CHAPTER 1

Introduction

Right now, waves of electromagnetic radiation in the 10kHz to 100GHz range are blasting out into space at the speed of light, carrying news of a revolutionary innovation. This radiation is emitting from Earth and has already reached over 1000 nearby stars. Encoded in the frequency and amplitude of these waves of radiation is evidence of an epoch-making new mode of communication which has developed relatively recently on this planet. This innovation has changed the face of our world and signalled our presence to the wider universe. The innovation is language, and the electromagnetic signal is generated by the more recent and comparatively inconsequential inventions called radio and television.

Only a tiny minority of the 6 billion-strong human population of Earth has more than a basic level of understanding of radio technology, and fewer still have a good grasp of the physics of electromagnetic radiation. Yet virtually all of humanity has an unconscious, profound and subtle knowledge of a language. Knowledge of language is universal. Humans acquire their knowledge of language apparently effortlessly, in all manner of circumstances, with only the most severely deprived individuals remaining language-less into adult life.

Sophisticated communication systems abound on Earth. Most species have a system of signals which enable them to communicate with other members of their species, or with members of other species. Bees communicate the distance and direction of pollen sources to other bees using an elaborate dance (von Frisch 1974). Numerous species of bird use song for marking out territory and for attracting mates (Hauser 1996). Bottlenose dolphins have personalised “signature whistles”, and can rapidly learn to produce the signature whistles of other dolphins (Tyack 1986; Janik & Slater 1997). It has been suggested that dolphins may use these whistles for addressing each other, either aggressively or affiliatively (Janik 2000).

Moving to species more closely related to humans, most primate species use systems of facial expressions and vocalisations to perform social functions such as issuing threats (see Hauser (1996) for review). Vervet monkeys have a system of alarm calls whereby different calls are given for different predator species, and vervets respond to these calls in a manner appropriate for best evading the associated predator (Cheney & Seyfarth 1990). Gibbons produce structured calling bouts, with calls of males in particular exhibiting structured combination of individual notes into "phrases", with phrases being repeated during a calling bout (Raemaekers *et al.* 1984). In addition to facial expression, chimpanzees use systems of gestural communication (Tomasello 1990; Tomasello 1996; Tomasello *et al.* 1997) for performing various social functions.

These communication systems appear to echo some aspects of language. What, then, makes language special? How did human language come to exhibit these unique features? The aim of this thesis is to answer this "how" question, with the aid of a set of computational models. This investigation forms the bulk of the thesis, from Chapter 2 onwards. However, before addressing the question of how language came to be as it is, it is necessary to tackle the first question above — what feature or combination of features makes language unique? This review, in Section 1.1, serves to highlight the features of language which then have to be explained later in a theory of language evolution. Section 1.2 outlines two competing theories of how humans come to acquire a language. These theories, in combination with the potential sources of relevant evidence outlined briefly in Section 1.3, form the basis of a number of broad theories of language evolution. These theories are discussed in Section 1.4. Finally, in Section 1.5, I highlight the need for theories of language evolution to be based on formal models. This forms the motivation for the remainder of this thesis, which is primarily concerned with insights gained from formal modelling approaches.

1.1 The uniqueness of language

Two steps are then necessary to clarify the difference between language and other naturally-occurring communication systems[1]. Firstly, we must identify the features of language

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[1] For the purposes of this chapter it is sufficient to rely on the rather naive notion of communication as a process by which individuals transmit information to other individuals. There is a great deal of debate about the proper definition of communication. Many definitions (e.g. those of Krebs & Dawkins (1984), Millikan (1984) and Hauser (1996)) appeal to the notion of functionality and design by natural selection. However, such notions are somewhat controversial with respect to language, as we shall see in Section

which require explanation. This is done in Section 1.1.1, based on a cross-section of introductory linguistics textbooks. Secondly, we must identify which of these features are present in other communication systems, in particular the communication systems of non-human animals. This analysis is carried out in Section 1.1.2. Based on these analyses, taxonomies of communication systems with respect to distinctive features can be developed. A taxonomy developed in Oliphant (2002) is reviewed in Section 1.1.3. This taxonomy is refined in Section 1.1.4. An explanation of the uniqueness of human language amounts to an explanation of the features which are present in language but not in non-human communication.

1.1.1 Design features of language

Most introductory linguistics textbooks include a list of *design features* of language (a term introduced by Hockett, e.g. Hockett (1960a), Hockett (1960b)) which the authors regard as important properties of language. Collating these proposed design features from a selection of five introductory texts (Burling 1992; Fromkin & Rodman 1988; Hudson 2000; O'Grady *et al.* 1996; Trask 1995), removing those which are proposed in a single text, yields the following list of seven design features of language:

Open-endedness: The set of sentences that could be produced or understood by a user of a language is infinite. (Burling, Fromkin & Rodman, Hudson, O'Grady *et al.*, Trask)

Cultural transmission: Language is learned (in some sense to some degree — see Section 1.2) by language users from other language users, as opposed to being genetically transmitted. (Burling, Fromkin & Rodman, Hudson, O'Grady *et al.*, Trask[2])

Arbitrariness: Typically, the form of a signal is arbitrarily related to its meaning. (Fromkin & Rodman, Hudson, O'Grady *et al.*, Trask)

Duality of Patterning: Small numbers of meaningless elements (phonemes in spoken languages) are combined to form large numbers of meaningful elements (words). (Burling, Hudson, O'Grady *et al.*, Trask)

Displacement: Language can be used to communicate about things in places, times or even possible worlds removed from the actual communicative act. (Burling, Hudson, O'Grady *et al.*, Trask)

1.4 — it has been argued that language is not designed for communication. I will provide a definition of communication which is sufficient for my purposes in Chapter 2, and consider some alternative definitions in Chapter 4.

[2] Trask in fact doesn't include cultural transmission in his introductory chapter, where he introduces the other design features of language. However, he does introduce it later in the book.

STIMULUS FREEDOM: Language users can potentially produce any signal they want at any time, and are not bound to producing a signal only when the appropriate stimulus is present. (Fromkin & Rodman, O'Grady *et al.*, Trask)

DISCRETE: The units of a language are distinguished from each other categorically, as opposed to grading into one another. (Burling, O'Grady *et al.*)

The design feature of open-endedness can be further decomposed into two features:

COMPOSITIONALITY: The meaning of an expression (excluding idioms and irregulars) is a function of the meaning of its parts and the way in which they are combined (Cann 1993; Krifka 2001).

RECURSIVENESS: An expression of a particular type can be a subpart of a larger expression of that type (see e.g. Burling (1992), Haegeman (1994), Hudson (2000)).

Recursiveness allows the creation of an infinite number of utterances. Compositionality makes the interpretation of previously-unencountered utterances possible — in a recursive compositional system, if you know the meaning of the basic elements and the effects associated with combining elements, you can deduce the meaning of any utterance in the system.

1.1.2 Design features of animal communication

In the process of identifying these design features of language, Burling (1992), Fromkin & Rodman (1988), Hudson (2000), O'Grady *et al.* (1996) and Trask (1995) explicitly contrast them with apparent design features of non-human communication systems. Some design features are identified as occurring in the communication systems of non-human animals, whereas other design features are identified as being unique to language.

OPEN-ENDEDNESS: All agree that this is unique to language.

CULTURAL TRANSMISSION: All agree that, in addition to language, song is culturally transmitted in some species of bird. In addition, Hudson suggests that the vervet alarm call system is culturally transmitted (apparently wrongly, as we will see below). With the exception of bird song, all other non-human communication systems are taken to be genetically transmitted. This is supported by a large cross-species review, which concludes that "although call structure [in non-human primates, our closest extant relatives] changes ontogenetically, no study has provided convincing evidence that acoustic experience is causally related to such changes" (Hauser 1996:315).

ARBITRARINESS: There is some disagreement on arbitrariness. Trask suggests that it is common, Hudson and O'Grady *et al.* suggest that it is only observed, outside of humans, in vervets. In fact, alarm calling systems seem to be fairly common, both in primates (for example, Diana monkeys (Zuberbuhler *et al.* 1997), Campbell's monkeys (Zuberbuhler 2001) and ringtailed lemurs (Pereira & Macedonia 1991)) and birds (various species of passerine birds (Marler 1957) and domestic chickens (Evans *et al.* 1993)).

DUALITY OF PATTERNING: All agree that this is unique to language.

DISPLACEMENT: All agree that bee dance is the only non-human communication system that allows displacement, and even then only with respect to the domain of foraging.

STIMULUS FREEDOM: Fromkin & Rodman, O'Grady *et al.* and Trask claim that all non-human communication systems are stimulus-bound, although Trask does admit to some anecdotal evidence of stimulus-free communication in animals.

DISCRETE: Burling claims that all non-human communication consists of graded signals. However, O'Grady *et al.* give the obvious counter-examples of bee dance (most species use one dance for food sources close to the hive and a completely different dance for distant food sources) and primate call systems (such as the vervet alarm call system).

How might non-human communication systems be classified according to our two additional features of recursiveness and compositionality? Bird song and gibbon calls consist of the repetition of notes and structured groupings of notes and therefore might be viewed as recursive, although only in a weak, conjunctive sense. However, these structured calls are typically interpreted as being used for territory maintenance, pair bonding or sexual advertisement (Raemaekers *et al.* 1984; Hauser 1996) and are therefore probably not compositional — no subpart of the signal stands for a subpart of the meaning, where the meaning could be interpreted as "this is my/our territory", "we are a couple" or "I would make a good mate". Furthermore, there is evidence that the gibbon calls may be largely genetically determined, although this has been contested (see Janik & Slater (1997) for a brief review). This characterisation of bird and gibbon song as structured, perhaps even weakly recursive, yet non-compositional may have to be revised if a better characterisation of what these animals are communicating about reveals that, in fact, certain aspects of their signals reflect certain components of the message they are trying to convey.

