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Stories and the Brain:

Neuroscience, Narrative, and Narrative Theory

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The ability to tell and follow a story requires cognitive capacities that are basic to the neurobiology of mental functioning. Neuroscience cannot of course reveal everything we might want to know about stories, but it is also true that our species would probably not produce narratives so prolifically if they weren't somehow good for our brains and our embodied interactions with the world. What kind of brains do we have that enable us to tell each other stories? And how do stories configure our brains? How plots order events in time, how stories imitate actions, and how narratives relate us to other lives, whether in pity or in fear–these central concerns of narratological theorists from Aristotle to Paul Ricoeur are perhaps surprisingly aligned with a variety of hot topics in contemporary neuroscience: temporal synchrony and the binding problem, the action-perception circuit in cognition, and the mirroring processes of embodied intersubjectivity. The processes through which stories coordinate time, represent embodied action, and promote social collaboration are fundamental to the brain-body interactions through which our species has evolved and has constructed the cultures we inhabit.

Triangulating our phenomenological experience as tellers and followers of stories with neuroscientific findings about embodied cognition and with narrative theories about plots, fiction, and reading is an attempt to understand the relation between language, cognition, and narrative–a goal that many thoughtful investigators across a variety of disciplines have pursued. One of the reasons why philosophers, literary theorists, and everyday readers have wondered about why and how we tell stories is that narrative has seemed to hold the key to how language and the mind work. Narratology is now at a turning point in its understanding of the relation between language, cognition, and narrative, poised between the formalist models of schemes, scripts, and preference rules inherited from structuralism and pragmatically oriented theories of narrative as embodied, intersubjective interaction. Whether and how these models can be reconciled is an important, unsettled question. Understanding the neurobiological bases of narrative may help solve this problem by showing how the ability to tell and follow stories aligns with how the brain processes language. In the first part of my talk, I will lay out a neurobiological model of narrative that explains how stories arise from and set in motion fundamental neuronal and cortical processes, and then in the second part I will ask how the aims and methods of narratology should be aligned to the best science about language and the brain.

1. The Neuroscience of Narrative

Stories help the brain negotiate the never-ending conflict between its need for pattern, synthesis, and constancy on the one hand and for flexibility, adaptability, and openness to change on the other. The brain's remarkable, paradoxical ability to play in a to-and-fro manner between these competing imperatives is a consequence of its decentered organization as a network of reciprocal top-down, bottom-up connections among its interacting parts. Narrative theorist Seymour Chatman attributes plot-formation to "the disposition of our minds to hook things together"; as he notes, "our minds inveterately seek structure." This is, indeed, a basic axiom of contemporary neuroscience. Against the cognitive need for consistency, however, the psychologist William James describes the brain as "an organ whose natural state is one of unstable equilibrium," constantly fluctuating in ways that enable its "possessor to adapt his conduct to the minutest alterations in the environing circumstances." The brain knows the world by forming and dissolving assemblies of neurons, establishing the patterns that through repeated firing become our habitual ways of interacting with the environment, even as ongoing fluctuations in these syntheses combat their tendency to rigidify and promote the possibility of new cortical connections. The brain's ceaseless balancing act between the formation and dissolution of patterns makes possible the exploratory play between past equilibria and the indeterminacies of the future that is essential for successful mental functioning and the survival of our species.

Stories contribute to this balancing act by playing with consonance and dissonance. Borrowing Frank Kermode's well-known terms, Ricoeur describes emplotment as "concordant discordance"–"a synthesis of the heterogeneous" that configures parts into a whole by transforming the "diversity of events or incidents" into a coherent story. According to Ricoeur, the act of "composing plots" converts "the existential burden of discordance" into narrative syntheses that give meaning to life's imbalances by constructing patterns of action. Even in the simplest narratives that approach what Gérard Genette calls the hypothetical "zero degree" of difference between the order of events in the telling and their order in the told, the conjunctions that join together the elements of the plot are invariably disrupted by twists and turns on the way to resolution. What Genette calls temporal "anachronies" (flash-forwards and flash-backs, for example, that disrupt the temporal correspondence between the telling and the told) further play with the competing impulses toward consonance and dissonance that are basic to narrative. The imbalances between pattern-formation and dissolution in the brain make possible this narrative interaction between concord and discord, even as the construction and disruption of patterns in the stories we tell each other help the brain negotiate the conflicting imperatives of order and flexibility. The neuroscience of these interactions is part of the explanation of how stories give shape to our lives even as our lives give rise to stories.

