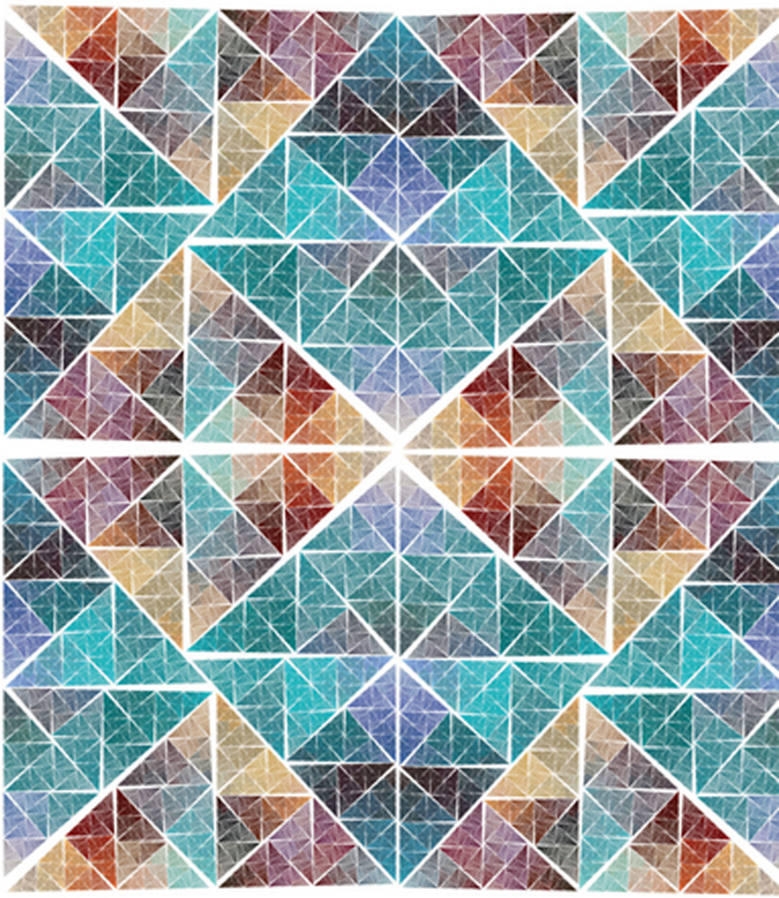
The Handbook of **Language Emergence**



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The Handbook of Language Emergence

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Introduction

Language Emergence

BRIAN MACWHINNEY

1. Introduction

This handbook presents 27 chapters covering a wide variety of topics in the study of human language. The core idea uniting all of this work is that alternative levels of linguistic structure emerge from patterns of usage across time. Emergentist analyses of this type are grounded on three core frameworks deriving from adaptive systems theory. The first is the Darwinian theory of evolution based on proliferation, competition, and selection. The second is the analysis of complex systems as structured hierarchically into levels, such that the properties and structures of higher levels of complexity are not fully predictable from properties on lower levels. The third is the theory of timeframes that holds that processes on different levels are linked to very different timescales that mesh together through competition in the present. These three frameworks are not unique to linguistic analysis. In fact, they are fundamental to scientific investigation of all physical, biological, and social processes.

This introduction contains five parts. First, we will describe how these three frameworks apply to the study of language. Second, we will consider how the overall emergentist framework relates to more specific explanatory linguistic frameworks, such as functionalism, cognitive linguistics, connectionism, embodied cognition, usage-based linguistics, and competition theory. Third, we will examine some of the specific emergentist mechanisms postulated by these various formulations. Fourth, we will contrast the program of Emergentism with the program of Universal Grammar (Chomsky, 1965) in terms of their respective analyses of ten core issues. Finally, we will examine how each of the 27 chapters in this volume contributes to our understanding of the overall emergentist program.

2. Frameworks Supporting Emergentism

This section examines the ways in which Emergentism relies on the three frameworks of natural selection, complexity theory, and timeframes.

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2.1 Competition

Competition is fundamental to biological processes. Darwin (1859) showed how the evolution of the species emerges from the competition between organisms for survival and reproduction. The three basic principles Darwin identified are proliferation, competition, and selection. Proliferation generates variation through mutation and sexual recombination. Organisms with different compositions then compete for resources or rewards such as food, shelter, and the opportunity to reproduce. The outcome of competition is selection through which more adaptive organisms survive and less adaptive ones disappear.

The combined operation of proliferation, competition, and selection is the major engine driving change in all biological and social systems. Emergentist approaches to language (MacWhinney, 1999) also view linguistic structures as arising from the processes of proliferation and competition. For the organism as a whole, the fundamental functional pressure is to reproduce. For language, the fundamental functional pressure is to communicate efficiently in ways that allow the listener to efficiently and accurately decipher the message. As MacWhinney, Bates, and Kliegl (1984) noted, "the forms of natural languages are created, governed, constrained, acquired and used in the service of communicative functions." Bates and MacWhinney (1982) noted that this functionalist position can be dissected into three separate claims. The first is that language change across generations is determined by communicative function; the second is that language acquisition in the child is shaped by communicative function; and the third is that language form in real-time conversations is controlled by communicative function. On all three levels, the facilitation of communicative function is viewed as depending on the availability of supporting neural mechanisms.