In contrast, bee dance could not be interpreted as recursive, but it seems somewhat compositional. The meaning of the dance (the direction and distance to the food source) is dependent on the angle of the straight portion of the dance (which gives direction relative

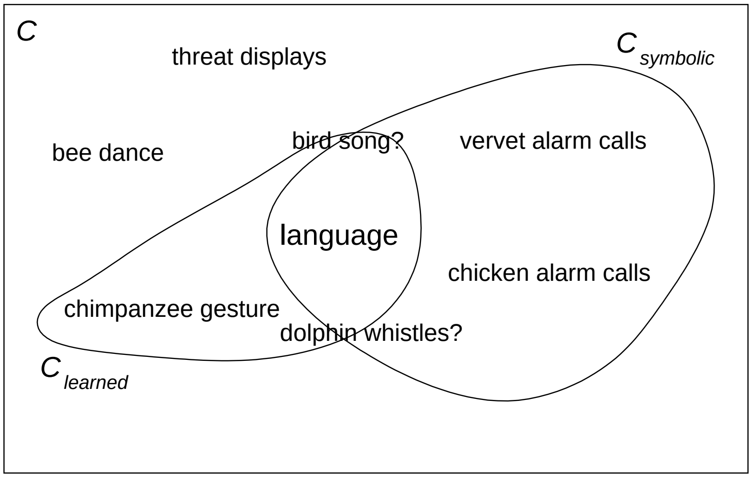

Figure 1.1: Oliphant's taxonomy of communication systems. The outer square, C, represents the space of all extant communication systems. Within this, there are some communication systems which are symbolic (the area labelled as $C_{symbolic}$), and some which are learned ($C_{learned}$). According to Oliphant, only (human) language is a member of $C_{symbolic}$ and $C_{learned}$.

to the sun) and the length of the straight portion of the dance (which gives distance). It is not clear that the meaning of the dance is dependent on the way these two parts are put together, as they are essentially part of the same action. There is also no evidence that the bee dance is culturally transmitted.

1.1.3 Oliphant's taxonomy of communication systems

Oliphant (2002) provides a taxonomy of communication systems based on two characteristics, symbolicism (related to arbitrariness) and learnedness (related to cultural transmission). Oliphant defines a symbol as "a sign that refers to the object that it denotes in a way that is arbitrary with respect to the process of conventionalization that established it" (Oliphant 2002:313). Non-symbolic systems can either be characterised as iconic (reference is by resemblance) or indexical (reference is by causal relation). Learned systems are acquired experientially (this typically involves cultural transmission, but may involve other processes, as discussed below with reference to chimpanzee gestures), whereas non-learned systems are specified genetically (and therefore genetically transmitted). Oliphant's taxonomy is illustrated in Figure 1.1. Oliphant's main conclusion is that language is the only communication system which is both learned and symbolic.

There are several features to note in Oliphant's taxonomy. Firstly, chimpanzee gestural communication is classified as learned but non-symbolic. Such gestural communication systems are formed by what Tomasello (1996) calls *ontogenetic ritualization*, whereby actions which are initially part of a process become ritualised shortcuts which stand for the whole process. Tomasello (1990) gives the example of an infant chimpanzee which moves its mother's arm in order to reach a nipple to feed. Over time, the action of the chimpanzee touching its mother's arm becomes a ritualised shortcut for this process, signalling to the mother that the infant needs to feed. The meaning and the signal are associated indexically, by being part of a causal chain, and are not arbitrarily associated. Furthermore, Tomasello *et al.* (1997) provide evidence that such ritualised signals are not culturally transmitted in chimpanzee populations once they become established.

Similar arguments based on indexicality apply to the evolution of innate non-symbolic systems such as primate facial expressions, threat displays and the bee dance, where the signal has presumably evolved from what was initially a preparatory stage for the full action of attacking, taking off or whatever.

Oliphant claims that alarm call systems, such as that of the vervet monkey, are innate and symbolic. As mentioned above, Hudson (2000) claims that the vervet system is culturally transmitted and therefore learned, so a clarification here is worthwhile. Seyfarth & Cheney (1986) and Hauser (unpublished data, cited in Hauser 1996, p306) report that the acoustic morphology of calls in vervets is essentially independent of age, "suggesting that experience plays a relatively insignificant role in shaping acoustic morphology" (Hauser 1996:306). However, vervets do become more specific with the use of their alarm calls as they mature. Infant vervets are as likely to give the eagle alarm call for a martial eagle as for non-predatory birds. Infant vervets have even been seen to give the eagle call on seeing falling leaves (Cheney & Seyfarth 1990). However, adult vervets give the eagle call in the appropriate circumstance (seeing a martial eagle) much more frequently than in inappropriate circumstances. Immature vervets must therefore learn when to apply their innately-given alarm calls. It is interesting to note that this categorisation process also appears to be partially innately coded — the eagle alarm call in immature vervets is only given to objects in the air, usually birds. Oliphant therefore argues that the mapping between objects in the air and the eagle call is innately specified and not learned, while learning somewhat refines the 'meaning' portion of the mapping.

Oliphant's classification of such alarm call systems as symbolic is interesting. Bee dance is classified as non-symbolic because it is hypothesised to have evolved from phylogenetic ritualization of preparatory movements for takeoff — the signal is causally related to the meaning. Oliphant presumably envisages an evolutionary scenario where the vervet call signals evolved from a situation where individuals, on sighting a predator, gave some involuntary vocalisation then took appropriate evasive action. Over time these vocalisations became phylogenetically ritualised into the call system. The only difference between this scenario and that proposed for the evolution of bee dance is that the hypothesised involuntary proto-alarm call is not causally related to the evasive action, and therefore arbitrary with respect to that action, which becomes the meaning of evolved call. However, we can imagine a scenario under which the vocalisation in the proto-alarm call system was part of the causal chain involved in performing the action of evading the predator — for example, anatomical constraints might require vervets to clear the air from their lungs before they can stand up. This would make the alarm call non-symbolic in Oliphant's classification. His classification appears to depend on knowing the evolutionary history of a signalling system, which we cannot do with any certainty.

There are two notable omissions from Oliphant's taxonomy — bird song and dolphin signature whistles. Certain types of bird song are at least partially learned, and may be interpretable as arbitrarily related to their meaning and therefore symbolic. Dolphins learn the signature whistle of other dolphins. If a dolphin's signature whistle reflects aspects of its physical characteristics then we might classify such learned whistles as iconic, given that there is a resemblance between a dolphin's whistle and its physical characteristics. However, if a dolphin's whistle is arbitrary then there is only an arbitrary relationship between the learned whistle and its meaning (the dolphin that produces that whistle) and therefore dolphin whistles would fall into the learned, symbolic portion of Oliphant's analysis alongside human language and, possibly, bird song. I would not like to commit to such an analysis, but merely raise it as an example of the problems which potentially arise when we attempt to distinguish language from non-language on categorial assessments in a limited number of dimensions.

1.1.4 Refining the taxonomy

Figure 1.2 gives a taxonomy of communication based on Oliphant's taxonomy, integrating the terms of three of the "design features" outlined above — cultural transmission, arbitrariness (for which I adopt Oliphant's definition of a symbol) and compositionality. Cultural transmission is preferred to Oliphant's "learnedness" classification. Compositionality is included without recursiveness.

According to this taxonomy, language is the only naturally-occurring communication system which is culturally transmitted *and* symbolic *and* compositional. The following chapters of this thesis will attempt to explain the evolution of communication systems which exhibit these properties.

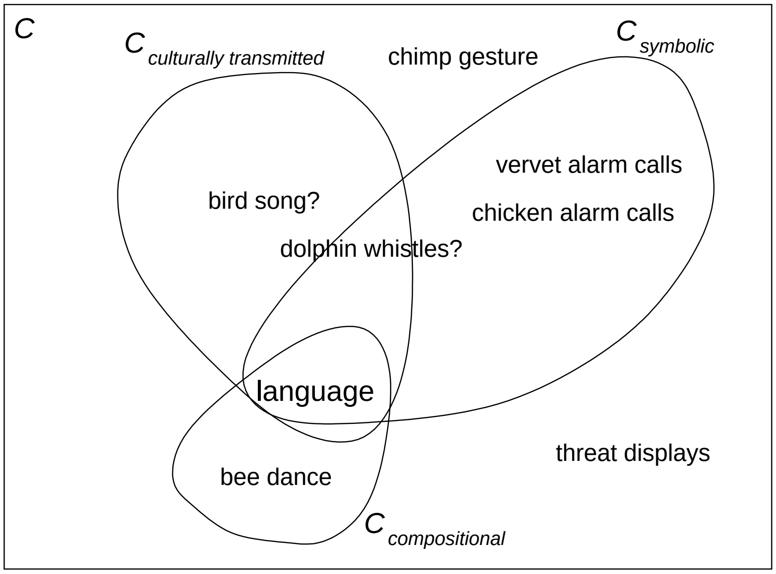

Figure 1.2: A new taxonomy of communication systems. Language is unique in occurring at the intersection of $C_{culturally\ transmitted}$, $C_{symbolic}$ and $C_{compositional}$ — only language is culturally transmitted, symbolic and compositional.

1.2 Theories of Language

We have established that language is unique. More specifically, language is unique in being culturally transmitted, symbolic and compositional. The concern of much of cognitive science, and linguistics in particular, has been to characterise what it means to have knowledge of a language with these features — how is language represented in the mind and how is this representation of language acquired?