Stories can draw on experience, transform it into plots, and then reshape the lives of listeners and readers because different processes of figuration traverse the circuit of interactions and exchanges that constitute narrative activity. First, the neural underpinnings of narration start with the peculiarly decentered temporality of cognitive processes across the brain and the body–disjunctions in the timing of intra-cortical and brain-body interactions that not only make possible but also actually require the kind of retrospective and prospective pattern-formation entailed in the narrative ordering of beginnings, middles, and ends. Next, the strangely pervasive involvement of processes of motor cognition not only in the understanding of action and gesture but also in other modalities of perception suggests why the work of creating plots that simulate structures of action can have such a profound effect on our patterns of configuring the world. Finally, if stories can promote empathy and otherwise facilitate the co-intentionality required for the collaborative activity unique to our species, the power and the limits of their capacity to transform social life ultimately depend on embodied processes of doubling self and other through mirroring, simulation, and identification, processes whose limitations are reflected in the strengths and weaknesses of narratives as ethical and political instruments. In each of these areas, narratives configure lived experience by invoking brain-based processes of pattern-formation that are fundamental to the neurobiology of mental functioning.

The concordant discordance of emplotment is based on the decentered, asynchronous temporality of the brain. One of the many ways in which the brain differs from a computer is that its temporal processes are not instantaneous and perfectly synchronized. Unlike electrical signals that discharge simultaneously at nearly the speed of light, action potentials at the neuronal level take more than a millisecond to fire, and different regions of the cortex respond at varying rates. For example, as neuroscientist Semir Zeki observes, in the visual cortex "colour is perceived before motion by [approximately] 80 ms [milliseconds]," and "locations are perceived before colours, which are perceived before orientations." The integration of neuronal processes through which conscious awareness emerges may require up to half a second. As Zeki points out, however, this "binding" (as it is called) is itself not perfectly homogeneous: "the binding of colour to motion occurs after the binding of colour to colour or motion to motion" because "binding between attributes takes longer than binding within attributes." More time is needed to integrate inputs from vision and hearing, for example, than to synthesize visual signals alone. Although we typically don't notice these disjunctions, the non-simultaneity of the brain's cognitive processes means that consciousness is inherently out of balance and always catching up with itself. As the neuroscientist Antonio Damasio puts it, "we are probably late for consciousness by about 500 milliseconds."

This imbalance is not a bad thing, however, because it allows the brain to play in the ever-changing horizonal space between past patterns and the indeterminacies of the future, the space that plots organize into beginnings, middles, and ends. Concord with no trace of discord would be disabling. In waking life, as neuroscientist Gerald Edelman observes, "groups of neurons dynamically assemble and reassemble into continuously changing patterns of firing." The synchronization of brain waves across the cortex makes possible the formation of neuronal assemblies and coordinates the workings of different regions of the brain. As cognitive scientists Bernard Baars and Nicole Gage explain, "normal cognition requires selective, local synchrony among brain regions," "highly patterned and differentiated" oscillatory patterns in which "synchrony, desynchrony, and aperiodic 'one-shot' waveforms constantly appear and disappear." But as Edelman explains, "if a large number of neurons in the brain start firing in the same way, reducing the diversity of the brain's neuronal repertoires, as is the case in deep sleep and epilepsy, consciousness disappears." In those conditions, "the slow, oscillatory firing of . . . distributed populations of neurons is highly synchronized globally," and global hypersynchrony paralyzes normal functioning by disrupting the to-and-fro of synchronization and desynchronization. In contrast to sleep and epilepsy, "consciousness requires not just neural activity," Edelman points out, "but neural activity that changes continually and is thus spatially and temporally differentiated"– "distributed, integrated, but continuously changing patterns of neural activity . . . whose rich functioning actually *requires* variability."

