivated by considerations of reduced computation: "...MI [Minimalist Inquiries (Chomsky 2002a)] proposes another reduction of computational burden: the derivation of EXP [the linguistic expression] proceeds by phase, where each phase is determined by a subarray LA_i of LA, placed in "active memory"." (Chomsky 2001:11-12), but while this is a general theme of minimalist investigations, the specific mechanism through which it is achieved - the phase - is an explicit stipulation. The phase is not "...something that emerges in the derivational dynamics because, otherwise, convergence would for some reason not be possible..." (Uriagereka 2000).

An even narrower stipulation is the introduction of the strong phase (Chomsky 2001:12), a phase which is a potential target for movement, and the point at which Spell-Out applies. The distinction between strong and weak phases appears to be introduced in order to set CP and v*P apart from TP and vP. The reasoning for this is far from clear. What is important is that the strong phase is yet another stipulation to add to the rapidly growing list.

Similarly, the cyclic nature of the Spell-Out operation in the derivation by phase era is stipulated. Again, it is proposed for reasons of computational reduction (although as we have seen above, it is unclear that it meets this objective), but does not fall out of any conceptual necessities. It might be argued that cyclic Spell-Out is a direct consequence of the phasal nature of the derivation, but there is no reason to suppose that the derivation could not proceed in a phasal manner, and once dealt with by the narrow syntactic component, the sub-derivations

[18]Providing that the probe is non-defective - see section 2.3.4.3 and Chomsky (2001).

being re-combined and subjected to just one Spell-Out operation applying at the end. Even if it were strictly necessary to assume cyclic Spell-Out on the phasal view of the derivation, the phase itself has been shown to be stipulated, so cyclic Spell-Out could not be granted non-stipulative status.

In section 2.3.3.1 it was mentioned that minimalism says that look-ahead should be ruled out. That is, the system should have no way of knowing what way the current derivation will pan out, it should have no way of figuring out what different derivational alternatives will lead to, but must risk later crashes by applying operations at the moment they present themselves. In section 2.3.4.5 it was briefly commented on that the derivation by phase architecture was argued to automatically reduce look-ahead possibilities by limiting access to the material of the current phase only.

However, what this consequence equates to is yet more stipulation in the system. In cases of successive cyclic wh-movement, the wh-phrase must move first to the specifier of its own CP, before moving onwards to the higher CP. In a phase-based system, this is because the probe (the higher C, specified with a [wh] feature) can only see as far as the edge of the lower phase. However, as the lower C head is not specified with a [wh] feature, the only reason for the first movement is to be able to satisfy the requirements of the later phase. Thus look-ahead must be stipulated to be possible in such cases. In a discussion of Object Shift processes, Chomsky (2001:26-27) is forced to once more sanction minimal look-ahead in order for the strict cycle to permit a movement that will not be authorised until the end of the phase. The details are as follows. In (4), the subject needs to be at the edge of the VP phase in order that the T probe can see it from its phase, and induce Agree and Move. However, if the object undergoes Object Shift within its VP phase, it will move to the edge (the position marked OS), and on completion of the VP phase, the subject will then not be visible to T. Look-ahead permits the subject to know that the object will vacate this position in the next phase, leaving only a phonologically empty element, which does not block the probe in the same manner in the highest specifier of VP. Consequently, the subject is allowed to move to the specifier of TP position before the object has vacated the edge of the VP phase. In other words, in order to account for the data that Object Shift provides, it is proposed that within the phase, there can be some limited foresight.

(4) [$_{TP}$ T [$_{VP}$ OS [SUBJ V OBJ]]]

The examples of successive cyclic movement and Object Shift not only strongly breach the minimalist assumption of no look-ahead, but involve stipulations which cannot be derived directly from any of the bare necessities of the system.

Some more general assumptions which have been argued to be stipulative are the adoption of X-bar theory, and the global economy conditions that guide the program. Seuren (2004) takes issue with the acceptance of X-bar theory as "fundamental" (Chomsky 1995b:172), and the assumption that "[i]n a minimalist theory, the crucial properties and relations will be stated in the simple and elementary terms of X-bar theory" (*ibid*), given that later (Chomsky 1995a), X-bar theory is thrown out in favour of a bare structure, as it is too complex and redundant to be consonant with minimalist ideas[19]. The issue should not be that earlier assumptions are not compatible with later ones; any theory should be allowed to evolve. However, assuming that the contents of a lexical array are arranged according to X-bar theory, or indeed, according to the bare phrase structure, is stipulative.