The handmaiden of competition is cooperation. As Bates and MacWhinney (1982) noted, humans have a great many ideas that they would love to express all at once. But language only allows us to say one thing at a time. One way in which language addresses this problem is by allowing motives to form coalitions. Bates and MacWhinney (1982) analyzed the possible solutions to competition as: (1) peaceful coexistence, (2) divide-the-spoils, and (3) winner-take-all.

We can illustrate these solutions by looking at subject marking in English. In the unmarked active transitive clause, the subject expresses a coalition of motives including agency, perspective, givenness, and topicality. This construction represents *peaceful coexistence* or coalition between the motives, because they all point in the same direction. In the vast majority of cases, these motives do in fact co-occur, yielding the active clause as the dominant form for transitive verbs. Peaceful coexistence depends on natural patterns of co-occurrence in the real world. For example, the properties of solidity, boundary, and firmness tend to co-occur for objects. Similarly, in animals, properties such as agency, movement, warmth, and directed attention all tend to co-occur. When speakers of a language choose to emphasize one of the features in a peaceful coalition over others, the coalition can break down, precipitating a *divide-the-spoils* solution. English uses the passive construction as a way of dividing the spoils between the topic/perspective that wins the main prizes of subject position and agreement and the agent, which is awarded the "consolation prize" of placement in a by-clause. For example, in the sentence *the cat was chased by a dog*, the subject *cat* is the topic and the agent *dog* is placed into the by-phrase. An alternative to the divide-the-spoils approach is the *winner-take-all* solution in which one motivation overrides the others. For English transitive verbs, this solution gives rise to a truncated passive, as in *the cat got chased*. In that construction, the agent is not expressed at all.

2.2 Hierarchical structure

Complexity arises from the hierarchical recombination of small parts into larger structures. For biological evolution, the smallest parts are the genes. For the brain, the smallest parts are the neuronal assemblies that generate competing ideas (Campbell, 1960). In his seminal article entitled "The Architecture of Complexity," Simon (1962) analyzed higher-level cognitive processes as hierarchically structured combinations of elementary information processes. These elementary pieces are configured in modules whose structure is (only) partially decomposable.

2.2.1 A simple example These basic architectural principles can be illustrated by the four levels of structure that emerge during protein folding (MacWhinney, 2010b). In this process, the *primary structure* of the protein is determined by the sequence of amino acids in the chain of RNA used by the ribosome as the template for protein synthesis. This sequence conveys a code shaped by evolution; but the physical shape of a specific protein is determined by processes operating after initial RNA transcription. The next structure to emerge is a *secondary structure* of coils and folds created by hydrogen bonding across the amino acid chain. These forces can only impact the geometry of the protein once the primary structure emerges from the ribosome and begins to contract. After these second structures have formed, a *tertiary structure* emerges from hydrophobic reactions and disulfide bridges across the folds and coils of the secondary structures. Finally, the *quaternary structure* derives from the aggregation of polypeptide subunits based on the ternary structures. It is this final structure that allows each protein to serve its unique role, be it oxygen transport for hemoglobin or antigen detection for antibodies. In this partially decomposable emergent system, each level involves a configuration of components from lower levels, but the biochemical constraints operative on each level are unique to that level and only operate once that level has emerged during the process of folding. If a given protein operates successfully, it promotes the adaptation of the whole organism, eventually leading to evolutionary selection for the DNA sequence from which it derives. This can be viewed as a type of backwards or downwards causality between levels (Andersen, Emmeche, Finnemann, and Christiansen, 2000).

2.2.2 Epigenesis Our bodies are formed from the proteins that emerge from patterns in the genome. However, the actual work of triggering the construction of the right proteins for the right structures is determined by epigenesis, which involves the expression of patterns in the DNA at particular times in particular tissues during development, both before and after birth. The human genome contains 3 billion base pairs. The human genome has only 20,000 protein-coding genes, and over 98% of the genome is dedicated to sequences controlling gene expression during epigenesis. The informational content of DNA is simply too small to fully specify the shapes of the many complex structures in the human body. Instead, we can view the genes as providing control parameters that serve as specific constraints on local processes of self-organization (Kelso, 1995; Murray, 1988). Although DNA itself only responds to environmental pressures through natural selection, epigenetic processes are highly sensitive to the actual configuration of body parts during both embryogenesis (Fernandez-Sanchez, Serman, Ahmadi, and Farge, 2010) and later tissue replacement (Chan, Hinz, and McCulloch, 2010).

In terms of complexity theory, what this means is that the hierarchy of structures emerging from the four levels of protein folding interlocks with an emergent hierarchical structure for individual tissues. Within the brain, gene expression is heavily dependent on induction by local structures (human.brain-map.org). The complexity achieved by the interlocking of the basic hierarchical code with additional hierarchical structures during epigenesis is enormous.