The ability of a plot to join concord and discord through temporal structures that order events while holding them open to surprise, variation, and refiguration is one instance of this necessary tension between pattern and change, synchrony and fluctuation, coordination and differentiation. Stories set in motion reciprocal processes of pattern-formation that are always already occurring beneath our awareness and that are fundamental to the brain's operation as a to-and-fro ensemble of neuronal assemblies that are constantly coming and going, waxing and waning. The concordant discordances of narrative play off of the brain's necessary, never-ending alternation between synchronization and desynchronization. By manipulating the time lags built into cognition, narratives can reinforce established patterns through the pleasures of recognition, providing support for the structures that build coherence across our temporal experience, or they can disrupt the expectations through which we build consistency and thereby make possible new patterns of synchronization. The conjunctions that smooth over temporal discordances can facilitate configurative activity, but the disjunctions inherent in these time-lags can also be productive by combating habitualization and promoting flexibility.

The temporality of the decentered brain makes mimesis possible because imitation is not a static correspondence of sign to thing but a dynamic configuration of an action. Aristotle famously claims that "tragedy is an imitation not of men but of *action*" and, further, that "performers *act* not in order to imitate character; they take on character for the sake of [imitating] actions." Narration is a kind of action (a linguistic making) that produces an organization of events (an emplotment of actions) that the reader or listener follows and reconstructs (the activity of comprehension).

Contemporary neuroscience suggests that the biological basis of these connections is an action-perception circuit that makes action fundamental to many cognitive processes that might seem unrelated to the control of various body parts by the motor cortex. Plots can play a central role in structuring our understanding of the world because action is thoroughly implicated in perception and cognition. Seeing, hearing, and touching are all active processes, for example, that are especially attuned to difference and change. For all modes of perception, exploratory activity of the environment provides ever-changing information about regularities and irregularities, and it is these differences to which the organism responds. Plots can play a central role in structuring our understanding of the world because action is thoroughly implicated in perception and cognition.

Recent experimental evidence on the responsiveness of the brain to imagined action and even to action words suggests that the brain is primed to respond to linguistically staged configurations of action, and these can have a profound effect on our cognitive processes because perception in many different modalities (vision, hearing, smell, touch) depends on embodied action. As neuroscientist Marc Jeannerod points out, many different experiments have shown that "imagining a movement relies on the same mechanisms as actually performing it." If the motor cortex and even muscle tissue can be excited by mental rehearsal of an action, that should also be true of linguistic simulations of actions, and there is experimental evidence that this is so.

Action seems to perform a fundamental role in coordinating different modalities of cognition, and this organizing role is crucial not only for language but also for narrative and our ability to construct and follow plots. The anatomical region of the brain central to these interactions is Broca's area, a region of the inferior frontal cortex adjacent to the sections of the motor cortex that control the mouth and the lips: "studies have shown this area to be active in human action observation, action imagery and language understanding." Impairments in Broca's area have long been known to result in difficulties producing and comprehending grammatical sentences. Patients with lesions in this part of the brain can understand and pronounce single words, "but they have great difficulty in aligning scrambled words into a sentence or in understanding complex sentences," and these deficiencies are "paralleled in non-linguistic modalities." A number of brain-imaging studies have shown, for example, that musical syntax is processed in Broca's area and that listening to musical rhythms activates the motor cortex.