Theories of language can be crudely divided into two paradigms — the Nativist paradigm, discussed in Section 1.2.1, and the Empiricist paradigm, discussed in Section 1.2.2, which encompasses various anti-Nativist positions

1.2.1 The Nativist paradigm

The dominant paradigm in linguistics, formed and directed by Noam Chomsky (e.g. Chomsky (1965), Chomsky (1972), Chomsky (1986), Chomsky (1995)), views language from the standpoint of individual psychology. Under this view, the domain of inquiry is the state of the mind of a person who knows a language – Internalised Language, or I-Language. Externalized Language, or E-Language, is then the epiphenomenal set of actual or possible behaviours produced by application of this internalised knowledge to a set of contingent situations in the external world.

In conjunction with this focus on I-language, Chomsky and others have advanced the notion of Universal Grammar (UG). “UG may be regarded as a characterisation of the genetically determined language faculty . . . an innate component of the human mind that yields a particular [I-]language through interaction with presented experience . . . UG is a theory of the ‘initial state’ of the language faculty, prior to any linguistic experience” (Chomsky 1986:3-4). Under a more refined analysis, UG may be decomposed into two parts — a “specification of permitted types of rules and permissible interactions among them” (Chomsky 1986:52) or “a system of principles associated with certain parameters of variation” (Chomsky 1986:221) (the hypothesis space for possible I-languages) and a Language Acquisition Device (Chomsky 1965) which specifies how presented experience determines the selection of a particular I-language from the range of possibilities admitted by the specification of permitted hypotheses. In addition to being innately specified, UG is viewed as being language-specific — “a system of grammatical relations and a system of morphological agreement . . . are totally useless to any other [non-linguistic] cognitive capacity; they are exquisitely specialized” (Jackendoff 2002:264).

This theory of UG was advanced to account for the seemingly insoluble problem of language acquisition. Fundamental to theories of UG is the observation that children must learn language from “meager and unspecific evidence” (Chomsky 1986:149). Pullum & Scholz (2002) provide a fairly rigorous survey of the ways in which the evidence presented to the child has been claimed to be meager and unspecific. These can be summarised as:

1. Children are not specifically or directly rewarded for their advances in language learning.
2. Children’s data-exposure histories are finite, but they acquire an ability to produce or understand an infinite number of sentences.
3. Children’s data-exposure histories are highly diverse, yet language acquisition is universal.
4. Children’s data-exposure histories are incomplete in that there are many sentences they never hear, yet can produce and understand.
5. Children’s data-exposure histories are solely positive — they are never given details of what is ungrammatical.
6. Children’s data exposure histories include numerous errors, such as slips of the tongue and false starts.

Such arguments are known as arguments from the *poverty of the stimulus*. Given that the evidence presented to language learners is so impoverished, the only possible explanation for universal language acquisition is that some of the knowledge of language must be prespecified in UG — UG constrains and guides the language acquisition process in such a way that, even given the paucity of evidence available to children, language is reliably acquired. As Chomsky puts it, language acquisition is interpreted as the "growth of cognitive structures [linguistic competence] along an internally directed course under the triggering and partially shaping effect of the environment" (Chomsky 1980:34). To put it in Jackendoff's terms, in order to explain the fact of language acquisition "we need a way for children to be . . . hampered by preconceptions — in fact hampered by the very same preconceptions as every other child. It is just that children's preconceptions happen to give them the right solutions" (Jackendoff 2002:84).

1.2.2 The Empiricist paradigm

The Nativist position on language acquisition can be summarised as the application of domain-specific, innate acquisition procedures to an impoverished set of evidence which leads to selection of a hypothesis from a domain-specific, innately prespecified space of hypotheses. The alternative approach, which I will call the Empiricist approach, can be characterised as follows: application of domain-general acquisition procedures to a (possibly rich) set of evidence leads to the selection of a hypothesis from a domain-general space of hypotheses.

This position in its most extreme form is expounded by Geoffrey Sampson (Sampson 1997), who argues that "biological constraints on language are limited to matters which are 'trivial' because they follow from properties of our speech and sense organs which are known to be genetically fixed" (Sampson 1997:25). For Sampson there is no innate LAD and no prespecified space of possible hypotheses, nor even an innate propensity to want to learn a language. Less extreme forms of the anti-nativist view are expressed by Popper, who suggests that "[t]he capacity to learn a language — and even a strong need to learn a language — is, it appears, part of the genetic make-up of man. By contrast, the actual learning of a particular language, though influenced by unconscious inborn needs and motives, is not a gene-regulated process and therefore not a natural process, but a cultural process" (Popper (1977:48), cited in Sampson (1997)). A similar position is adopted by some cognitive scientists working in the connectionist paradigm such as Bates & Elman (1996) who argue that domain-general learning techniques may explain more of language than was previously thought, while allowing that "[e]ven if we assume that a brain (real or artificial) contains no innate knowledge at all, we have to make crucial assumptions about the structure of the learning device, its rate and style of learning, and the kinds of input that it 'prefers' to receive" (Bates & Elman 1996:1850).

Proponents of this anti-Nativist position are often called upon to refute perhaps the strongest argument in favour of UG — the argument from the poverty of the stimulus. Pullum & Scholz (2002) investigate the evidence behind the fourth aspect of the poverty of the stimulus (given above), that children never encounter certain sentence constructions which would be required to acquire an I-language by a learning procedure unconstrained by UG. One example is the structure-dependent generalisation about subject-auxiliary inversion in question formation in English, introduced as an example of the poverty of the stimulus in Chomsky (1971).

(1.1) The dog in the corner is hungry
(1.2) Is the dog in the corner hungry?
(1.3) The dog that is in the corner is hungry
(1.4) Is the dog that is in the corner hungry?
(1.5) *Is the dog that in the corner is hungry?

The interrogative in 1.2 could be derived from the declarative in 1.1 by two possible strategies. Under the (correct) structure-dependent hypothesis, the auxiliary in the main clause in the declarative is fronted. Under the (incorrect) structure-independent hypothesis, the first auxiliary in the declarative is fronted. These two competing hypotheses are indiscriminable on the basis of exposure to sentences 1.1 and 1.2. The interrogative in 1.4, derived from the declarative in 1.3, shows that the structure-dependent hypothesis is correct, as the structure-independent movement hypothesis would generate the (ungrammatical) 1.5. Chomsky claims that “you can go over a vast amount of data of experience without ever finding such a case [as 1.4]”. Pullum & Scholz (2002) in fact found examples of the discriminating case in every corpus they examined, including newspaper text, a play, a poem, a transcription of a television program and, notably, a corpus of child-directed speech.

The assault on the empirical bases of the poverty of the stimulus argument is a relatively recent endeavour. Consequently, it is not clear to what extent the other aspects of the argument will survive closer inspection. One aspect of the argument does seem to be on fairly solid ground, however — given that the set of possible sentences of a language is infinite, we can be sure that no child will hear them all during the process of language acquisition. Does this problem of acquiring a system of infinite productivity from a finite set of data therefore force us to accept the strong Nativist concepts of UG and the LAD? Not necessarily. Experiments such as that outlined in Elman (1993) show that, given a particular maturation schedule, domain-general statistical learning techniques can extract grammatical regularities from finite exposure to word strings. These regularities could potentially allow children to produce and understand an infinite range of utterances.

1.3 Evidence for language evolution

What sources of evidence are available to guide and constrain theories of the evolution of language? Potentially there are two main types of evidence. Archaeology could provide us with evidence which directly shows the course of the evolution of language or the language faculty. However, as discussed in the next Section, such evidence proves to be of limited utility. A second possible source is in present day phenomena — the way we acquire and use language today might suggest its evolutionary origin.

1.3.1 Archaeological evidence

The main problem with archaeological evidence is that language does not fossilize. The earliest direct evidence we have for the existence of language comes from the Sumerian writing systems, the earliest examples of which occur around 3000BC (Kramer 1963). However, it is unlikely that this date reflects the origin of language — writing is essentially a technical innovation, and a significant proportion of the world's population today remains illiterate while having an intimate and subtle knowledge of a language.

Given the absence of direct evidence of the origins of language, the archaeological record has been searched for indirect evidence of language. This search can be broadly categorised into two strands: the search for evidence of the origins of biological correlates of language, and the search for cultural correlates of language. The biological correlates of language are typically taken to be in the brain and the vocal tract. These both consist of soft tissue so, somewhat ironically, neither of these fossilize either. We can, however, draw some indirect conclusions on the evolution of these indirect markers of language.

Brain size, as estimated by cranial volume, has increased down the hominid line. This trend of increasing brain size is summarised in Table 1.1, which gives the estimated brain sizes for the main recognised species of hominids. The various species of australopithecines, which were among the earliest hominids (appearing approximately 5 million years ago), had brain sizes estimated to be between 400 and 550ml, comparable with extant apes of a similar stature. Early modern *Homo sapiens* have brain volumes of 1200–1700ml, comparable with anatomically modern *Homo sapiens*.

Brain size is not the only measure we have of the evolution of brains in the hominid line — see, for example, the evidence on sulcal patterning discussed in the summary of

Species	Date of appearance	Estimated brain size
australopithecine (various)	5m BP	400–500ml
Homo habilis	2.4m BP	500–800ml
Homo erectus	1.8m BP	750–1250ml
Homo sapiens (archaic)	400,000 BP	1100–1400ml
Homo sapiens (early modern)	130,000 yrs BP	1200–1700ml

Table 1.1: The trend in brain size. Approximate date of appearance in the fossil record (in years before present) and estimated brain size for ancestors of modern humans. Data on australopithecines from Wood (1992). Data on *Homo* from Stringer (1992).