Pinker & Jackendoff (2005:221) criticise the global economy conditions that derivations are subject to as "...not particularly economical", and further "...not independently motivated by least-action principles of physics, resource limitations in cognitive information processing, or mechanical symbol- or step-counting in some formal notation...Rather, they are a mixture of metaphors involving speed, ease, cost, and need, and anthropomorphic traits such as "greed", "procrastination", and "last resort". Their desired effects on linguistic structures are explicitly stipulated, and would have to be spelled out as complicated conditions on operations in any explicit implementation." Although the particular economy conditions they cite have been dispensed with in the phase-based theory, the point stands that not all of the economy measures that the MP references have a clear independent rationale. While fewer rather than more operations has an obvious minimal interpretation, the Phase Impenetrability Condition, or the Minimal Link Condition do not. In sum, the theories within the MP are highly

[19] In the *Simpler Syntax* framework too (Culicover & Jackendoff 2005), the complexities of X-bar theory are replaced with a barer (and in this case, also flatter) structure on the basis that "...the correct structure is the minimal structure sufficient to account for the regularities of word and morpheme order and for the correspondence between strings and meanings" (*ibid*:108).

stipulative, resorting to unmotivated (with respect to conceptual necessity) assumptions when faced with an empirical or theoretical impasse.

6.7 Shifting the Burden of Explanation

On reading the minimalist literature, a question that naturally arises is how a system can be so sparse but yet account for a wealth of intricate data. In other words, why is the MP system of language so much simpler than alternative views, and why has it taken linguistics this long to realise that the machinery does not have to be so complex? The answer to these questions is that minimalism is not truly as simple as a brief glance through the literature might suggest. What the reader is presented with is a theory of a very limited part of the system. What the reader is not so overtly presented with is the abundance of operations and processes taking place in the non-syntactic components of the system.

The MP manages to maintain its economic character by focusing on the syntax, and overlooking to a large extent the phonology and the semantics. Indeed, closer examination reveals that much of what previous generative theories explained in terms of syntactic devices and operations has been relegated to the phonological and semantic components in the MP. With little space given over to these components, the façade of economy and simplicity can be easily upheld. In this section, I will show that shifting the burden of explanation in this way has obscured much of the machinery from view, but that it is still there. Importantly, the components of the grammar to which the complexity is moved - phonology, semantics, and the lexicon - must be interpreted as belonging to the narrow language faculty. As argued in the previous chapter, the processes underlying the complexities are both uniquely linguistic, and uniquely human[20]. Consequently, in shifting the burden of explanation in this way, the complexity does not vanish.

The phonological component of the grammar takes over much responsibility previously assigned to the syntax. Operations which were subject to frequent analysis in earlier generative syntactic theories are now spoken of infrequently, and where they are, they are relegated to the remit of the phonology[21]. Such operations include both optional and obligatory movement rules, and the operations required to account for free word order languages.

Optional movement rules such as heavy NP shift, extraposition, and topicalisation were given strictly syntactic explanations in earlier generative theories.

[20]While semantics in a broad sense may not be entirely unique, the particular aspects of it that control the complexities under discussion are. A detailed picking apart of the unique properties of the semantic component of the grammar is beyond the current scope.

[21]For one such position, see Boeckx & Stjepanovic (2001).

Under a transformational grammar analysis, a transformational rule would apply to the deep structure (5a) to derive the surface structure in (5b), while a GB analysis would posit an adjunction operation to move the heavy constituent to a sentence-final position.

(5) a. Every day I take [the bus driven by the man from next door] to work.
b. Every day I take to work [the bus driven by the man from next door].

Although somewhat difficult in these earlier theories, within the MP framework, optional movements become impossible by virtue of the fact that all movement operations should be motivated by feature checking. No movement should be permitted if it does not result in such a checking operation. So, how does the minimalist account for heavy NP shift, for example? The assumption taken is that such movements do not alter the semantics of the sentence in question, and so can take place in the phonological component. However, while this might be true for the case of heavy NP shift, it is not so clear that topicalisation doesn't play with the semantic representation in any way[22]. Scrambling effects and free word order too are assumed by minimalists to be part of the phonological component of the grammar.

So, the machinery to deal with these effects and phenomena is still assumed to exist in the language faculty, but by moving it outside of the narrow syntax, the minimalist can maintain his simplicity argument. However, as the MP is a program which explicates the narrow language faculty in full - of which, phonology, as Fitch *et al.* (2005) note, "...must be, by definition, a part..." - simply shifting the relevant computational apparatus to another component will not do.

What is more controversial than the shift to the phonological component of optional and stylistic movement processes is the position taken in Chomsky (2001) that what could reasonably be considered core movement processes should also be expelled from the narrow syntax. Both object shift[23] and a thematisation/extraction rule responsible for the derivation of, among others, passives

[22] The problem noted in section 2.3.4.4 also still stands: the MP is not confined to explaining the narrow syntax, but must consider the phonological component too. Minimalist considerations should obviously hold in this part of the system in the same way, so optionality should be ruled out here also.

[23] See also Holmberg (1999) for a phonological account of object shift.

and unaccusatives (see Chomsky (2001:20ff.)), are taken to apply in the phonological component, where earlier theories would have assumed a syntactic analysis involving deep structure to surface structure transformational rules, or DP-movement (to the canonical subject position for reasons of Case assignment in the case of passives (Chomsky 1981), and to a specifier position (Spec/Agr_OP (Ouhalla 1999)) above the VP in the extended IP projection, licensed by verb movement, in the case of object shift (Holmberg 1986)).