This region of the brain is also apparently crucial for narrative. A recent experiment by Patrik Fazio revealed that "a lesion affecting Broca's area impairs the ability to sequence actions in a task with no explicit linguistic requirements." His group showed patients with Broca's aphasia "short movies of human actions or of physical events," and they were then asked to order, "in a temporal sequence, four pictures taken from each movie and randomly presented on the computer screen." Curiously, although these patients could still recognize before-after relations between physical events, they had a harder time reconstructing the order of human actions. Their ability to remember and compose a sequence of represented actions was impaired. This result suggests that the patients in Fazio's study suffered a deficiency in the capacity for emplotment, the ability to produce and follow configurations of action. Such an inference is consistent with Fazio's claim that "the complex pattern of abilities associated with Broca's area might have evolved from its premotor function of assembling individual motor acts into goal-directed actions." This capacity for organizing action into meaningful sequences makes the brain ready for language, but it also prepares the brain for narrative. Broca's area is vital for language as well as narrative because both entail the structuration of symbolic action.

Our intuitive, bodily-based ability to understand the actions of other people is fundamental to social relations of many kinds, including the relation between story-teller, story, and audience. This ability undergirds the circuit between the representation of a configured action emplotted in a narrative and the reader's or listener's activity of following the story as we assimilate its patterns into the figures that shape our worlds. In an illuminating analysis of the "kinematics" of narrative, cognitive literary theorist Guillemette Bolens distinguishes between "kinesic intelligence" and "kinesthetic sensations"–"our human capacity to discern and interpret body movements" of other people as opposed to the "motor sensations" we may have of our own actions, whether voluntary or involuntary: "I cannot feel the kinesthetic sensations in another person's arm. Yet I may infer his kinesthetic sensations on the basis of the kinesic signals I perceive in his movements. In an act of kinesthetic empathy, I may internally simulate what these inferred sensations possibly feel like via my own kinesthetic memory and knowledge." The ability to understand the actions represented in a story (what is told) as well as to follow the movements of the narration (the telling) requires both kinds of cognitive competence–the hermeneutic capacity to configure signals into meaningful patterns (kinesic intelligence) and the intuitive sense of how the structures emplotting the actions and the forms deployed in the narration resonate with my own unreflective, habitual modes of figuring the world (embodied in my kinesthetic sensations).

The kinesic intelligence and kinesthetic empathy that we use to understand stories entail a kind of doubling between self and other that, according to Maurice Merleau-Ponty, makes the alter ego fundamentally paradoxical. As Merleau-Ponty explains, "the social is already there when we come to know or judge it" because the intersubjectivity of experience is primordially given with our perception of a common world–and yet, he continues, "there is . . . a solipsism rooted in living experience and quite insurmountable" because I am destined never to experience the presence of another person to herself. The kinesthetic empathy Bolens describes is paradoxically both intersubjective and solipsistic, for example, inasmuch as I "internally simulate" what the other must be feeling as if her sensations were mine which, of course, they are not (otherwise I wouldn't need to infer them on the basis of my own). Following a story is similarly a paradoxical process, with both intersubjective and solipsistic dimensions, whereby my own resources for configuring the world are put to work to make sense of another, fictive, narrated world that may seem both familiar and strange and that may either reinforce or disrupt my sense of the world's patterns, because its figurations both are and are not analogous to mine.

The doubling of self and other in the exchange of stories can have a variety of beneficial or potentially noxious social consequences. Following a story is a fundamentally collaborative transaction that can promote the "shared intentionality" that Michael Tomasello and other neurobiologically oriented cultural anthropologists identify as a unique human ability that other primates seem to lack. What Tomasello calls "'we' intentionality" is the capacity for "participating in collaborative activities involving shared goals and socially coordinated action plans (joint intentions)." The fundamental "skills of cultural cognition" made possible by shared intentionality begin with parent-infant "proto-conversations" that involve "turn-taking" and "exchange of emotions"–activities also entailed, of course, in telling and following stories–and such collaborative interactions culminate in what is known as the "ratchet effect" of cumulative cultural evolution. This ability to engage in coordinated activity is analogous to what neuroscientists of music observe in the predisposition of infants "to attend to the melodic contour and rhythmic patterning of sound sequences" and in their attunement "to consonant patterns, melodic as well as harmonic, and to metric rhythms."