Wilkins & Wakefield's (1995) paper below. However, this kind of evidence is extremely controversial. The general trend of increasing brain size is less controversial, but probably less useful. We do not know the minimum brain size required to support a language. It is common to equate an increase in brain size with an increase in general intelligence, and for those working in the Empiricist paradigm, where language is seen primarily as a consequence of general intelligence, this suggests that the capacity for language may have emerged further down the hominid line. However, this still does not tell us when, or whether the increase in brain size was driven by selection for language abilities or selection for general intelligence. The picture of increasing intelligence is even less relevant if we follow the Nativist paradigm, where language is seen as a consequence of a specific mental organ.

The evolution of the vocal tract has also been the subject of lively debate. The soft tissue of the vocal tract does not fossilize, but the shape of the vocal tract, the height of the larynx, and the degree of respiratory and articulator control have all been estimated based on markers which do fossilize — for example, the flexion of the base of the skull, the morphology of the hyoid bone, the width of the hypoglossal canal and the width of the thoracic vertebrate canal (see Fitch (2000) for review). However, much of this evidence is controversial — as Fitch concludes, "despite an extensive and disputatious literature, most potential fossil cues to phonetic abilities appear inconclusive, suggesting that it will be difficult to reconstruct the vocal behavior of our extinct ancestors with any certainty" (Fitch 2000:263). Even if we could reconstruct the vocal behaviour of our extinct ancestors, it would perhaps not provide any direct answers as to the evolution of language. The evolution of the vocal apparatus required for speech has little relevance for those who argue that language was initially based on a gestural system (Hewes 1973; Corballis 2002). Even if we accepted that speech was the initial modality used for language, and were able to pin down a definite date when the capacity for speech began to evolve, this would still be compatible with several competing theories: speech could have been a preadaptation for language, or could have co-evolved with language (as suggested by Lieberman, discussed below), or could have evolved as a consequence of selection pressures for efficient signal production arising from the presence of fully-fledged language.

The study of the evolution of some of the supposed biological correlates of language is therefore not terribly illuminating — not only is the archaeological evidence often debatable, but the correspondence between these physical characteristics and language is not well-established. This has led some researchers to focus on the appearance of cultural artifacts in the archaeological record. Writing is one such cultural artifact. The account of Wilkins & Wakefield (1995) appeals to the relevance of tools, another cultural artifact. The fact that the inventory of tools (or at least tools which remain in the fossil record) remained fairly constant until the late Paleolithic period, when it underwent explosive diversification, might suggest that there was some biological change which lead to a cultural revolution which impacted upon the range of tools individuals were capable of learning to manufacture. However, this is not necessarily the case. It could be that the capacity for a complex tool kit was present long before such a tool kit was in place — cultural innovations do not necessarily coincide with biological ones. Secondly, and of more relevance from our point of view, there is no obvious link between tools and language. While language may be involved in the cultural transmission of tool-making skills, we cannot conclude the presence of language from the presence of tools. We certainly cannot conclude the absence of language from the absence of tools.

Others have appealed to the origins of “symbolic culture” (ochre staining or cave art) as evidence of the origins of language (e.g. Knight (1991), Knight *et al.* (1995)). While we might agree that the presence of art indicates the presence of language, we are not forced to do so — it just seems unlikely that people who were so much like ourselves as to indulge in cave paintings did not have language. Most manifestations of “symbolic culture” are so recent as to make this position fairly uncontroversial anyway. And we still cannot conclude that the absence of art reliably indicates the absence of language — art may be a fairly recent cultural innovation.

To summarise, the evidence from the archaeological record on the evolution of language is fairly sparse and of limited use. This is either due to the debatable nature of the archaeological data, or the lack of clarity as to what that data tells us about language.

1.3.2 Current-day evidence

Far better sources of evidence are available in living species in the world today. While current-day evidence cannot directly show us the time-course of the evolution of language, it can give us a valuable insight into the kinds of processes — biological or cultural — which might have been involved in the origins and evolution of language. There are 7 sources of present-day evidence which can potentially shed some light on such questions:

1. Language uniqueness
2. Language universals
3. Genetic deficits
4. Cross-species comparison
5. Language acquisition
6. Language change
7. Creolization

Explanations of the uniqueness of language and the limited range of cross-linguistic variability evidenced in the languages of the world follow naturally from the notion of genetically-encoded UG. Only humans have language because only humans have UG, without which language cannot be acquired. Language universals (see e.g. Greenberg (1966)) exist because UG constrains the range of possible I-languages to vary in limited ways. Properties which all languages share are therefore presumed to be direct reflections of the constraints imposed by UG. Uniqueness and universals can then be seen as a consequence of the biological evolution of the language faculty in our species.

Non-biological accounts of language and language evolution also have to account for the presence of linguistic universals. Typically, such universals are attributed to universal aspects of the *use* of language, rather than universal constraints on the possible forms of language — see Newmeyer (1998) for review (Chapter 3 in particular). The uniqueness of language to humans has variously been attributed to consequences of the uniquely high degree of encephalization in humans (e.g. Bickerton (2000), Christiansen & Conway (2002)), humans' uniquely sophisticated understanding of others as intentional agents (Tomasello 1999) or the unusually long developmental period in humans (Elman 1993).

Myrna Gopnik (Gopnik & Crago 1991; Gopnik 1994) presents evidence from the study of a family, known as the KE family, where approximately half of the members of the family suffer from a heritable language impairment. According to Gopnik, this impairment is specific to inflectional marking of tense and number, and other than these problems the subjects are of normal IQ, and have “no reduction in the range of movement or the tone of the mouth and tongue musculature” (Gopnik 1994:113). Furthermore, the heritable impairment seems to be a consequence of a point mutation in a single gene (Lai *et al.* 2001). This appears to indicate the presence of a “language gene” — a gene which, if mutated, has specific and deleterious consequences for a subset of the tasks involved in language acquisition and processing.

The presence of a language gene would seem to suggest that language evolution must have involved the emergence of some language-specific biological capacity in our species. However, Gopnik’s data and conclusions have been attacked. Gopnik claims that members of the family who carry the mutated gene are of normal intelligence. Vargha-Khadem *et al.* (1995) conclude that “the affected family members have both verbal and performance intelligence quotient (IQ) scores that are on average 18–19 points below those of the unaffected members” (Vargha-Khadem *et al.* 1995:930). Furthermore, empirical studies suggest that “the affected members’ disorder transcends the generation of morphosyntactic rules to include impaired processing and expression of other areas of grammar, grossly defective articulation of speech sounds, and, further, a severe extralinguistic orofacial dyspraxia” (Vargha-Khadem *et al.* 1995:930). This serves to cast doubt on the picture of the KE family mutation as a mutation in one of the genes encoding UG — the impairment may be a consequence of genes encoding for several functions, including language, or may be a consequence of a more general cognitive and physical impairment.

We can also examine how language is acquired by humans, and how languages change in human populations. I will make reference to this type of data later in the thesis, in particular in the closing sections of Chapters 3 and 5. We can also make cross-species comparisons of neural or physiological devices which have been implicated in language, and consequently hypothesise about whether such devices are evolutionary recent or not. Hauser *et al.* (2002) provide an excellent survey of this comparative approach. I will make reference to this type of evidence later in the thesis, in particular with respect to vocabulary acquisition experiments in apes.

Finally, the Nativist account of language offers a fairly straightforward account of creolization. The classic creolization scenario involves a group of individuals with no common language being brought together, typically being forced to live or work together. In such populations, a *pidgin* typically emerges — an ad-hoc system of communication, which borrows vocabulary from the various languages represented in the group (known as the substrate languages), and from the language of the ruling body (the superstrate language). Pidgins are typically highly simplified grammatically, and are tolerant of extreme ranges of grammatical variation. Creolization occurs when children begin to learn pidgins as their first language. Creoles are typically more expressive than pidgins, more elaborate grammatically and exhibit less variation across and within individuals.

Derek Bickerton (Bickerton 1981; Bickerton 1984) further claims that superficially unrelated (and geographically dispersed) creoles exhibit certain common features, and concludes that “creole similarities stem from a single substantive grammar consisting of a very restricted set of categories and processes, which will be claimed to constitute part, or all, of the human species-specific capacity for syntax” (Bickerton 1984:178). The common elements of creole languages (for example, fronting of focussed elements, certain arrangements in the determiner system, handling of tense, modality and aspect by preverbal free morphemes occurring in a certain fixed order), according to Bickerton, are a consequence of a highly specific innate prespecification of language — “The LBH [Language Bioprogram Hypothesis] claims that the innovative aspects of creole grammar are inventions on the part of the first generation of children who have a pidgin as their linguistic input, rather than features transmitted from preexisting languages . . . the LBH claims that the most cogent explanation of this similarity is that it derives from the structure of a species-specific program for language, [which is] genetically coded” (Bickerton 1984:173). In other words, the degenerate nature of the linguistic input available to children in pidgin-speaking communities forces them to fall back on the default grammar encoded in their genes. The fact that these genes are shared by all members of the species means that all creoles share certain features. This suggests that language evolution is primarily a biological process.

Bickerton’s account of creolization and creole universals as reflexes of the default settings of UG is incompatible with the Empiricist position on language, and is also largely incompatible with accounts of language evolution which appeal to a significant role for cultural processes. There are two main strands of argument against it. Firstly, it has been argued (see e.g. Singler (1990)) that there are numerous exceptions to Bickerton’s putative creole universals. Secondly, it has been argued that most of the correspondences between creoles can be attributed to the influence of common substrate (e.g. Holm (1988)) or superstrate (Haspelmath (1989)) languages.