2.2.3 Interlocking linguistic hierarchies These principles of elementary units, partial decomposability, level-specific constraints, and backwards causality also apply to the study of language, where the interactions between levels and timeframes are so intense. For language, there are six major, partially independent, hierarchies: auditory phonology, articulatory phonology, lexicon, syntax, embodied roles, and communicative structure. Each of these systems is represented in partially distinct neuronal areas (MacWhinney, 2009), and each displays hierarchical composition between levels. For example, lexical items are composed of syllables that are then further grouped into prosodic feet to produce morphemes. Morphemes (Racz et al., chapter 5, this volume) can be combined to produce compounds, derivations, and longer formulaic strings (Sidtis, chapter 26, this volume). Articulatory form is composed hierarchically from motor commands that are grouped into gestures (Donegan, chapter 1, this volume) that eventually produce syllabic structures. Syntactic patterns can be coded at the most elementary level in terms of item-based patterns, which are then grouped on the next level of abstraction into constructions, and eventually into general syntactic patterns. At the most elementary level, communicative structures involve speech acts that can then be grouped into adjacency pairs from which higher-level structures such as topic chains and narrative structures can emerge. Each of these hierarchies is tightly linked to others. For example, syntax and lexicon are linked on the level of the item-based pattern and also in terms of the local organization of parts of speech in the lexicon (Li, Zhao, and MacWhinney, 2007). Given the interactive nature of these interlocking hierarchies, full decomposition or reductionism (Fodor, 1983) is clearly impossible (McClelland, 1987). Instead, the primary task of systems analysis is to study the ways in which the various levels and timeframes mesh. Stated in the terms of the Competition Model (MacWhinney, 1987), analysis is a matter of measuring the strength of competing forms or patterns and their interactions during both on-line and off-line processing (Labov, 1972).

2.3 *Timeframes*

To understand the mechanics of pattern combination, we must examine inputs from processes operating across contrasting timeframes (MacWhinney, 2005, 2014a). Broadly speaking, we can distinguish four major timeframes:

1. *Processing*. The timeframe of processing occurs at the moment of speaking. Here, psycholinguists have focused on the neural basis for on-line processing of words and sentences during production and comprehension, whereas conversation analysts have focused on the social basis for the ways in which we take turns and share ideas.

2. *Consolidation*. On-line processing leads to the storage of experiential traces in memory. Some traces last for only seconds, others persist across decades. Memory processes can also support the emergence of higher levels of structure through generalization that vary through the course of a human lifespan.
3. *Social diffusion*. Linguistic forms diffuse through processes of social memesis (Mesoudi, Whiten, and Laland, 2006) across interactional networks. Sociolinguists have shown that the changes triggered by these processes can extend across days or centuries.
4. *Genetic diffusion*. Within timeframes ranging from decades to millennia, we can trace the diffusion and consolidation of genetic support for producing spoken and written language (Arbib, chapter 27, this volume).

For convenience, we refer to these as "timeframes," although it would be more accurate to call them "space-time frames" because they involve both unique spatial configurations and unique temporal configurations. For example, social memesis can arise either within the spatial frame of face-to-face interaction or the spatial frame of communication over the Internet, and differences in these spatial frames can also impact the immediacy of the timeframes involved.

Within each of these four major timeframe divisions, there are many individual timeframes with their own unique ways of achieving processing, consolidation, and diffusion operations on structures at the various linguistic levels. What is crucial is that the structures emerging on all of these timeframes must be able to exert some impact on language use at the moment of speaking. Sometimes, the relevant structures lie dormant for months or years before achieving activation. For example, the *what's X doing in Y* construction found in *what is this fly doing in my soup* (Kay and Fillmore, 1999) only surfaces rarely. When it occurs, it expresses a unique configuration of shock or pretended shock regarding some untoward condition, and either enough social solidarity to withstand the intended irony or else a power differential that allows for expression of some level of disapprobation or even accusation. In order to operate effectively, this pattern must have been consolidated into long-term memory in a way that permits efficient retrieval when this unique situational configuration arises. The various sociolinguistic and affective assignments needed to activate this pattern depend on the computation of the status of personal relations as they have developed across days, months, and years. These computations must then be linked to more immediate practical judgments regarding the unexpected nature of the condition (i.e., the fly in the soup). If the relevant, but rare, preconditions are not fulfilled, we may select a more neutral statement, such as "Oh goodness, there is a fly in my soup."

2.3.1 Timeframes for processing Fluent speech depends on a smooth temporal meshing of multiple neurolinguistic processes, each with its own timeframe. Speech relies on a loop (Feldman, 2006) for the repetitive production of syllables lasting about 150 ms each (Massaro, 1975). MacNeilage (1998) argue that the unmarked CV (consonant–vowel) structure of syllables is homologous with the lip-smacking gesture in other primates. In their frame–content theory, the positioning of the jaw and articulatory closures for the consonant constitutes the "frame" and the positioning of the tongue for the vowel constitutes the "content." The generation of these gestures is controlled by the *pars opercularis* (Bookheimer, 2007). This is the part of the inferior frontal gyrus closest to the motor cortex areas that control the tongue and lips. In a syllable-timed language like Spanish, this circuit produces a clear periodicity of syllabic gestures. We can think of this process as a wheel revolving with a periodicity of 150 ms. However, the output of this first wheel is then further modified by a second wheel that imposes syllabic stress. This second wheel operates not at the timeframe of the syllable, but at the slightly longer timeframe of the metrical foot. The imposition of stress on the syllabic chain can be based either on lexical signals or on conversational emphases. The wheels that drive these syllable-level activations must also be meshed with the wheels that link syntactic and lexical processing. The activation of words in temporal cortex must be gated by syntactic patterns represented in inferior frontal cortex. Usually, this gating meshes smoothly with the wheels driving syllable activation. However, if some information arrives late or is judged to be incorrect, speech errors can arise (Dell, Juliano, and Govindjee, 1993). Such errors can arise from the impact of neural and peripheral physiological factors, such as exhaustion, inattention (Donegan, chapter 1, this volume), drugs, lesions, or degeneration.