The verb movement process of V2 languages is also noted in Chomsky (2001) to be phonological, his reasoning being that in the bare phrase structure of minimalism which no longer forces there to be just a single specifier position for any head, there is no natural notion of a *second* syntactic position[24]. This shift is generalised to cover not just V-to-C head movement, but other head movement processes too: "[t]here are some reasons to suspect that a substantial core of head-raising processes...may fall within the phonological component." (*ibid*: 37). One main reason given is that the LF representations of equivalent expressions in different languages should be the same, despite whether head movement processes take place or not. For example, French verbs move to the inflectional head in cases where English verbs do not, but the semantic representations of the French and English equivalent expressions should be identical. As movements which don't affect the semantics in any way no longer need to be part of the narrow syntax, these head movement processes can consequently be relocated to the phonology. Another reason given is head movement's violation of the c-command requirement on movement. Not only does it seem curious to remove what previously constituted such a large part of the syntactic machinery on this limited basis, an empirical problem also holds - head movement can have semantic import (Benedicto 1997), a situation which should be impossible for any PF operation, given that the semantics no longer has access to what is going on. What this means is that even if movement is not conceptually necessary (see section 6.3 above), the theory must provide some other way for the narrow syntax to account for the facts that have traditionally resulted in appeal to head movement; moving the explanation to PF will not suffice.

A slightly different way in which minimalist theories of language shift the burden of explanation concerns the conception of the lexicon in these theories. As described in chapter 2, minimalism is strongly lexicalist, attaching to lexical

[24]This reasoning does seem a little weak, however. Despite a lack of stipulation on the number of specifiers, surely it is still possible to see what *second* means.

items a weight previously reserved for the derivational component of the grammar. In the MP, the lexicon is extensive; items are specified there not just with the basic set of phonological, semantic and syntactic features earlier generative theories would have posited, but also with a plethora of uninterpretable formal features. These latter features take over much of the work that would formerly have been the remit of the syntactic component, once more allowing the claim of economy to be defended.

The uninterpretable formal features drive the derivation of a linguistic expression; they determine which items can be merged together, and they force, and license, movement of items to positions different from where they are first merged. We might then ask, without these features, how would the derivation proceed? The answer, of course, is that grammatical rules and processes in the syntactic component could equally well propel the derivation, as they did in GB theory, for example. So, while in the MP we have Case features which check under the Agree operation applied to a probe and goal with matching ϕ-features, GB posited an assignment operation, whereby a transitive verbal head assigned accusative case to an object DP under government, and the inflectional head assigned nominative case to the subject DP in a Specifier-Head relation[25]. While in the MP we have [wh] features which check under Agree at longer distances in wh-in-situ languages, and locally when an additional [EPP] feature forces movement in non-wh-in-situ languages, GB posited a movement operation shifting a wh-phrase from its base position to the specifier position of CP, in combination with a parameter which determined the level at which the specifier position of an interrogative CP must be filled (surface structure in non-wh-in-situ languages, but only LF in wh-in-situ languages). And while in the MP we have to posit an [EPP] feature in order to get the movements the data requires, GB posited a generic Move-α rule (or a Movement Theory module of the grammar, depending on the specific view taken).

As Pinker & Jackendoff (2005:222) observe, the lexicon is "...packed with abstract morphemes and features...whose main rationale is to trigger the right syntactic phenomena, thereby offloading work from the syntactic component and preserving its "minimalist" nature." Once more then, the minimalist has shifted

[25]Later work within the GB framework assuming Pollock's (1989) Split Infl Hypothesis understood all types of Case to be assigned in a Specifier-Head relation - nominative by the Agr_S head to the subject in Spec/Agr_SP, and accusative by the Agr_O head to the object in Spec/Agr_OP (see e.g. Ouhalla (1999) for a clear sketch of the details).

the burden of explanation to a component of the grammar outside the narrow syntax. But once again, minimalism fails in its economy claim; rather than reducing the computational machinery, it merely conceals chunks of it in little discussed components of the grammar peripheral to minimalist deliberation.

6.8 Phenomena Left Unexplained

The final problem which this chapter will point to is the fact that the MP has not reached the high levels of explanatory adequacy that it aims for. In other words, minimalism leaves a number of phenomena without a satisfactory account. While this might not be unexpected, given that minimalism is still a work in progress, still figuring out the details of language, it does raise a question. As earlier sections of this chapter have shown, extra stipulations and operations have been added to the bare minimum in many instances to explain the data. In the case of the phenomena that are not yet resolved within the framework, is it the case that they can be easily assimilated into the system as it stands, or is it the case that they too lead to further addition to what should be conceptually necessary? If it is the latter[26], then the system grows even more, deviating yet further from the economical minimal system it claims to be.