The comparison to music is instructive because rhythmically coordinated action beneath conscious awareness can be both enabling and disabling. The sensation of boundaries dissolving in experiences of rhythmic interaction and harmonic unification–what Nietzsche famously attributed to the Dionysian powers of music to overwhelm Apollonian line and form–may miraculously, even sublimely transport us outside of ourselves, but it can also result in well-documented contagion effects (the shared thrills of an audience response at a concert, for example, or the collective enthusiasm of a crowd at a sports event or a political rally) that disable cognitive capacities for criticism and evaluation. Although perhaps less sweepingly powerful, the experience of being carried away by a narrative may similarly transport the listener and seem to erase boundaries between worlds. If not as intoxicating as the Dionysian abandon that Nietzsche describes, such an erasure of self-other differences may facilitate the inculcation of patterns of feeling and perceiving and have a more powerful impact on habitual pattern-formation than cooler, less absorbing, less transportive exchanges of signs and information. The ideological workings of narrative–its ability to inculcate, perpetuate, and naturalize embodied habits of cognition and emotion–are optimized as the "not" in the doubling of self and other disappears. If stories ask us to suspend disbelief to immerse ourselves in the illusion they offer, this invitation may be a temptation to the dissolution of boundaries that the demystifying suspicions of ideology-critique rightly resist in order to shake the hold on us of habits of thinking and feeling whose power we may not recognize because they are so deeply ingrained, familiarized, and naturalized. The capacity of stories to facilitate beneficial social collaboration and to habitualize ideological mystification are two sides of the some coin.

2. Neuroscience and Narratology

The goal of classical narratology was to construct the ideal taxonomy–the classificatory scheme that would identify the fundamental elements of narrative and their rules of combination, based on the model of how grammar and syntax determine meaning by establishing the structural relations between the constituent parts of a logical, ordered system. Whether inspired by Saussure's prioritization of *langue* over *parole* (the presumably stable, orderly structures of language as opposed to the contingencies of speech) or Chomsky's claims about universal grammar (the inborn cognitive structures that constitute what Pinker memorably calls the "language instinct"), the assumption was that the structures of mind, language, and narrative are homologous, innate, and universal. Some versions of cognitive narratology still operate within the structuralist paradigm, either tacitly or explicitly. As narrative theorist James Phelan explains, "cognitive narratology . . . shares with [structural narratology] the same goal of developing a comprehensive formal account of the nature of narrative" and "conceives of its formal system as the components of the mental models that narratives depend on in their production and consumption." These "mental models" are the frames, scripts, and preference rules that Manfred Jahn defines and explains in his authoritative accounts of cognitive narratology. Explaining the aims of "post-classical narratology," Jan Alber and Monika Fludernik endorse this project: "cognitive narratologists . . . show that the recipient uses his or her world knowledge to project fictional worlds, and this knowledge is stored in cognitive schemata called frames and scripts."

Whether these mental constructs can do justice to the cognitive processes they purport to describe is highly questionable, however. The formalist goal of identifying orderly, universal structures of mind, language, and narrative does not match up well with the unstable equilibrium of the temporally decentered brain or the probabilistic processes through which cognitive connections develop and dissolve. There is a growing scientific consensus that the formalist model of innate, orderly, rule-governed structures for language should be cast aside because it does not fit with what we know about how the brain works. As the science of cognition and language has shifted, so too must narratology adjust its methods and aims.

New versions of cognitive narratology have arisen to challenge the structuralist paradigm. As Karin Kukkonen and Marco Caracciolo explain, advocates of an "embodied, enactive" view of cognition argue that, rather than "conceiv[ing] of the mind" as a structure of "abstract, propositional representations" like "frames" and "scripts," narrative theory should understand "the human mind as shaped by our evolutionary history, bodily make-up, and sensorimotor possibilities, and as arising out of close dialogue with other minds, in intersubjective interactions and cultural practices." Whereas first-generation cognitive science was "firmly grounded in a computational view of the mind," with "frames, scripts, and schemata" functioning as "mental representations that enable us to make sense of the world by serving as models of specific situations or activities," second-generation cognitive science shares with phenomenology and the pragmatism of Dewey and James an emphasis on the interactions between embodied consciousness and the world in "feedback loops" through which "experience shapes cultural practices" even as "cultural practices help the mind make sense of bodily experience." Rather than prioritizing the construction of taxonomies, schemata, and systems of rules to explain how the mind works and to account for narrative by disclosing its underlying cognitive structures, second-generation narratology "insist[s] on the situated, embodied quality of readers' engagement with stories and on how meaning emerges from the experiential interaction between texts and readers." A quest for structures and rules has been displaced by an emphasis on the interactions between embodied minds, stories, and the world.