This meshing of processes for syllable production is only one of the ongoing timeframe synchronizations arising in language processing. Others involve monitoring of conversational sequencing for projected turn completion, topic continuation, alignment feedback (Hopper, chapter 14, this volume), gesture processing (Zlatev, chapter 21, this volume), and comprehension feedback (Clark, chapter 15, this volume). Still other meshed processes operate during language comprehension, as listeners attempt to use lexical items and syntactic cues to construct mental models (MacWhinney, 2008b) that mesh with ongoing input from the speaker and the situation.

2.3.2 Timeframes for consolidation The processes of speaking and listening leave traces in terms of patterns of connectivity in the brain. The ways in which these patterns are consolidated depend on biochemical processes at the level of the synapse, as well as larger patterns controlled by interactions between cortical areas. In order to understand how the brain consolidates inputs across diverse timeframes, it will help to take a detour into the simpler world of the honeybee. Menzel (1999) explains how honeybee cognition relies on five memory phases, each involving different cellular processes, different timeframes, and different environmental challenges. The first phase is early short-term memory (eSTM). When foraging within a single patch of flowers of the same type, bees are able to maintain attention on a pollen source through activity within an activated neural ensemble (Edelman, 1987; Pulvermüller, 2003) without consolidation. In the second phase, of late short-term memory (lSTM), synthesis of the PKA protein kinase works to solidify the currently active circuit, as the bee shifts between contrasting pollen sources. The third phase, of middle-term memory (MTM), spans a timeframe of hours and involves the formation of covalent modifications in the synapses between neurons. During these first three timeframes, bees have not yet returned to the hive, but are still processing flowers encountered during a single foraging bout. The fourth phase of memory consolidation relies on the formation of early long-term memories (eLTM) through the action of nitrous oxide (NO) and PKC1. This type of consolidation is important, because it allows the bee to return to remembered pollen sources even after a trip back to the hive. The fifth phase of consolidation, in late long-term memory (LLTM), operates across a timeframe of over three days, using PKC2 protein synthesis for even more permanent memories regarding ongoing use of pollen sources. Thus, each of the five phases of memory consolidation is responsive to the nature of the memory that must be retained to allow the bee to continue successful foraging.

When the bee is trying to decide where to fly, her decision is impacted by an array of wheels that mesh in the current moment. Some of the wheels derive from the memories for pollen sources described above. Others derive from activities in the hive, including the dances of other bees. Still others relate to the season, the need to defend the hive, and so on. Bees have an evaluation neural module that works to mesh information from all of these sources, much as our language production device serves to mesh inputs from all sorts of memories and motives. For both the bee and the human speaker, this meshing of timeframes all occurs at the moment of deciding either where to fly or what to say.

This linkage between environmental tasks, timeframes, and neuronal processes is not unique to bees. However, these relations are particularly transparent in the honeybee, because of the way in which the distribution of flowers structures the bee's environment. We find the same five memory mechanisms operating across these timeframes in humans. However, for humans, there are additional mechanisms that support even more complex consolidation over longer timeframes for integrating increasingly complex memories. Many of these additional mechanisms rely on links between the hippocampus and the cortex (McClelland, McNaughton, and O'Reilly, 1995; Wittenberg, Sullivan, and Tsien, 2002), including episodic storage in the medial temporal lobes (Daselaar, Veltman, and Witter, 2004). In addition, the frontal lobes provide a hierarchical system of executive control involving increasingly complex and longer-term structures as one moves from the posterior to anterior frontal areas (Koechlin and Summerfield, 2007).

Consolidation impacts processing through connectivity and item strength. Consider the three stages in the learning of the English past tense as an example. During the first stages of learning, children pick up irregular past-tense forms, by rote. In the second stage, they acquire the combinatorial past tense that produces forms, such as *jumped* and *wanted*. During this period, there is a competition between rote and combination (MacWhinney, 1975b). Because the combinatorial form gathers strength from its use across many verb types, it will occasionally win, leading to the production of **goed* and **falled*. In the third stage of learning, the child consolidates the representations of individual irregular forms such as *went* and *fell*, so that they can dominate when placed into competition with combinatorial patterns.

The role of consolidated pattern strength and specificity in governing such competitions is fundamental across all linguistic domains (MacWhinney, 1987), and the results of these competitions can be predicted quantitatively from experimental and corpus data (McDonald and MacWhinney, 1989). Both first (MacWhinney, 2014b) and second (MacWhinney, 2012) language learners begin with highly specific patterns and formulas (Sidtis, chapter 26, this volume) from which they then form higher-level generalizations. However, there are also many competitions between forms on the same level. For example, during comprehension of the word *candle*, there is a brief moment at word onset when *candle* competes with *candy*, *camera*, *calendar*, and other words beginning with *ca-* (Allopenna, Magnuson, and Tanenhaus, 1998).