A clear case of this problem is pointed out by Broekhuis & Dekkers (2000:388): "...parameterization is difficult to capture in domains that do not involve differences in word order". In other words, the parameters which were central to GB explanation of cross-linguistic variation hit rough waters in minimalist theories. Parameters such as wh-in-situ, or verb second, do not succumb to these difficulties, as they can still be accounted for under minimalism in terms of movement. In earlier theories, a strong [wh] feature on C to attract the wh-phrase in non-wh-in-situ languages became, in later theories, an [EPP] feature on C to drive the movement[27]. Earlier strong features on both C and I to attract the verb and first position element in V2 languages in later theories again were replaced by [EPP] features. However, parameters that cannot be directly explained through movement processes face a much harder time fitting in with minimalist machinery. Let us look at two illustrative examples in some depth.

The pro-drop parameter - the ability of a language to omit the subject pronoun - was traditionally assumed to be licensed by rich agreement morphology on the verb; Spanish has rich agreement morphology, so permits a null subject, English does not:

[26] This seems a reasonable assumption; if it were the former, we would expect these phenomena to have already been given an elegant and minimal analysis using the available machinery.

[27] Although, of course, a problem with both analyses is posed by languages which show optional wh-movement, such as (colloquial) French (Lefebvre (1982), Ouhalla (1999)).

(6) (Juan) está triste.
(7) *(John) is sad.

The distinction between null-subject and non-null-subject languages was thus hypothesised to derive from a parameter set during the acquisition process, as defined in Rizzi (1986):

(8) Pro-Drop Parameter:
   a. *pro* is governed by X^o
   b. Let X^o be the licensing head of an occurrence of *pro*; then *pro* has the grammatical specification of the features on X^o co-indexed with it[28].

The minimalist approach to the data in (6) and (7) requires stipulation and complexity. The assumption that the null subject *pro* is licensed by the agreeing head can no longer be maintained in a system where the head in question (the verb, or some inflectional projection thereof) is understood to hold unspecified uninterpretable features, their values being assigned under Agree with an element in its local domain (the subject). Inherently, *pro* cannot be specified with ϕ-features. Therefore, it cannot enter into an Agree relation with the verbal head and assign values to its unspecified ϕ-features. There are two possible routes forward[29] - (i) the ϕ-features on a verbal (or inflectional) head in pro-drop languages are interpretable, thus disposing of the requirement that *pro* assign it values for these features (Alexiadou & Anagnostopoulou (1998), Manzini & Roussou (1999), Manzini & Savoia (2002), Platzack (2003)), or (ii) *pro* does have interpretable ϕ-features, and can thus value the uninterpretable features of the verbal head via Agree in the same way as a non-null subject would (Holmberg 2005). In this case, *pro* would be phonologically null only.

Whether we choose (i) or (ii) above, the nature of the null element in pro-drop languages forces the theory to make additional stipulations. If we go with

[28]This concisely articulated parameter is not, of course, enough to explain cases of pro-drop where there is no agreement morphology on the verb (e.g. Cantonese), or cases of partial pro-drop, where a null subject is only licensed in certain contexts (e.g. in the position immediately to the right of the inflected verb in Old French (Kroch 2001)). However, echoing a point made in a number of places in this thesis already, I am not concerned in this chapter with a comparison of the MP and GB theory, nor indeed of an evaluation of the explanatory adequacy of GB parameters, but with an investigation of the nature of perfection in minimalist theories. I will now turn to that question.

[29]The intricate details of the two proposals will not be discussed here; the general points are sufficient for the current discussion.

(i), we are forced to assume that the distribution of uninterpretable versus interpretable features differs cross-linguistically. Specifically, (i) forces us into the position where the ϕ-features of verbs are uninterpretable in languages which don't allow a null subject, and interpretable in those languages that do. Of course, a cross-linguistic difference such as the ability to drop subject pronouns may require the underlying system to possess some sort of reflecting dichotomy; the diversity must be explained somehow, and a dichotomy is not bad by definition. However, it is the nature of the dichotomy that is problematic. It requires undermining of the fundamental concept of interpretability; that is, a verb is not intrinsically singular or plural, feminine or masculine, or indeed first, second or third person in the same way that a pronoun is. If the features on the verb must be interpretable, it forces us into the undesirable position where this appears to be the case. Further, there is also a rather circular feel to the argument; in order to licence null subjects, the verbal head must have interpretable ϕ-features, but in order to licence interpretable ϕ-features on the verbal head, null subjects must be possible.