In addition to these disputes over the source of “creole universals”, other studies of creolization suggest that cultural, rather than genetic, processes may play an important role in language genesis. Nicaraguan Sign Language (Kegl & Iwata 1989; Kegl *et al.* 1999) gives us an insight into the birth of a language with a reduction in the confounding factors of substrate and superstrate influence and power asymmetries typically associated with creolization situations. Nicaraguan Sign Language emerged when previously isolated deaf individuals throughout Nicaragua were brought together in schools for the deaf. Prior to arriving at the school, the isolated deaf individuals communicated using idiosyncratic homesign systems. While such systems may exhibit some degree of structure (Goldin-Meadow & Mylander 1990) they are characterised as "idiosyncratic, variable even within the individual, and lacking most characteristics, particularly syntactic, of what we would recognize as a full-fledged human language" (Kegl *et al.* 1999:179). Shortly after arriving at the school these homesigners had developed a shared system of signs and grammatical devices. This shared system developed into a fully-fledged sign language after several years and several influxes of new, typically young, deaf individuals. The use of grammatical devices by deaf individuals shows significant effects for both age of entry into the school and year of entry into the school, with younger individuals entering the school in later years producing the most sophisticated signing.

Based on the emergence of Nicaraguan Sign Language and the failure of groups of deaf individuals to develop full-blown language under different social circumstances, Ragir (2002) argues that "the emergence of new languages, both signed and spoken, depends on: (1) a *critical mass* of individuals generating shared patterns of linguistic practices; (2) historical continuity maintained by a continuous influx of new participants into the language pool; and (3) an exchange of information about diverse cooperative activities".

This suggests that the Language Bioprogram Hypothesis, as simply stated above, cannot be right — if degenerate linguistic input automatically triggered the default, innate grammar then isolated individuals would effectively self-creolize, and we would expect isolated deaf individuals to use sign systems which had the structure of early creoles. The fact that creolization is dependent on a critical mass of individuals and a degree of historical continuity suggests that there must be some factor other than innate knowledge at play in creolization events, and possibly in linguistic evolution in general.

1.4 Theories of language evolution

The (somewhat limited) evidence outlined above, in conjunction with the two major explanatory paradigms for language (Nativist and Empiricist) form the basis for a number of theories of the evolution of language. These can broadly be separated into two groups — *adaptationist* and *non-adaptationist* theories. Adaptation is the process by which an organism changes to fit its environment. Adaptationist accounts emphasise the role of natural selection and what we will (for the moment) call cultural selection in the process of adaptation — pressures acting on genetic and cultural transmission favour organisms which fit, or are adapted for, their environment, such that over time a population of such organisms comes to fit its environment rather well. In the most extreme adaptationist position, every aspect of an organism's behaviour is seen as an adaptation to fit some part of the organism's environment.

Non-adaptationists deemphasise the role of adaptation in explaining characteristics of an organism, preferring to focus on the role of chance events, architectural constraints and exaptation in evolutionary processes. Architectural constraints limit and shape the ways in which organisms develop, due to laws of growth and form (Thompson 1961) or environmental influences on development. These architectural constraints can lead to *spandrels* (a term adapted from architecture by Gould & Lewontin (1979)), where architectural constraints lead to structures which appear to be designed for some purpose, but are in fact not. Exaptation (a term introduced in Gould & Vrba (1982), sometimes replaced with the somewhat more transparent term of "evolutionary reappropriation") is the process by which some aspect of an organism, either a spandrel or an adapted trait, is put to a new use by that organism.

Theories of the evolution of the linguistic capacity and language have appealed to all three of these aspects of evolutionary processes — adaptation, architectural accidents and exaptation. Non-adaptationist accounts, viewing the capacity for language as a spandrel or an exapted trait, will be reviewed first, in Section 1.4.1, in part because such accounts have found favour with influential figures in linguistics. Adaptationist accounts, which appeal to both biological adaptation of the language capacity and cultural adaptation of language, will be reviewed in Section 1.4.2.

1.4.1 Non-adaptationist accounts

The non-adaptationist accounts reviewed here cover a fairly wide spectrum. Chomsky and Piattelli-Palmarini view the language capacity as a spandrel. Bickerton views it as a trait arising either through chance events, such as a saltationary mutation or a fluke of ontogeny, or, in his later account, as an exaptation. Lieberman and Wilkins & Wakefield view the capacity for language (as distinct from the capacity for speech) as an exaptation of neural machinery for motor control, whereas Tomasello sees language as a consequence of a more general capacity for cultural transmission.

Chomsky Noam Chomsky, the founder of the theory of innate UG, has been notoriously reluctant to offer an account of the origins of this innate and language-specific organ of the human mind. According to Chomsky, "it is safe to attribute this development [of UG] to 'natural selection', so long as we realize that there is no substance to this assertion, that it amounts to nothing more than a belief that there is some naturalistic explanation for these phenomena" (Chomsky 1972:97). Chomsky's preferred explanation for the origins of UG is dependent on as-yet-unknown laws of growth and form:

> "The answers may well lie not so much in the theory of natural selection as in molecular biology, in the study of what kinds of physical systems can develop under the conditions of life on earth" (Chomsky 1988:167)
>
> "We know very little about what happens when 10^{10} neurons are crammed into something the size of a basketball, with further conditions imposed by the specific manner in which this system developed over time. It would be a serious error to suppose that all properties, or the interesting properties of the structures that evolved, can be 'explained' in terms of natural selection." (Chomsky 1975:59)
>
> "Language is off the chart. That is the basic conclusion that follows from his [Hauser's 1996] comprehensive review of comparative communication. That doesn't mean that language is not the result of biological evolution, of course we all assume it is. But what kind of result of biological evolution? ... It is simply not understood how the physical channel constrains and controls the process of selection, beyond simple cases ... there is no way to find the answer, not just for language but for cognition altogether. Others feel that they can do something. But telling stories is not very instructive. You can tell stories about insect wings, but it remains to discover how they evolved." (Chomsky 2002:Chapter 4)

While these points have some merit, taking them fully to heart essentially rules out any attempt to explain the evolution of the language faculty. Indeed, Chomsky's position has been been criticised as "a retreat to mysticism" (Jackendoff 2002:234). Recently (Hauser *et al.* 2002) Chomsky's position has softened somewhat and he acknowledges the potential role of cross-species comparison as a test on, and possible source of insight into, theories of language evolution.

Piattelli-Palmarini Piattelli-Palmarini (1989) is somewhat ambivalent between spandrel and exaptation accounts of the capacity for language — "innate, very specific, and highly abstract structures governing language and cognition may be seen as 'spandrels', that is, biological traits that have *become* central to our whole existence, but which may well have arisen for some purely architectural or structural reason ... or as a by-product of evolutionary pressures driven by other functions" (Piattelli-Palmarini 1989:19). He supports this position with an argument based on the fact that language could be other than it is, and still be adaptive:

> "Even if a trait *is* useful and actually enhances the life expectancy of individuals who possess it, this fact does *not* grant the inference that the trait is there *because* it is useful . . . Adaptive constraints are typically insufficient to discriminate between real cases and an infinity of alternative, incompatible mechanisms and traits which, although abstractly compatible with the survival of a given species, are demonstrably absent. This applies, and with bells on, to perfectly adaptive linguistic structures that could ideally have been present, but which are, as a matter of fact, wrong for *us* . . . linguistic principles are all, obviously, compatible with our survival, but they are not uniquely (nor, for that, even approximately) 'determinable' under the adaptationist constraint *alone*" (Piattelli-Palmarini 1989:18–19).

Pinker & Bloom (1990) identify two possible responses to Piattelli-Palmarini's point that other forms of language might be equally functional. Firstly, they argue that all adaptations are compromises between a variety of constraints, therefore the purpose of an adaptation may not be obvious when considered from the perspective of a single constraint. Secondly, and perhaps more tellingly, they point out that "many 'arbitrary' constraints may have been selected simply because they defined parts of a standardized communicative code in the brains of some critical mass of speakers" (Pinker & Bloom 1990:718). Certain "perfectly adaptive linguistic structures" might not be present simply due to historical contingencies, reinforced by the need for something approximating consensus among language users.

We might take a weakened version of Piattelli-Palmarini's position on board, and concede that some aspects of the design of the language faculty are constrained by considerations such as architecture, costs and so on. Indeed, not to do so would be somewhat ridiculous — as Maynard Smith has pointed out "[i]f there were no constraints on what is possible, the best phenotype would live for ever, would be impregnable to predators, would lay eggs at an infinite rate, and so on" (Maynard Smith 1978:32). Piattelli-Palmarini's point is therefore not as forceful as he obviously feels. It is weakened still further by an obvious confusion in his argument. In the very same paragraph he claims that "*Only* those who espouse an *instructivist* [transfer of structure from the environment to the organism, i.e. learning] paradigm are in need of direct adaptive constraints. If, on the contrary, one adheres to the thesis of strong innatism, adaptive constraints become *ipso facto* weak, trivial and theoretically irrelevant" (Piattelli-Palmarini 1989:19). This appears to be a non-sequitur "with bells on". Previously we were dealing with the evolutionary history of UG, either a history of exaptation or adaptation. In a strongly innatist position these can either be exapted or adapted — there is nothing that rules out adaptation of the LAD in the strongly innatist position, although Piattelli-Palmarini would prefer that we did. Piattelli-Palmarini then switches to dealing with adaptive constraints on language *acquisition*. Adaptive constraints on *learning* in the strongly innatist position are, by definition, irrelevant, as in the scenario Piattelli-Palmarini envisages there is no such thing as learning — "we would gain in clarity if the *scientific* use of the term were simply discontinued" (Piattelli-Palmarini 1989:2). However, there is no need for adaptationists to appeal to adaptive constraints on learning — some do, but others might favour Piattelli-Palmarini's discontinuation of the term altogether yet still feel that the innate UG arose through adaptation.