2.3.3 Timeframes for social diffusion Short-term processes must mesh with consolidated long-term processes. Typically, the consolidation of linguistic patterns depends on the interplay between neural and social encoding. Individual language users can only consolidate forms if those same forms are also adopted by the wider community. In this sense, language can be viewed as a collection of social memes that are internalized by group members. Language includes internalized memes for controlling conversational sequencing, alignment, code switching (Li, chapter 23, this volume), and many other social interactions. These social patterns must also mesh with individuals' motor control of physical systems for maintaining gaze contact, proxemics, and postural alignment. This means that social groups can only adopt patterns that also work out well for individuals in terms of both processing and consolidation.

Both sociolinguists (Poplack and Cacoullos, chapter 12, this volume; Foulkes and Hay, chapter 13 in this volume) and typologists (Bybee and Beckner, chapter 8, this volume; Givón, chapter 9, this volume; Hawkins, chapter 10, this volume) examine patterns of language diffusion and change. Sociolinguists often focus on changes within a single language, whereas typologists are often concerned with comparisons of patterns of change across languages. By combining information from these two methodologies, we can derive an even more complete understanding of how forms diffuse, consolidate, compete, and decay within contrasting social groups across time.

2.3.4 Timeframes for genetic diffusion The slowest-moving biological timeframes are those that link to the DNA. Although modern human languages may derive from an ancestral language spoken in the Late Pleistocene, earlier changes in human physiology and neural circuitry going back 300,000 years and more provided a platform for the more recent advances (Donald, 1991; MacWhinney, 2008a). Because language depends on such a great diversity of structures, abilities, and processes, individuals often suffer from developmental disabilities reflecting variations in the stability of genetic support for language (Kang and Drayna, 2011). Typically, these variations involve either sporadic mutations on specific genes (Fisher and Scharff, 2009), complex gene–gene interactions as in autism, or major errors in disjunction such as Down Syndrome or Williams Syndrome. However, there is virtually no evidence for differences between current human populations in terms of basic genetic support for language learning and production.

Epigenesis (Waddington, 1957, 1977) involves the expression of the genetic code during human development. The long-term instructions encoded in the DNA must mesh with the shorter-term processes of genetic regulation and expression that can be triggered by tissue structures and body plans, as well as environmental inputs such as stress, diet, or chemicals. To understand the meshing of timeframes during epigenesis, we need to develop increasingly detailed dynamic system models of brain–body interactions (Thelen and Smith, 1994), neurogenesis, lateralization, plasticity, disability (Bishop, 2013), and neural degeneration (Kempler and Goral, 2008).

3. Emergentist Approaches

Recent work in linguistics has produced a variety of theoretical frameworks with overlapping goals and assumptions. Among these are functionalism (Givón, 1979), Systemic Functional Grammar (Halliday and Matthiessen, 2004), Processing Emergence (Hawkins, 2004; O'Grady, 2005), Cognitive Grammar (Langacker, 1987), Usage-Based Linguistics (Bybee and Hopper, 2001), Variable Rule Analysis (Kay, 1978), the Competition Model (MacWhinney, 1987), Construction Grammar (Goldberg, 2006), Conceptual

Metaphor Theory (Lakoff and Johnson, 1980), Blending Theory (Fauconnier and Turner, 1996), Optimality Theory (Bresnan, Dingare, and Manning, 2001; Kager, 1999), and the Neural Theory of Language (Feldman, 2006). In cognitive psychology, theories such as Parallel Distributed Processing (Rumelhart and McClelland, 1986), Self-Organizing Maps (Kohonen, 2001), Bayesian Modeling (Kemp, Perfors, and Tenenbaum, 2007), Information Integration Theory (Massaro, 1987), and Dynamic Systems Theory (Thelen and Smith, 1994; van Geert and Verspoor, chapter 14, this volume) provide quantifiable predictions regarding the outcomes of competition. In social psychology, theories such as Memetics (Mesoudi et al., 2006) and Social Priming (Bargh, Schwader, Hailey, Dyer, and Boothby, 2012) explain how memes diffuse and consolidate. In addition, formulations from neurolinguistics such as mirror neurons (Arbib, 2010), Mind-Reading (Mitchell et al., 2008), Embodied Cognition (Pecher and Zwaan, 2005), and Common Coding (Schütz-Bosbach and Prinz, 2007) link up well with many aspects of functionalist linguistics.

Faced with this embarrassment of theoretical riches, students often ask what is the relation between Emergentism and all these other approaches. The answer is that all of these approaches fall under the general category of Emergentism, because all recognize the importance of the principles of competition, hierarchicality, and timeframes that we have been discussing. Where these approaches differ is in terms of their *emphases*. For example, given a metaphor such as *choking poverty*, Embodied Cognition emphasizes mappings of this metaphor to the source domain of the body, Mind-Reading highlights ways in which this metaphor activates particular areas of the brain, usage-based analysis focuses on the conventionalization of the metaphor through usage, and memetics examines the spread of the metaphor across communities. Integration of these contrasting emphases can force us to refine our empirical analyses. For example, we may want to contrast the processing of conventionalized metaphors with those of more novel metaphors in terms of the ways in which they activate embodied representations.