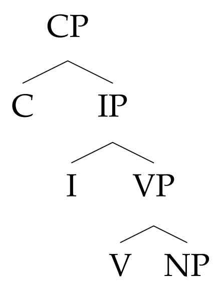
If we go for option (ii), the difficulty we face is that the null pronominal element found in subject position in certain languages now looks very different to its original characterisation. In other words, *pro* is no longer a pronominal element which gets its identity from a governing head; with interpretable ϕ-features, *pro* has its own identity already. Although option (ii) might appear preferable to the minimalist from the point of view that *pro* now looks like any other pronoun or DP, its phonological emptiness remains a restriction which the system must account for somewhere; in other words, the system must explain in some manner why the particular pronouns in question can be dropped. If (ii) is correct, we are forced to say that the null pronoun first values the uninterpretable ϕ-features of the inflectional/verbal head, and is then licensed by those same valued features, surely undesirable reasoning. The only other option would be to add, perhaps in the form of an additional feature of some sort, further complexity to the system in order to account for the lack of phonological content of the subject pronoun.

Apart altogether from the issues minimalist theories face in dealing with the null pronominal *pro*, there is a significant economy concern with accounting for the actual parameterisation of pro-drop. Holmberg (2005) proposes that the difference between Spanish-type languages, which allow null subjects, and English-type languages, which don't, should be analysed in terms of a more restrictive

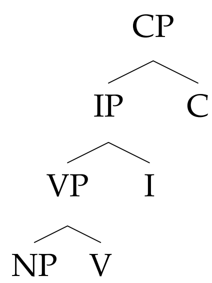
EPP condition in non-null-subject languages: in these languages, an [EPP] feature can only be checked and removed by merging a goal which is not phonologically empty. In pro-drop languages, the element merged into the position in which the [EPP] feature is checked can be phonologically null, hence *pro*. This is a clear stipulation of the type discussed in section 6.6 above. It is not only a stricter addendum to the EPP stipulation itself, it is also a condition without any motivation deriving from general minimalist principles. It would thus appear to strongly violate conceptual necessity, leaving the pro-drop parameter highly unamenable to the MP framework.

A second parameter of the grammar which leads to a requirement for additional conditions is the directionality parameter. This parameter distinguishes between languages in which heads precede their complements (like English, as in (9a)), and languages in which heads follow their complements (like Japanese, as in (9b)).

(9) a.



b.



Within the GB framework, the parameter was framed in terms of a simple ordering effect in X-bar theory; head-initial languages select their complements to the right, head-final languages to the left.

Under minimalism, there appear to be three options for how to frame this parameter. The first is simply a minimalist interpretation of the GB parameter; as Saito & Fukui (1998) present it, the Merge operation is constrained by the following parameter:

(10) K = $\{\gamma, <\alpha, \beta>\}$, where $\gamma \in \{\alpha, \beta\}$

a. $\gamma = \alpha$: head-initial, left-headed

b. $\gamma = \beta$: head-final, right-headed

However, it is unclear how this parameter falls out of any notion of conceptual necessity, or derives from the general principles or architecture of minimalism. This means that the system will have to have some additional complexity in order to account for it.

A second option is to posit a linearisation rule in the PF component of the grammar, what seems to be the usual place for ordering processes in the MP. In other words, in the narrow syntax Merge would not be constrained in the manner above, and at PF, the linearisation rule would look after any illicit orderings. However, the problem in this case is that it becomes very unclear what grounds would be used for deciding which of the pair of elements entering a Merge relation would project, if directionality is not applicable at that point. Whatever this decision is based on, it would again add complexity to the system. A final option, following Kayne (1994), is to assume that all phrases in all languages are basically left-headed, and that movement processes give the surface order. But here too there is a problem of the same anti-minimalist class - all manner of extra machinery in the narrow syntax, in the form of features to drive the movement processes required to get the orderings correct, would have to be posited.

A further issue is the case of mixed-headed languages. It is not enough to draw a line between head-initial and head-final languages. A third class are those languages in which certain heads select their complements to the right, and certain heads select their complements to the left. Of course, mixed-headed languages raised a problem with the GB analysis too, but for the MP, they force the system to become yet more complicated. It is not enough for the grammar to have some way of distinguishing right-headed languages from left-headed languages, it must also mark in some manner the directionality of each type of head, and in each language. Thus it must distinguish an English V head which selects to the right from a Japanese V head which selects to the left from a Dutch V head which selects to the left, but at the same time distinguish an English D head which selects to the right from a Japanese D head which selects to the left from a Dutch D head which selects to the right. One possibility is to sub-categorise the parameter (see Huang (1994) on Chinese), but this still leaves the system in the position of violating minimalist guidelines of simplicity and economy. Another possibility is to follow Travis (1984) in suggesting an interaction between the head directionality parameter, and parameters which determine the direction in which θ-roles are assigned. However, translating Travis' proposal into a minimalist feature-driven framework proves difficult given that case and θ-roles are no longer assigned, eliminating any notion of direction.