One more criticism of Piattelli-Palmarini's position should be noted. Piattelli-Palmarini is a strong innatist, meaning, among other things, that he views the language capacity as language-specific. However, he prefers an exaptationist account of this language capacity to an adaptationist account. Exaptation, by definition, cannot apply to an apparatus which can serve only one purpose, therefore Piattelli-Palmarini should abandon either his exaptationist account or his language-specificity constraint. Similarly, it is not clear that a spandrel could be said to be specific to one function, since spandrels are, by definition, not "for" any function at all.

Bickerton Bickerton provides an account of the evolution of the language faculty which is, at one level, an adaptationist account. However, Bickerton's early formulation of the account appeals to a single macro-mutation delivering much of the language faculty, while his later accounts become more exaptationist in flavour.

Bickerton's original account (Bickerton 1990) proposes that there was, prior to language, an agrammatical protolanguage[3], the capacity for which possibly evolved due to selection pressures arising from group foraging activities (Bickerton 2002). Mutation of a single gene then delivered, from the base of protolanguage, the capacity for full-blown modern language, including the capacity for syntax and the modern human vocal tract. This gene was then fixed in the population by means of natural selection.

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[3] Bickerton claims that we see evidence of this protolanguage in children under two, pidgin speakers and signing apes. However, the content of protolanguage and the various pros and cons of the proposal are not, for our purposes, of great relevance to the remainder of Bickerton's account.

The early formulation of Bickerton's proposal is somewhat naive. As Hauser (1996) notes, relatively simple physical attributes are encoded in multiple genes. The odds seem to be against a single gene which encodes a fairly sophisticated language faculty and, entirely coincidentally, the appropriate vocal apparatus to make efficient use of this neural architecture. Depending on one's interpretation of the evidence on "language genes" provided by the studies of the KE family, this either proves that the language faculty is coded in multiple genes, or that a single "language gene" would at least require that other general intelligence or speech genes be set up appropriately.

Bickerton (1998) abandons the macro-mutation account for the transition from protolanguage to language, but his account remains saltationary. Bickerton proposes that some of the necessary neural apparatus for language — mental apparatus dealing with theta analysis[4] and motor control of the (not fully modern) vocal tract — were present in the brains of protolanguage users, but unconnected. Through ontogenetic chance (formation of connections between the two areas) these areas became connected in the brains of certain individuals, resulting in the possibility of conceptual structure being imposed on the production of protolanguage, giving us the capacity for language. Bickerton proposes that "the linkage of theta analysis with other elements involved in protolanguage would not merely have put in place the basic structure of syntax, but would also have led directly to a cascade of consequences that would, in one rapid and continuous sequence, have transformed protolanguage into language substantially as we know it today" (Bickerton 1998:353). Bickerton suggests some of these consequences might include the evolution of the modern human vocal tract and development of further neurological apparatus for language processing and storage. Bickerton therefore views the emergence of the language capacity as a process of exaptation followed by adaptation. However, the burden of the account still falls on the initial exaptation of resources used in protolanguage, facilitated by unspecified phylogenetic or ontogenetic factors which allowed the theta analysis component of the brain to connect to the vocal motor control areas. Bickerton offers no detailed explanation for this initial exaptation, although Wilkins & Wakefield (1995), discussed below, offer a possible account compatible with Bickerton's.

Bickerton (2000) retreats from this analysis. He reasons that protolanguage would be used for discussing past events, therefore we should expect it to have had access to thematic roles via memory. Secondly, he claims that all brain regions are linked to one another, therefore the tightly modularised separation of the theta analysis component and vocal motor component would not exist. Bickerton therefore suggests that these areas

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[4] Which can be characterised for the purposes of Bickerton's argument as "who did what to who with what".

of the brain were linked in the protolanguage-capable brain, but could not communicate with one another due to a lack of “signal coherence” resulting from the small number of neurons in the pre-human brain. Bickerton proposes that increases in brain size overcame this signal coherence, allowing the regions of the brain responsible for theta analysis to impose structure on motor output. The syntactic brain was born, followed by the familiar avalanche of consequences, which Bickerton now proposes include canalization of learned behaviours via the Baldwin effect. Once again, this is essentially an exaptationist account (exaptation of resources resulting from increased brain size), with subsequent adaptive change.

Hurford (2002b) criticises Bickerton’s 1998 and 2000 efforts, not on the vagueness of the mechanisms appealed to (although this does merit comment in passing) but on the assumption that theta analysis areas, when wired up to vocal motor areas, gives rise straightforwardly to clausal structure, and the rest of syntactic structure follows trivially. Hurford identifies several features of language (for example, duality of patterning, the morphology-syntax distinction, case marking, anaphor-antecedent relationships, and passivization) which play no role in pre-linguistic representation but could reasonably be argued to play a role in communication over a noisy serial channel. Hurford’s point is that syntax, and linguistic structure more generally, is not just theta analysis with a flourish, but a system which exhibits the appearance of design for communicating complex structures over a serial channel. While Bickerton could reply that he allows time for such aspects of language to emerge during the “cascade of consequences”, if there is much more to language than theta analysis then Bickerton’s account has simply covered the simplest aspect of its emergence and paid lip-service to subsequent processes.

Lieberman Classifying the work of Philip Lieberman as adaptationist or exaptationist is a somewhat fraught exercise, partly due to the difference in focus of Lieberman’s work from the other theories outlined here. While the other non-adaptationists are primarily concerned with the (non)evolution of UG as it pertains to syntax, Lieberman’s main focus is on speech, which is a peripheral matter in the Chomskyan paradigm. Lieberman takes a classically adaptationist position on the evolution of the physiological and neurological bases of speech — “all primates are furthermore adapted for phonation at the expense of respiratory efficiency. Anatomically-modern *Homo sapiens* continues this trend toward more efficient vocal communication” (Lieberman 1984:324–325).

However, Lieberman views the capacity of the human brain for language, meaning essentially syntax, as an exapted trait: “the rules of syntax derive from a generalization of neural mechanisms that gradually evolved in the motor cortex to facilitate the automatization of motor activity [for tool use in (Lieberman 1984), bipedal locomotion and tool use in (Lieberman 2000)]. Human syntactic ability, in this view, is a product of the Darwinian mechanism of preadaptation" (Lieberman 1984:67). In this respect, taking the Chomskyan grammar-centric view of language, Lieberman is a non-adaptationist. Language only arises through the combination of the adapted speech mechanism and the exapted trait: "The synergetic effect of rapid data transmission through the medium of encoded speech and the cognitive power of the large hominid brain probably yielded the full human linguistic system" (Lieberman 1984:329)

Unlike Chomsky and Piattelli-Palmarini, but in common with Bickerton, Lieberman allows for some post-exaptation adaptation of the syntactic capacity:

> "As the central cognitive mechanism, the brain, gradually increased its power, the selective advantage of peripheral input-output mechanisms like human speech also would have increased . . . The presence of a fully encoded speech system in recent hominids may also have more directly contributed to the development of complex syntactic organization in human languages." (Lieberman 1984:325)

Lieberman's treatment of the evolution of the human vocal apparatus is very thorough, and supported by a degree of evidence not seen in the other accounts of the evolution of language. However, his treatment of syntax is somewhat threadbare. Lieberman's statement that syntax is simply a generalisation of motor control falls foul of Hurford's (2002b) criticism of Bickerton — if language is not simply slightly elaborate theta analysis, nor is it a generalisation of movement. Lieberman could mount a similar defence to Bickerton, that the aspects of language which Hurford discusses arose during the period of adaptation following the exaptation event. However, Lieberman also fails to offer more than a hand-waving explanation of how the "synergetic effect" of a large brain and apparatus capable of rapid data transmission would lead to even the rudiments of language.

Tomasello Michael Tomasello's theories on the cultural evolution of language will be expounded in more detail in Chapter 2. Tomasello's full account of the evolution of language is exaptationist, with a heavy focus on cultural processes resulting from the proposed exaptation. Tomasello suggests that the key adaptation:

> “arose at some particular point in human evolution, perhaps fairly recently, presumably because of some genetic and natural selection events. This adaptation consists [of] the ability and tendency of individuals to identify with conspecifics in ways that enable them to understand those conspecifics as intentional agents like the self, possessing their own desires and beliefs. This new mode of understanding other persons radically changed the nature of all types of social interactions, including social learning, so that a unique form of cultural evolution began to take place over historical time, as multiple generations of developing children learned various things from their forebears and then modified them in a way that led to an accumulation of these modifications” (Tomasello 1999:202)

This exaptationist account is somewhat different from the accounts propounded by Piattelli-Palmarini and Bickerton. For Piattelli-Palmarini the mental capacity for language is a spandrel, but is language specific. Cultural processes play no role in his model. For Bickerton, in his later accounts at least, the language capacity is exapted from the protolanguage capacity (possibly with additional exaptation of resources resulting from an increase in brain size), is language-specific and results in consequential evolution, some of which might involve (minimally) cultural processes. For Tomasello, the capacity to view others as intentional agents is a general cognitive ability, rather than being language-specific, and results in consequences which are driven by purely cultural processes.