Although these various approaches all invoke concepts of competition and hierarchicality, they differ in terms of the specific quantitative methods they utilize. For example, Parallel Distributed Processing (Rumelhart and McClelland, 1986), Self-Organizing Feature Maps (Kohonen, 2001), and Dynamic Systems Theory (Thelen and Smith, 1994) all represent networks of connections, but differ in the ways in which algorithms operate on these connections. Underneath this apparent divergence, there is a core mathematical framework (Farmer, 1990) that derives from their shared reliance on emergentist principles. Similarly, Construction Grammar (Goldberg, 2006) is a direct outgrowth of work in Cognitive Grammar (Langacker, 1987), differing largely in terms of the detail with which it analyses competitions between constructions.

Among the various emergentist approaches, there are three that have tackled the problem of understanding the meshing of timeframes. First, sociolinguistic analyses, such as those presented by Poplack and Cacoullos (chapter 12, this volume), have succeeded in tracing changes and continuities in grammar and lexicon over decades and even centuries. Second, researchers such as Goodwin (2000a), Sfard and McClain (2002), and Lemke (2000) have shown how the use of artifacts (tools, maps, books, color chips, computers) during interaction can provide links to long-term timeframes. Third, researchers in child language (Bates and Goodman, 1999) and second language (Verspoor, de Bot, and Lowie, 2011) have developed longitudinal corpora to trace the ways in which competing processes interact across several years. However, the full study of the meshing of alternative timeframes in linguistic analysis (MacWhinney, 2005, 2014a) remains a task for future theories, databases, and models.

4. Mechanisms of Emergence

The three major conceptual frameworks supporting Emergentism are competition, hierarchicality, and timeframes. To derive specific predictions and analyses from these frameworks, we need to link them to particular mechanisms of emergence. In this regard, it is helpful to survey some of the most important emergentist mechanisms that have been proposed.

1. *Proliferation*. Linguistic patterns are inherently variable at the levels of both the community and the individual. Understanding the sources and results of this variation is a fundamental task for virtually every branch of language studies.
2. *Competition*. Individuals must continually make choices between alternative ways of expressing intentions. Psychological models of this process (Anderson, 1983; Ratcliff, Van Zandt, and McKoon, 1999) assume that the winners in this competition are the forms with microfeatures that most closely match the intended outcome. On the neuronal level, competition is implemented by summation of synaptic input across the neuron's cellular membrane.
3. *Generalization*. Emergentist accounts, such as Parallel Distributed Processing (PDP), Bayesian networks, the Competition Model, and construction grammar, emphasize the ways in which generalizations emerge from the extraction of similarities across collections of more specific items or episodes. These accounts assume that, on the neuronal level, generalizations arise from shared patterns across items. Generalization plays a major role in theories of polysemy (MacWhinney, 1989), metaphor (Gibbs, in press), and prototype application (Taylor, in press). Some accounts also postulate multiple hierarchically organized levels of generalization for syntactic constructions (Culicover and Jackendoff, 2005; McDonald and MacWhinney, 1991; Perfors, Tenenbaum, and Wonnacott, 2010) and categories (Kemp et al., 2007).
4. *Error correction*. Learning theories often emphasize the importance of corrective feedback for errors (Rumelhart and McClelland, 1987). However, this feedback can also involve failure to match self-imposed targets, as in the DIVA model of phonological learning (Guenter and Perkell, 2003).
5. *Self-organization*. Mechanisms such as the self-organizing feature map (Kohonen, 2001) provide alternatives to mechanisms based on error correction. An important assumption of these models is that the brain prefers to establish connections between local units, rather than between distant units (Jacobs and Jordan, 1992).
6. *Topological organization*. Self-organizing feature maps reflect the method of topological organization found throughout the cortex (Hauk, Johnsrude, and Pulvermüller, 2004; Wessinger, Buonocore, Kussmaul, and Mangun, 1997). To the degree that connected areas can rely on such organization, they can maximize communication to achieve activation and inhibition between areas.
7. *Criticality*. There is increasing evidence (Shew and Plenz, 2013; Uhlig, Levina, Geisel, and Herrmann, 2013) that cortical circuits operate at criticality. This means that spike transmission depends on neurons being poised in a dynamic equilibrium

that allows maximally faithful information flow through quick-phase transitions. Criticality is also maximized through the ways in which neural networks are self-organized. Criticality can also play a role in higher-level structures, including the dynamics of interpersonal communication.