Not everything, to be sure, in first-generation cognitive narratology need be abandoned. Jahn describes "'seeing X as Y' as a foundational axiom" of cognitive narratology, and this idea is indeed scientifically sound. Configurative processes of categorization and pattern-formation–what existential phenomenologist Martin Heidegger similarly calls the "as-structure " (*Als-Struktur*) of understanding–are crucial to embodied cognition and narrative, but they need to be understood in non-schematized, interactive form. One reason why gestalt theory has been a resource from which neuroscientists like Semir Zeki, cognitive psychologists like James J. Gibson, and phenomenologists like Maurice Merleau-Ponty have all repeatedly drawn is its appreciation of the role that figuration or "seeing as" plays in cognition. This is, for example, the epistemological moral of the famously ambiguous rabbit-duck gestalt (the beak of the duck shifting if we see the shape as a rabbit, a new part-whole configuration that transforms it into a pair of ears). This gestalt is a model of cognition because the circular, recursive work of configurative pattern-building ("seeing as") animates not only vision but cognitive processes of all kinds. Making a case for what he calls "carnal hermeneutics," phenomenologist Richard Kearney similarly observes that the "'as-structure' is already operative in our most basic sensations." This is because, as Merleau-Ponty points out, "the smallest sense-datum is never presented in any other way than integrated into a configuration and already 'patterned.'" It is consequently a basic principle of contemporary neuroscience that "categorization (or conceptualization) is a fundamental process in the human brain . . . There are ongoing debates about how categorization works, but the fact that it works is not in question."

It is a mistake, however, to reify these configurative processes into mental modules that bear no relation to the anatomy of the embodied brain or to posit linear logical models of cognitive decision-making that do not correspond to the reciprocal, to-and-fro movements of figuration in experience, in the cortex, or in the interactions between brain, body, and world. These are some of the problems with the terminology of frames, scripts, and preference rules employed by cognitive narratology. As Jahn acknowledges, these notions were developed by "artificial intelligence" theorists "to replace the concept of context by more explicit and detailed constructs" that "aim at reproducing a human cogniser's knowledge and expectations about standard events and situations"–with "frames" referring to "situations such as seeing a room or making a promise," and "scripts" encompassing "standard action sequences such as . . . going to a birthday party, or eating in a restaurant." The brain is not a computer, however. As hermeneutic phenomenologist Hubert Dreyfus points out, computers lack context, background, and prior experience that we as embodied conscious beings typically employ in testing hypotheses about how to configure a situation we encounter, whether in a text or the world, and replacing this deficiency by positing pre-set mental constructs that do the work only displaces the problem that needs to be solved. Rather than explaining the processes whereby the embodied brain configures experiential contexts, these constructs instead call attention to what computers can't do.

"Seeing as" sets in motion interactions between brain, body, and world that are fluid, reciprocal, and open-ended, and pre-set schemata like frames and scripts are too rigid and linear to do justice to these sorts of dynamic, recursive processes. This is why psychologist Richard

Gerrig, whose work on reading is widely (and rightly) respected among cognitive narratologists, has recently parted company from what Jahn describes as the mainstream view, in the process rejecting the term "schema" as too rigid and formulaic. Gerrig prefers instead to speak of "memory-based processing," a concept that recognizes that "readers' use of general knowledge" is "more fluid and more idiosyncratic" than the terminology of frames and scripts can capture.