Wilkins & Wakefield The final non-adaptationist account of the origins of the human capacity for language differs somewhat in perspective from the others. Wilkins & Wakefield (1995) deal with the processes which lead up to a cognitive capacity which could be reappropriated by language, rather than assuming such an apparatus and dealing with the post-exaptation scenario.

Wilkins & Wakefield present an account under which Broca’s area and the parieto-occipito-temporal junction (POT), which includes Wernicke’s area, are necessary elements of a brain supporting language. Auditory, visual and somatosensory inputs are initially processed in unimodal association areas of the cortex. These unimodal representations then converge to form multi-modal representations of sensory input. Finally, these multi-modal representations converge at the POT — “[t]he POT is, in essence, an area of integration for the three neocortical sensory association areas . . . the ‘association area of association areas’ ” (Wilkins & Wakefield 1995:163). Wilkins and Wakefield argue, following an idea originally suggested by Geschwind (1964), that this capacity to form amodal representations is crucial to the capacity to acquire lexical items.

Following Tallal & Schwartz (1980) and Greenfield (1991), Wilkins & Wakefield suggest that Broca's area is responsible for temporal sequencing and hierarchical organisation of information. In the human brain, the POT and Broca's area are connected by a large, myelinated fibre tract, allowing information to pass between them rapidly. In their account, Broca's area hierarchically structures the amodal representation of the outside world, resulting in the development of a featural, amodal, hierarchical representation — an abstract, structured semantic representation. A similar process allows auditory or visual input to become associated with these amodal concepts — arbitrary symbolic reference becomes possible.

Wilkins & Wakefield make a case that this organisation of the human brain arose, not through selection pressures related to communication, but through pressure for improved motor skills required to fashion and use tools such as throwing stones, which have obvious uses in hunting. Skilled motor control requires larger amounts of motor cortex and somatosensory cortex devoted to controlling the hand. The necessary feedback between somatosensory cortex and motor cortex resulted, in Wilkins & Wakefield's account, in selection pressure for rapid transfer between these two physically distant regions of the brain, which in turn led to the formation of the bidirectional, myelinated fibre bundle connecting sensory to motor cortex (including Broca's area). There is some neurophysiological evidence to support this association between the evolution of motor cortex and somatosensory cortex — "each architectonic subdivision of the sensory association cortex is directly and reciprocally connected to the subdivision of motor association cortex with which it shares an equivalent state of evolutionary differentiation" (Wilkins & Wakefield 1995:174). Concurrent expansion of the visual cortex and the temporal lobe resulted, due to the close proximity of the three posterior lobes, in an overlap of the information flowing through each lobe, and the POT junction formed. Evidence for this account is provided in the archaeological record, which shows that stone tools began appearing at a time coincident with the appearance of *Homo habilis* (Harris 1983), while sulcal patterning on fossil endocasts suggests that *habilis* possessed the POT and a modern Broca's area. However, the interpretation of endocasts is controversial, as Wilkins & Wakefield acknowledge. Ralph Holloway notes in his commentary on Wilkins & Wakefield's article that "there is not one single well-documented instance of paleoneurological evidence that unambiguously demonstrates a relative expansion of the parietal-ocipital-temporal junction in early *Homo*" (Holloway 1995:191).

Wilkins & Wakefield therefore present a scenario under which selectional pressures for tool use lead to the appropriate neural and cognitive apparatus for language. Their account of how language exapted these facilities is speculative, although they offer:

> "As is well known, primates are noisy animals . . . It is not unreasonable to assume that *H. habilis* too were noisy animals, with a systematic repertoire of calls. It also seems reasonable to think that a habiline child might have recruited from this call repertoire to create a linguistic sign . . . These acoustic signals, simply part of the primate call system for the adult vocaliser, might have taken the form of linguistic signs in the mind of the child" (Wilkins & Wakefield 1995:179).

1.4.2 Adaptationist accounts

In contrast to these non-adaptationist explanations of the evolutionary origins of the faculty for language in humans, several adaptationist accounts have been advanced. These accounts appeal to the biological adaptation of the human species in response to the pressure to communicate, or the cultural adaptation of languages to pressures to be expressive or learnable.

Pinker & Bloom Pinker & Bloom (1990) present the classic adaptationist account of language. Working within the Chomskyan framework of UG, Pinker & Bloom suggest that "the ability to use a natural language belongs more to the study of human biology than human culture: it is a topic like echolocation in bats" (Pinker & Bloom 1990:707). Their position is that language exhibits the appearance of design and is supported by an innate UG, therefore the origins of UG must explicable in terms of natural selection.

What is language designed for? According to Pinker & Bloom, language is adapted for the communication of propositional structures (in the internal representational "language of thought") over a serial channel. Pinker & Bloom identify a dozen features of language which they argue exhibit the appearance of design for this function. For example, they argue that major lexical categories are used to distinguish basic ontological categories, phrase structure and overt case marking provide surface cues to the structure of the underlying propositional representations, and verb affixes signal temporal aspects of events.

Pinker & Bloom go on to identify scenarios where language exhibiting these design features might offer a selective advantage. They propose that the hunter-gatherer lifestyle hypothesised to characterise our recent evolutionary predecessors would favour an ability to communicate information about toolmaking, ecology and the behaviour of plants and animals. "Devices for communicating precise information about time, space, predicate-argument relations, restrictive modification, and modality are not wasted in such efforts" (Pinker & Bloom 1990:724). Secondly, they emphasise the value of language in supporting social interactions, which put "a premium on the ability to convey such socially relevant abstract information as time, possession, beliefs, desires, tendencies, obligations, truth, probability, hypotheticals, and counterfactuals . . . Furthermore, in a group of communicators competing for attention there is a premium on the ability to engage, interest and persuade listeners. This in turn encourages the development of discourse and rhetorical skills and the pragmatically relevant grammatical devices that support them" (Pinker & Bloom 1990:725). According to Pinker & Bloom, UG evolved as a direct consequence of the payoff it provided in relation to these communicative functions.

Jackendoff Jackendoff (2002) offers what is essentially an elaboration of the position of Pinker & Bloom (1990) that the language faculty arose through natural selection. Jackendoff focuses on possible stages in the evolution of the language faculty, following Pinker & Bloom in assuming that any increase in expressive power or precision will offer selective advantages. Jackendoff is not concerned with the ecological context in which such adaptations might have arisen, or how innovations would spread through populations, although he "agree[s] with practically everyone that the 'Baldwin effect' had something to do with it" (Jackendoff 2002:237).

Jackendoff's schedule for the evolution of language is depicted in Figure 1.3 (based on Jackendoff (2002), Fig 8.1, p238). There are several points worth noting. Firstly, Jackendoff views the human language faculty as having evolved out of preexisting primate conceptual structure *and* primate call systems — his first step on the path to language is the step from stimulus-bound to stimulus-free signalling. Secondly, cultural transmission is implied in Jackendoff's second step, to use of an open vocabulary. Thirdly, Jackendoff's account is clearly influenced by Bickerton's notion of a protolanguage intermediate between primate communication and modern language, but differs from it in the respect that, for Jackendoff, protolanguage exhibits the very beginnings of syntax. The transition to using symbol position to convey basic semantic relationships occurs prior to the protolanguage stage, whereas for Bickerton at the protolanguage stage words are "randomly concatenated" (Bickerton 1998:349).

Dor & Jablonka Dor & Jablonka (2000) provide a version of the adaptationist argument which differs from that offered by Pinker & Bloom (1990) and Jackendoff (2002) in the degree of focus on cultural processes. For Pinker & Bloom and Jackendoff the evolution of language is basically due to the evolution of the language faculty via biological evolution, possibly with the Baldwin effect playing some poorly specified role. Dor & Jablonka bring the role of cultural innovation followed by genetic assimilation to the fore, in what they call "the evolutionary spiral".

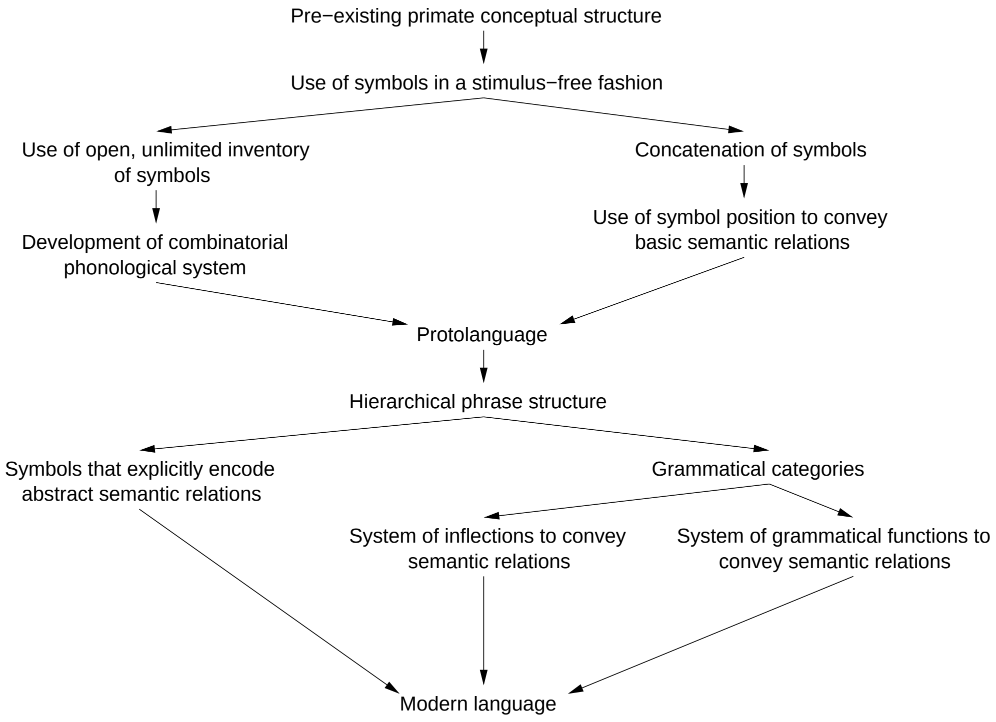

Figure 1.3: Jackendoff's schedule for the evolution of language. Necessary preadaptations appear on top of subsequent adaptations. Adaptations which are logically independent appear side by side.