The parameters above do appear to have some account within a minimalist framework. What they do not have, however, is a simple, economic, bare essentials account. Parameterisation is just one case of the MP failing to account for the empirical facts in an economical manner. Further suggestions, such as the lack of explanation for the word features of particular languages (Berwick 1998), for copying strategies such as negative concord and pronominal first-person copying in serial verb constructions (Seuren 2004), for secondary case assignment (*ibid*), or for the fact that certain uninterpretable features assumed to drive movement (e.g. [wh] features, or focus features) have an interpretable character (Newmeyer 2003), highlight the fact that it is difficult to see how the MP could achieve anything approaching its objective level of explanatory adequacy without recourse to additional mechanisms, operations, sub-categories, and features.

6.9 Conclusions

In this chapter we have seen that the minimalist language faculty is not what it at first seems. The minimalist is not justified in claiming simplicity, and economy for the human language faculty, or indeed for his descriptive apparatus. In turn, if the system is not a simple and economic one, then the minimalist is also not justified in claiming that the system is perfect or optimal.

The reasons for this assertion are both varied and plentiful. Anti-minimalism of the methodological flavour is seen in the degeneracy of representation and derivation, or the number of levels of representation posited. Anti-minimalism of the substantive type is even more conclusive. The system exhibits degeneracy in the form of copied elements, and imperfection in the generation of multiple derivations to be selected between. The system exhibits extraneous operations in the form of Move, and Agree. The system exhibits numerous stipulations which derive neither from general non-language-specific principles of economy, or indeed from the central tenets of the MP: feature strength, phases, Case as disparate from other features, minimal look-ahead. The system moreover still exhibits much of its previous complexity, minimalism merely attempts to disguise it by displacing the relevant details outside the narrow syntax. Thus, while the narrow syntax shrinks, the phonological component and the lexicon expand proportionately. There are furthermore a good deal of language facts - parameters such as pro-drop and directionality, and the thorny issue of syntactic ambiguity - which don't fit easily into the minimal architecture, suggesting that the system will be forced to become even more complex to account for them. Finally, the disregard of competing motivations makes it unclear how optimality should be measured in any case. This is seen in the question of how optimal Agree, phases, cyclic Spell-Out, and sub-arrays in fact are.

So, the minimal language faculty is not actually minimal. In the words of Culicover & Jackendoff (2005:88): "[i]n its overt philosophy MP is indeed minimalist. But in practice, it is a variant of PPT [Principles and Parameters Theory]". The question is: where do these findings leave us? The facts revealed in this chapter wholly support the central claim of this thesis. The issue that minimalism poses for theories of language evolution is that it proposes a system that shows little evolutionary plausibility. That is, if the minimalist system were truly minimal, it would be incompatible with an evolutionary account driven by gradual adaptation. However, this system has now been shown to be unreal; it is merely an exaggerated application of minimalist principles, a cleverly constructed obscuring of the facts employed to capture an ideal. That the MP is not evolutionarily plausible is unsurprising given that the system of language it promotes is internally inconsistent, and untrue. Minimalism is not minimal; there are hidden complexities and degeneracies in the system. As a result, the evolutionary claims of saltationism and macromutations that it demands need not be pursued. The system *as it actually exists* then is fully compatible with what we know of how evolution works. The more creditable scenario of a gradual and piecemeal evolution of a complex and imperfect system has thus received further valuable support through a systematic dismantling of the minimalist language faculty.

CHAPTER 7

Conclusions: Towards an Evolvable Theory of Syntax

7.1 Evolution as a Constraint on Theories of Language

The central investigation of this thesis has been the evolutionary plausibility of the MP. The preceding chapters have examined a number of ways in which that particular style of syntactic theorising fails to satisfy one constraint which we might place on our accounts of the language faculty - the constraint of evolvability. Recall from chapter 1 that any theory of language must be developed with a specific question in mind. Whether our concern is acquisition, processing, language variation, or indeed evolution, the construction of a theory of language must begin with some problem to be focussed on. As the theory is underdetermined by the data, a theoretical focus must be employed to constrain the theory.

In this final chapter, I will review the results of using evolvability as the constraining factor. That is, I will ask what types of features and processes this constraint entails for the language faculty; what would it mean for our theory of language to be not simply descriptively adequate and explanatorily adequate, but also evolutionarily adequate. I will then draw together the conclusions that have been reached in the preceding chapters to deduce a clear and logical rationale for rejecting the MP as a reasonable way to look at language. Finally, I will suggest some ways in which the current work could be extended in the future to bring us closer to answering the fundamental questions of how and why language evolved.

7.1.1 What will an Evolvable System of Language Look Like?

The choice made at the beginning of this thesis to pursue evolvability as a constraint on theories of language has resulted in the delineation of a system with a number of characteristic properties. This choice has allowed us to answer the question: what would an evolvable language faculty have to look like? Section 4.8 suggested three basic features that a theory of language constrained by considerations of evolvability will include. An evolvable language faculty is likely to be modular in its architectural design. That is, in order to be evolvable, the language faculty should be comprised of a number of sub-components, each with its own functional responsibility, yet able to interact with the others in order for some common function to succeed. An evolvable language faculty is likely to exhibit degeneracy in its structure. That is, we should expect it to include multiple ways of carrying out the same function, allowing break-down of one part not to spell break-down of the entire system. Modularity and degeneracy, in turn, lead to a further property - robustness. That is, an evolvable language faculty must have the means for withstanding potential damage.