The linear, overly tidy notion that cognition is governed by preference rules also needs to be abandoned. According to Jahn, "a preference rule is usually cast in the form *Prefer to see A as B given a set of conditions C*." In its favor, the notion of "preference" is not absolute and leaves a little wiggle-room for probabilistic variation, but the problem with structuring preferences into "rules" is that these posit a linear chain of decision-making, following the form of a logical proposition: if C, then A implies B. This linear, mechanical, logical structure is not an adequate representation of how cognitive decision-making happens either in neurobiology or experience. Neurobiologically, it bears little relation to the interactive, top-down, bottom-up processes of the dynamical systems of synchronization and desynchronization in the brain. Neuronal assemblies form and dissolve according to patterns of habituation that result from the reciprocal reinforcement of connections that can be displaced by other syntheses, and these interactions are not like linear, mechanical algorithms. Experientially, the uni-directional logic of preference rules is unable to capture the to-and-fro circularity of "seeing as" in the phenomenological process of configuring part-whole relations in a text or in life. Reading is not linear logical processing, and embodied cognition cannot be adequately modeled either by ordered hierarchies of modules or mechanical, linear algorithms.

The work of "seeing as" is not localizable in any particular region of the cortex but extends across the brain, the body, and the world. It is not governed by rules but develops habitual patterns through repeated experiences and is consequently always open to disruption, variation, and change. The formalist goal of identifying orderly, universal structures of mind, language, and narrative doesn't match up well with the messiness of the brain or with how cognitive patterns emerge from our embodied experiences of the world. The consensus among neuroscientists is that the brain is a bushy ensemble of anatomical features whose functions are only partly fixed by genetic inheritance and are to a considerable extent plastic and variable depending on how they connect in networks with other, often far-flung cortical areas. These connections develop and change through experience according to Hebb's law, a fundamental axiom of neuroscience: "Neurons that fire together, wire together." As neuroscientist Stephen E. Nadeau points out, "brain order is chaotic rather than deterministic; rules are not defined but instead emerge from network behavior, constrained by network topography" and connectivity (not all parts of the cortex can do everything, and they cannot interact if they are not linked by the axons through which neurons exchange electro-chemical charges). Whatever order can be found in language and cognition results, he explains, from patterns of reciprocal relationship "acquired through experience," and these patterns are attributable less to innate, genetically determined anatomical structures than to "statistical regularities of experience."

The brain, in short, is not an orderly structure consisting of rule-governed relations between fixed elements like a computer with hard-wired connections between components that operate according to logical algorithms. Much messier, more fluid, and more open to unpredictable (if not unlimited) developments than this linear, mechanical model assumes, the brain is an ever-changing ensemble of reciprocally interacting parts whose functions may vary according to how they combine with other elements. Modular models of the brain, once popular during the heyday of "artificial intelligence" models in cognitive science, have fallen out of favor because cortical regions are not autonomous and orderly. As neurophenomenologist Shaun Gallagher observes, the brain is "a dynamical system [which] cannot be explained on the basis of the behavior of its separate components or in terms of an analysis that focuses on the synchronic, or static, or purely mechanical interactions of its parts"; "the parts of a dynamical system do not interact in a linear fashion" but, rather, "in a non-linear way, reciprocally determining each other's behavior." Patterns of relationship can become established over time as particular interactions recur and reinforce existing connections or propagate and strengthen new ones, but how repeated experiences lead to the formation of habits through Hebbian "firing and wiring" is a better model for understanding these patterns than the genetically fixed, orderly structures assumed by the epistemological formalists. Pre-programmed modules and linear algorithms are not a good model for understanding the workings of the brain.