Dor & Jablonka suggest a scenario where a hominid community uses some culturally-transmitted communication system which is subserved by a genetically-encoded propensity to acquire such a system. Note that Dor & Jablonka consider culturally-transmitted communication systems to be common in mammals, despite the view expressed by Hauser (Hauser (1996), discussed in Section 1.1.2) that this is not the case. In this population, linguistic innovations such as "new lexical items for specific referential meanings ... some more abstract markers for existing and novel conceptual distinctions ... new pragmatic conventions for linguistic communication" (Dor & Jablonka 2000:49) came about, through teleological processes, as a result of pressure to improve communication. Such useful innovations then spread through the population. "Crucially ... the establishment of the innovation also raised the demands for social learning imposed on individuals in the community ... the linguistic innovations which established themselves in the community changed the social niche, and the inhabitants of this new niche had to adapt to it" (Dor & Jablonka 2000:50). According to Dor & Jablonka this adaptation occurred through genetic assimilation, with a genetic endowment which permitted easier language acquisition spreading through the population. The process then repeats with further innovations and so on.

This scenario is opposed to that proposed by Deacon, whose account I present below. Dor & Jablonka also put a strong emphasis on the role of conscious, functionally-motivated innovation in shaping language, an issue which I will return to in Chapter 2 in connection with Tomasello's account of cultural evolution.

Deacon Deacon (1997) presents an adaptationist account which differs from the accounts of Pinker & Bloom and Jackendoff in placing relatively little emphasis on the biological evolution of the language faculty and more emphasis on cultural processes. His account is therefore superficially somewhat similar to that of Dor & Jablonka, but makes entirely different predictions.

Deacon identifies the enlarged prefrontal cortex of the human brain as the key biological component of language — "[t]he contributions of prefrontal areas [of the cortex] to learning all involve, in one way or another, the analysis of higher-order associative relationships . . . These are the most critical learning problems faced during symbol[5] acquisition" (Deacon 1997:264). Deacon regards this aspect of brain morphology as a consequence of language, rather than an exapted trait:

> "The remarkable expansion of the brain that took place in human evolution, and indirectly produced prefrontal expansion, was not the cause of symbolic language but a consequence of it. As experiments with chimpanzees demonstrate, under optimal training conditions they are capable of learning to use a simple symbol system. So, it is not inconceivable that the first step across the symbolic threshold was made by an australopithecine with roughly the cognitive capabilities of a modern chimpanzee, and that this initiated a complicated history of back-and-forth escalations in which symbol use selected for greater prefrontalization, more efficient articulatory and auditory capacities, and probably a suite of other ancillary capacities and predispositions which eased the acquisition of this new tool of communication and thought. Each assimilated change enabled even more complex symbol systems to be acquired and used, and in turn selected for greater prefrontalization, and so on." (Deacon 1997:340)

Deacon suggests that the fitness advantage of symbolic communication is due to the type of social and communicative benefits outlined in Pinker & Bloom (1990). So far, then, this is a fairly minor modification to the theory proposed by Pinker & Bloom. Deacon,

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[5] Deacon's definition is somewhat different from the definition I have adopted.

however, places heavy emphasis on the cultural evolution of language itself, resulting from the pressure on language during cultural transmission:

> "The structure of a language is under intense selection because in its reproduction from generation to generation, it must pass through a narrow bottleneck: children's minds . . . Language operations that can be learned quickly and easily by children will tend to get passed on to the next generation more effectively and intact than those that are difficult to learn. So, languages should change through history in ways that tend to conform to children's expectations." (Deacon 1997:110)

Under this view, the apparent innate endowment of humans to acquire language in the face of the poverty of the stimulus is merely an illusion, induced by the focus on language as a facet of individual psychology, rather than a culturally-transmitted adaptive system: "Human children appear preadapted to guess the rules of syntax correctly, precisely because languages evolve so as to embody in their syntax the most frequently guessed patterns. The brain has co-evolved with respect to language, but languages have done most of the adapting" (Deacon 1997:122).

This last sentence highlights the difference between the positions of Deacon and Dor & Jablonka — for Dor & Jablonka, the genetic makeup of a population changes to match the population's language, whereas for Deacon the onus is on a population's language to change to match the population's acquisition abilities. Deacon's position is also counter to that of Jackendoff, who states that "the limited number of possible choices to which children are constrained had better be the *right* ones, otherwise they won't learn" (Jackendoff 2002:84). One consequence of Deacon's view of language itself as an adaptive entity is that the choices children are constrained to are *guaranteed* to be the right ones, because language adapts to fit them.

1.5 Formal models

The brief review of theories of language evolution outlined above reveals several problems. Firstly, as indicated by the rough classification of theories as either non-adaptationist or adaptationist, there is a fairly fundamental disagreement as to whether the evolution of language can be explained in terms of properties of language itself, as the adaptationists have it, or in terms of some other properties of humans or processes of human evolution, as the non-adaptationists have it. Secondly, there tends to be a disagreement about what the evidence actually means — for example, Lieberman and Deacon both allow chimpanzees some modest language-like capacity, but while Lieberman presents this as evidence of his exaptationist account of a capacity for syntax, Deacon presents it as a gateway into an adaptationist account of language evolution. Similarly, dependent on one's interpretation of the KE family "language gene" evidence, it can be taken as indicating the presence of a genetically-encoded language faculty or the dependence of language on other, more general, cognitive abilities.

These two problems are not unique to the field of language evolution. Biologists have had a similar debate about the limits of adaptationism and the role of exaptation with respect to the evolution of traits in general, and the evidence in most fields of scientific enquiry is somewhat susceptible to interpretation. There is, however, a third problem exemplified in this review which I intend to address in this thesis.

All the theories outlined above are purely verbal — the authors of each theory present the evidence which they feel supports their theory and develop their theories in ways which seem most consistent, both internally and with the evidence. Problems arise when competing theories rely on approximately the same premise, but make rather different predictions. For example, Bickerton and Jackendoff both present theories which include a protolanguage phase. For Bickerton, once semantic relationships begin to impinge on the ordering of surface forms language emerges in a fairly straightforward, and for Bickerton fairly non-interesting, process. For Jackendoff, the ordering of constituents in protolanguage is already influenced by semantic considerations, but there is still a great deal to be explained. As another example, Dor & Jablonka and Deacon agree that cultural and genetic processes play a part in the evolution of language. However, Dor & Jablonka predict that genes will adjust to accommodate language, whereas Deacon predicts that language will accommodate the learning biases encoded in the genes. There is no way to tell which theory is more plausible, given that both are based on purely verbal reasoning and both appear to be internally consistent. The problem is that our intuitions about how complex dynamical processes, such as the gene-culture transmission of language, will unfold are notoriously poor.

Formal models can be a powerful tool for conducting this kind of "opaque thought experiment" (Di Paolo *et al.* 2000). Firstly, constructing a formal model can reveal whether the consequences of a proposed interaction are as predicted. Secondly, formal models help to identify which parts of the behaviour of a system rest on which assumptions — to give a hypothetical example, a formal model might reveal that Deacon is correct (and Dor & Jablonka are wrong) that cultures adapt to genes, given the assumption that the process of cultural evolution is ten or more times faster than genetic evolution. The extent to which these assumptions match up with the theoretical background and empirical evidence then gives a measure of the value of the theory underlying the formal model — to continue the example above, if there were good theoretical and empirical reasons for assuming that cultural evolution is always at least 50 times faster than biological evolution, the formal model would tend to support Deacon's position against that of Dor & Jablonka. Formal models allow a degree of rigour to be brought to the study of the evolution of language.

1.6 Guide to the thesis

The rest of this thesis is devoted to the discussion and development of formal models of language evolution, and the extrapolation from these models to theories of language evolution. I will focus in particular on the evolution of symbolic vocabulary and compositional structure. Much of this thesis will attempt to explain these aspects of language in terms of the cultural adaptation of language itself to pressures acting during the cultural transmission of linguistic form — symbolicism and compositionality are a consequence of cultural transmission. I will also investigate how biological evolution of learning apparatus can impact on this cultural evolution. In this respect, much of this thesis is an elaboration of Deacon's position that "[h]uman children appear preadapted to guess the rules of syntax correctly, precisely because languages evolve so as to embody in their syntax the most frequently guessed patterns. The brain has co-evolved with respect to language, but languages have done most of the adapting" (Deacon 1997:122).

In Chapter 2 I will review general and language-specific models of cultural transmission. This will form the basis for Chapter 3, in which I describe computational models which shed light on the learning biases necessary to support a culturally-transmitted symbolic vocabulary. In Chapter 4 I then investigate how these learning biases might have evolved. In Chapter 5 I turn to the cultural evolution of compositional structure, and identify two pressures which lead to the emergence of compositionality. These pressures arise from the poverty of the stimulus problem and a particular bias in learners. In Chapter 6 I model the evolution of this learning bias. Finally, in Chapter 7 I draw conclusions from the research outlined in this thesis, and highlight potential areas in which my general approach could be expanded.