These three features point to two further properties of an evolvable language faculty. Firstly, systems which show modularity and degeneracy, and are, as a result, robust, will be complex. Section 4.5 confirmed complexity as a crucial property in a system which has evolved, through illustration of evolution's predisposition to complexification. Secondly, the interaction of these indicative features of evolvability were shown to lead to the conclusion that the system involved must have a gradual adaptive evolutionary history. Without degeneracy, and the robustness it entails, a system has the propensity to be lethal; thus, degeneracy and robustness are directly adaptive. Furthermore, degeneracy and modularity are likely to arise through tinkering; hence they are the result of gradual adaptive evolutionary processes.

7.2 Reconciling Minimalism and Evolution

In section 3.5.2 a choice was presented on how to solve the incompatibility of minimalism and evolution: (1) show that minimalism is right, and exclude a gradual adaptive evolutionary account for the language faculty, or (2) show that a gradual adaptive evolutionary account is right, and exclude minimalist theories. In other words, the MP can only be said to be evolutionarily plausible if evolution is not understood in the usual manner of involving the gradual adaptive process of natural selection, but is instead understood as involving only the physical processes of growth and form. Chapters 4 through 6 have shown why we should take the second of these routes - showing that the language faculty has evolved gradually through adaptive processes, and hence that the MP cannot be correct.

The MP and the gradual adaptive account are incompatible because of the simplicity thesis of the MP. It was argued in sections 4.3 and 5.3 that language is not simple and atomic, as minimalists see it; rather, it is highly complex. Section 4.3.4 further reasoned that language shows signs of not simply being complex, but of being adaptively complex. The nature of the intricate assembly of the language faculty's components appears to be intimately related to the functions that the faculty must carry out; in other words, it has the appearance of design. This presents us with one piece of support for (2) above.

The MP and the gradual adaptive account are also incompatible because of the evolvable features discussed above. Section 4.8 revealed these features to be evident in the language faculty in a number of ways. Language is modular in both an external and an internal sense; itself it is one module within human cognition more generally, and that module, in turn, is composed of different linguistic modules. Language shows degeneracy[1], for example in synonymy, and in means for indicating grammatical functions. Language is robust, for example in allowing us to develop sign language when the normal acquisition channels are unavailable, or in dealing with incomplete signals in communicative interactions. The minimalist language faculty must rule out these properties as a result of its perfection thesis. Moreover, these properties are implicative of a system with a gradual adaptive evolutionary history. Hence, this presents us with one

[1]Recall from section 4.8.1 that degeneracy is defined as multiple different sub-systems carrying out the same function (contrasting it with redundancy, in which multiple identical sub-systems carry out the same function).

more argument for rejecting the MP, in support of (2).

The MP was argued in chapter 6 to be internally flawed. That is, extraneous operations, stipulations, and unresolved competing pressures, indicate that there are severe impediments to the perfection that minimalists claim for the language faculty. As a result, while not presented with direct confirmation of (2), we are presented with an unambiguous case for rejecting (1).

7.2.1 A Grand Unified Theory of Language

The MP has been portrayed by some (e.g. Pinker & Jackendoff (2005), Culicover & Jackendoff (2005)) as Chomsky's attempt at a grand unified theory of language. Indeed, from his own writings, it is clear that his belief is that because language itself is now much more clearly understood than ever before, we can seek to fit it into an account of the larger cognitive architecture: "...what conditions are imposed on the language faculty by virtue of ... its place within the array of cognitive systems of the mind/brain..." (Chomsky 1995a:385). He suggests that the MP will succeed in developing such a grand unified theory by tackling a new type of question "...the question "why"? Why these principles and not some other principles?" (Chomsky 2004:151).

This thesis has shown that the MP is not the grand unified theory of language that some of its proponents might have hoped it to be. As Culicover & Jackendoff (2005:544) rightly warn "...a simple Grand Unified Theory of language would be an amazing achievement. On the other hand, given that language is situated in the brain, itself a product of evolution, we find ourselves willing to back off from a Grand Unified Theory and to acknowledge that language is as riddled with eccentricities as every other part of the biological world, arising through the contingencies of evolutionary history." This thesis has shown that we are a long way from establishing such a theory; an abundance of interacting and competing considerations from numerous different disciplines must all be taken into account in its construction. The arguments in the preceding chapters can be viewed, then, as a cautionary note to be mindful of in pursuing the goal of developing a grand unified theory of language. Ignoring the data that other fields have to offer will result only in incomplete, and therefore erroneous, theories.