8. *Memory consolidation*. Repeated use of a muscle or bone will lead to its growth and strengthening. Language functions in a similar way. Each use of a sound, word, or construction in a particular context strengthens the memory for that form and increases its ability to compete with alternative forms. As we noted in our discussion of memory consolidation in honeybees, consolidation processes are sensitive to the relevance of memories in alternative timeframes (Squire, 1992). These alternative methods of consolidation rely on an array of biochemical processes and patterns of connectivity between the hippocampus and the cortex (McClelland et al., 1995; Schmajuk and DiCarlo, 1992; Wittenberg et al., 2002). Consolidation operates initially within individuals, but then extends over time to impact wider social and dialectal groups.
9. *Structure mapping*. Theories of metaphor, metonymy, and analogy in cognitive linguistics often assume some method of mapping from the structure of a source domain to a target domain (Gentner and Markman, 1997). Mechanisms of this type can also be used to account for convergence between cognitive systems (Goldstone, Feng, and Rogosky, 2004).
10. *Embodied representations*. The representations and schemas used in cognitive linguistics align well with neurolinguistic theories of body image (Knoblich, 2008), embodied perspective-taking (MacWhinney, 2008b), empathy (Meltzoff and Decety, 2003), and situated spatial processing (Coventry, in press).
11. *Common ground*. The establishment of embodied representations benefits from the fact that we all share the same body type, thereby allowing physical mirroring (Arbib, chapter 27, this volume). On a still higher cognitive level, we also construct shared mental representations of places, events, goals, and plans that provide common ground, upon which language structures and conversational patterns can depend (E. Clark, chapter 15, this volume).
12. *Conversational pressures*. Linguistic structures adapt to frequent conversational patterns. For example, Du Bois (1987) has argued that ergative marking emerges from the tendency to delete the actor in transitive sentences, because it is already given or known. Similarly, Donegan (chapter 1, this volume) and Bybee and Beckner (chapter 8, this volume) explain how a loosening of demands for precision can stimulate lenition processes in phonology that eventually lead to further grammatical changes.
13. *Item-based patterns*. The theory of item-based patterns (MacWhinney, 1975a, 1982; Tomasello, 2000) provides an underpinning for construction grammar (Goldberg, 2006), as well as solutions to the logical problem of language acquisition (A. Clark, chapter 17, this volume; MacWhinney, 2004).
14. *Composition*. Syntactic theories must deal with the ways in which words cluster into phrases. Emergentist models of comprehension such as that described in O'Grady (2005) show how this can be done in an incremental fashion. In this area, the emphasis in UG Minimalism on the Merge process (Chomsky, 2007) is compatible with emergentist accounts. However, compositionality is also required for basic action processing (Arbib, chapter 27, this volume; MacWhinney, 2009; Steedman, 2004), quite apart from its role in language.

15. *Perceptual recording*. Studies of infant auditory perception have revealed that, even in the first few months, infants apply general-purpose mechanisms to record and learn sequential patterns from both visual and auditory input (Thiessen and Erickson, chapter 18, this volume).
16. *Imitation*. Human children display a strong propensity to imitate gestures (Meltzoff and Decety, 2003), actions (Ratner and Bruner, 1978), and vocal productions (Whitehurst and Vasta, 1975). Imitation in both children and adults is the fundamental mechanism postulated by usage-based linguistics.
17. *Plasticity*. Children with early left focal lesions are able to recover language function by reorganizing language to the right hemisphere. This plasticity in development is a general mechanism that supports a wide variety of emergent responses to injury or sensory disability (MacWhinney, Feldman, Sacco, and Valdes-Perez, 2000).
18. *Physical structures*. Phonologists have shown that the shape of the vocal mechanism has a wide-ranging impact on phonological processes (Ohala, 1974). The articulatory system can be characterized as an assemblage of springs and dampers whose functioning is expressed through sets of differential equations (Boersma and Hayes, 2001; Story, 2002). For example, when singers use vibrato, they set up a resonance at 5–6 Hz, between the cricothyroid and thyroartenoid muscles. This resonance can be modeled by the vibrating string formula, as applied to the underlying dynamic mechanical system (Titze, Story, Smith, and Long, 2002). Rather than stipulating phonological rules or constraints (Bernhardt and Stemberger, 1998) for phonological patterns, we can view them as emergent responses to underlying physical pressures (Donegan, chapter 1, this volume). Further physical effects on emergent processes include coupling of the vocal cords to jaw movements (Iverson and Thelen, 1999), diffusion reactions during epigenesis (Murray, 1988), and many others.
19. *Epigenesis, Homeostasis, and Homeorhesis*. Earlier, we discussed ways in which brain and body structures arise during epigenesis. To understand the organic basic of language disorders, we need to trace through the ways in which relevant brain and body structures emerge during neurogenesis. It is likely that many forms of disability arise from errors in patterns of connectivity between language processing areas during embryogenesis. However, even after the brain is formed, epigenetics continues to determine neural support for language through the homeostasis and homeorhesis. Homeostasis is the ability of the body to maintain structures despite cell loss. Homeorhesis is the ability of the body to maintain ongoing processes despite perturbations. Both of these abilities arise from epigenetic control of gene expression, which is in turn sensitive to physical and chemical pressures from existing structures and processes.

This is a very incomplete listing of the many mechanisms and pressures that shape the emergence of language. Understanding how these mechanisms and others related to them mesh across timeframes to produce complex language structures is the major task facing emergentist approaches to language.

5. Emergentism and Universal Grammar

The modern study of language can be viewed as the tale of two competing paradigms: Universal Grammar (UG) and Emergentism. Over the last two decades, the dialogue between Emergentism and UG has focused on ten core issues. Let us consider how UG and Emergentism approach each of these issues.

1. *What Is Language?* UG focuses its attention on a narrow definition of language (Hauser, Chomsky, and Fitch, 2002) that involves the recursive application of rules in modules of the syntactic component. This emphasis leaves large areas of lexicon, phonology, dialogue, meaning, and interpretation outside of the domain of the language faculty. In contrast, Emergentism treats all of the components of human language, including those controlling communication, as parts of an interlocking, unified system.
2. *The Uniqueness of Recursion*. UG (Chomsky, 1995) and Emergentism (MacWhinney, 1987) both recognize the central role of recursive combination in producing sentence and discourse structure. However, UG holds that syntactic recursion is a criterial and unique feature of human language, linked specifically to the language faculty (Hauser et al., 2002). In contrast, Emergentism views recursion as arising from the combined activities of memory, lexicon, discourse, and role activation (MacWhinney, 2009).
3. *Rules vs. Cues*. A fundamental claim of the Emergentist program is that linguistic structures emerge from patterns of usage. This emphasis arose in reaction to the emphasis in earlier UG theories on large systems of ordered rules (Chomsky and Halle, 1968). These stipulated rule systems were formulated without any linkage to functional motivations. In later UG formulations (Chomsky, 1981; Chomsky and Lasnik, 1993), rules gave way to principles, parameters, and constraints. In contrast, emergentist analyses have focused on understanding how patterns arise from usage, generalization, and self-organization (MacWhinney, Malchukov, and Moravcsik, 2014).
4. *Irrelevance of E-Language*. UG seeks to base linguistic theory on the competence of the ideal speaker–hearer. This competence is characterized as I-Language (internal language) in contrast to E-Language (the external language of the community). Emergentism rejects the decoupling of I-Language and E-Language, as well as the attempt to separate competence and performance. Instead, it views the individual's linguistic abilities as emerging from interactions with the wider social community. It is through such interactions that we develop structures that achieve conceptual consensus (Goldstone et al., 2004; Wittgenstein, 1953).
5. *The Sudden Evolution of Language*. UG holds that language evolved recently as a way of supporting more elaborate cognition, rather than for purposes of social interaction. In contrast, Emergentism views language as deriving from a series of neurological and physical adaptations (Arbib, chapter 27, this volume), driven by an adaptation of the human species to a specialized niche involving upright posture, control in large mobile social groups (Geary, 2005), and support for delayed infant maturation (MacWhinney, 2008a).
6. *Simple Genetic Determination*. UG seeks to link the appearance of language to very specific genetic changes (Fisher and Scharff, 2009) in the last 70,000 years, perhaps involving one or two genetic changes. Emergentism views language as grounded on a wide-ranging set of genetic adaptations across millions of years.
7. *Speech Is Special*. Generative theory has often been associated with the idea that, in terms of auditory processing, "speech is special" in the ways that innate

faculty-specific abilities guide phonological development and structure. In contrast, emergentist approaches emphasize the role of physiological mechanisms in controlling articulation (Oller, 2000). They also view auditory learning as governed by basic aspects of the auditory system and temporal processing constraints (Holt and Lotto 2010).

8. *A Critical Period for Language Learning*. Many UG formulations hold that there is an expiration date on the special gift underlying language learning and use (Lenneberg, 1967). Emergentist accounts attribute the gradual decline in language learning abilities to entrenchment of the first language, parasitic transfer of first language abilities, and social isolation (MacWhinney, 2012).
9. *Modularity of Mind*. UG emphasizes the encapsulated, modular composition of grammar (Fodor, 1983). Emergentist accounts emphasize interactivity between permeable, emergent modules (McClelland, Mirman, and Holt, 2006).
10. *Poverty of the Stimulus*. UG holds that there is insufficient information in the input to the language learner to properly determine the shape of the native language (Piattelli-Palmarini, 1980). As a result, language learning is guided by a rich set of innate hypotheses regarding the shape of Universal Grammar. Emergentist accounts emphasize the richness of the input to the learner and the role of item-based (MacWhinney, in press) and distributional (A. Clark, chapter 17, this volume) learning strategies in achieving effective learning of complex structures.

The fact that the two approaches offer such different analyses for such fundamental issues has been a major impetus to ongoing empirical and theoretical work in each of these ten areas. However, the focus of work in Emergentism is now shifting away from the debate with UG toward the detailed articulation of an explanatory account of language structure based on the integration of the principles of competition, hierarchicality, and the meshing of processes across timeframes.

6. Applying Emergentism

The current volume presents 27 chapters that explore the application of Emergentism to various aspects of language structure and development. The chapters are organized into five major parts: basic language structures, language change and typology, interactional structures, language learning, and language and the brain. Let us take a brief look at the core issues addressed by the chapters in each of these parts to see how their findings relate to the overall program of Emergentism.

6.1 Basic language structures

This part examines the emergence of linguistic structures. In the first chapter, Patricia Donegan contrasts the conventionalized historical processes found in morphophonology with the automatic natural processes involved in phonology. Whereas morphophonological rules are sensitive to morphological factors such as morpheme boundaries, affix types, and word class, phonological processes are sensitive just to phonetic features. This contrast between the two levels of phonological control shows