7.3 Future Directions

Some final questions to be addressed concern the potential development and extensions of the themes and conclusions of this thesis. How should we proceed from here in tackling the language evolution question? How can the discussion in this thesis be applied to future research?

7.3.1 Evolutionarily Plausible Minimalist Theories

Two options suggest themselves for formulating a minimalist theory of language which *is* evolutionary plausible. Such a theory would thus aim to satisfy the evolvability constraint, but also take into account the importance of a minimalist methodology. The first option is to begin, as the MP does, with language. The first step would be to create a minimal theory of the language faculty, where *minimal* is understood as conforming to the weak minimalist thesis of Occam's razor, but not to the strong minimalist thesis of perfection. Once a minimal theory of the system has been constructed, the second step would be to analyse that system's conformance to what we know of how evolution works, adjusting it accordingly.

Culicover & Jackendoff's (2005) *Simpler Syntax* framework takes the first step of minimising language in a non-MP manner. The narrow language faculty, under this conception, is minimal in that it "...imputes the minimum structure necessary to mediate between phonology and meaning" *(ibid*: 5) without imposing "...the further criterion...that language is maximally simple, general, and elegant – independent of empirical observations" *(ibid*: 89). Their view of syntax holds onto many traditional judgements about the structure of sentences, but rejects extraneous operations and features such as movement, null elements, and functional category projections.

This framework has also begun the second step of fitting the system into our evolutionary expectations. Its *Toolkit Hypothesis* suggests that language evolved gradually, the result of a tinkerer, providing "...human communities with a toolkit of possibilities for cobbling together languages over historical time" *(ibid*: 5). This hypothesis accounts for the existence of many differing languages by assuming that "[e]ach language, in turn, "chooses" a different selection and customization of these tools to construct a mapping between sound and meaning" *(ibid)*. Future research could profitably work at expanding and pinning down the details of the Toolkit Hypothesis. That is, one promising direction would be to use the evolutionary conclusions developed in this thesis to constrain and sharpen the language faculty that Simpler Syntax suggests.

The second option for constructing an evolvable theory of syntax is to begin with the evolutionary details, and then minimise the resulting system. Jackendoff's (2002) gradual, staged framework examined in section 5.7.3.1 takes the first step. He delineates a system that is built up over evolutionary time in a gradual and incremental fashion. The system conforms to evolutionary expectations in that it exhibits evolvable features such as modularity, complexity, and adaptiveness, yet it is missing a precise characterisation of the component parts. Thus, a further direction for future research would be to draw on the anti-perfection arguments in this thesis in fine tuning the system of language that Jackendoff's stages entail to conform to the weaker methodological minimalism, without the implausible stronger perfection thesis.

7.3.2 Determining the Nature of FLN

This thesis has examined the nature of the split between the broad and narrow language faculties in some detail. Chapters 5 and 6 both led (albeit in different ways) to the conclusion that the division envisaged by Hauser *et al.* (2002) is misplaced. Their conception of language advances that the narrow language faculty, in contrast to the broad language faculty, is simple and perfect, and that its one defining property is recursion. While chapter 5 showed that there exist in language a number of properties additional to, and independent of, recursion that are not found in other domains, and that recursion is not restricted to language, chapter 6 employed the particulars of minimalist theories to illustrate that the narrow language faculty is, in fact, imperfect and complex in many ways, and therefore likely to be characterised by more than one single property.

Both of the above options for formulating an evolvable theory of syntax are concerned ultimately with the delineation of the narrow language faculty, and the FLN/FLB split. That is, any theory which claims to answer questions of the evolution of our language capacity must, as chapter 5 stipulated, clearly outline what it is that has evolved; what the uniquely human and uniquely linguistic elements of the capacity are. A third option for future research then, is to use comparative studies to definitively situate the many features of language and cognition considered in the preceding chapters on the correct side of the divide.

7.4 Final Remarks

The constraint of evolvability on language has received in recent times considerable attention from those working in a diverse range of fields. A glaring absence from this set of researchers has been linguists (at least until very recently). This thesis has demonstrated not only that considerations of evolvability are a reasonable point from which to begin our investigations of the human language capacity, but also that linguists need to place significantly more emphasis on the evolutionary implications of their theories. An in-depth exploration of one such theory of language – the Minimalist Program – from an evolutionary perspective has had results on two levels. Firstly, the framework of minimalism has been shown to be implausible when the constraint of evolvability is imposed on it. Secondly, at a higher level of investigation, it has been shown that ignoring pertinent facts from fields which impinge on our own will prevent us from attaining the ultimate goal of a complete theory of language.

Appendix A

Published Papers

This appendix contains an article published in a conference proceedings volume prior to the completion of this thesis (Parker (2006)).

PARKER, A. R. 2006. Evolving the narrow language faculty: Was recursion the pivotal step? In *The Evolution of Language: Proceedings of the 6th International Conference on the Evolution of Language*, ed. by A. Cangelosi, A. D. M. Smith, & K. Smith, 239–246. World Scientific Press.

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