The structures of neural anatomy are limiting but not ultimately defining. Different cortical locations have particular functions that can be disabled if they are damaged, but no region works alone, and its role can vary according to how it reciprocally interacts with other areas. Function and connectivity can change with experience. The visual cortex of a blind person, for example, can adapt and become responsive to touch when reading Braille, and some sight-deprived people as well as animals have been shown to have superior sound localization because the unused parts of their visual cortex are recruited for auditory functions. These instances of plasticity may seem exceptional, but they are examples of the general rule that the "function of individual brain regions is determined, in part, by the network of brain regions it is firing with." According to neuroscientist Karen Lindquist, this is why there is "little evidence that discrete emotion categories can be consistently and specifically localized to distinct brain regions." Her review of the experimental evidence shows, for example, that the amygdala is not uniquely and exclusively associated with fear but is also active "in orienting responses to motivationally relevant stimuli" that are "novel," "uncertain," and "unusual." Various studies have similarly shown, she points out, that the anterior cingulate cortex, typically connected with disgust, "is observed in a number of tasks that involve awareness of body states," including "awareness of body movement," "gastric distention," and even orgasm.

Anatomical location and cortical structure alone cannot explain embodied cognition. Brain-body-world interactions can affect not only internal connectivity but also the functions of particular cortical regions. To understand a complex cognitive phenomenon like vision, emotion, or language, it is not enough to identify structure and modularity (as the formalist models assume); it is necessary, rather, to trace the configurative, non-linear, to-and-fro processes through which various components of our dynamic cognitive systems interact and reciprocally constitute each other.

Language is what neuroscientists call "a bio-cultural hybrid" that develops through the interaction of inherited functions and anatomical structures in the brain with culturally variable experiences of communication and education. Although some parts of the brain are known to be linked to language (lesions in Broca's and Wernicke's areas, for example, can disrupt syntactical or semantic processes), Nadeau points out that "linguistic function taps the entire cerebrum," and recent fMRI-based research has confirmed that language entails far-flung syntheses of cortical areas and connections between the brain and the body. There is no single module that governs language and no discrete, anatomically identifiable set of regions that would constitute the grammar unit predicted by structural linguistics. As Nadeau explains, "the grammar anyone of us uses is not intrinsically universal. . . . Instead it is based on the statistical regularities of our own linguistic experience (instantiated in neural connectivity), which have been determined by the modest community of people we have conversed with or read."

Such a probabilistic model also helps to explain the duality of language as a set of regularities open to innovation, variation, and change. As neuroscientist Jean-Pierre Changeux argues, the Hebbian explanation of stochastic regularities offers a better account of the creative capacities of language than pre-fixed formal systems can provide. On the one hand, language is a set of shared codes, evident in its recurring patterns, that support intersubjective communication and well-formed sentences. On the other hand, the irregularities of language are also vitally important because they make possible unpredictable if constrained possibilities for linguistic innovation through rule-governed or rule-breaking creativity. In accord with a probablistic model, structures do not completely decide in advance all the ways they can be used (innovation within the rules is possible), and sometimes new configurations can emerge as previous connections are replaced by new ones (transgressing existing rules is not always wrong, as with a novel metaphor that at first may seem like a category mistake but then becomes accepted and gets adopted into the lexicon).

If language and narrative are bio-cultural hybrids, any trans-cultural, trans-historical regularities in their functions and forms are a product of variable but constrained interactions between brain, body, and world and not universals that are homologous to logical structures of the mind. The sources of these regularities are typically both biology and culture; it's not simply that nature is fixed and culture variable. Similarly, any recurring patterns in the stories we typically tell each other are the mixed products of interactions between our species' neurobiological equipment and repeated experiences we are likely to undergo. If stories across the world have recurrent forms, this is not a result of narrative structures that reflect universal cognitive schemata. Rather, as bio-cultural hybrids, the patterns identified by various narrative theories have probably developed because evolved cognitive proclivities shared by members of our species have interacted with recurrent, typical experiences to produce configurative relations between brain, body, and world that demonstrate statistical regularities. These patterns are not logical structures but habitual configurations that are variable but constrained within limits that are attributable to the regularities of both biology and experience.

Cognitive narratology needs to break with its structuralist legacy and embrace the paradigm-shift proposed by the various pragmatically oriented, phenomenological theories of narrative that have contested the formalist program. If we want to understand stories, logical structures and taxonomies won't do the job. What we need to know, rather, is how elements combine into patterns through their interactions in lived experience and embodied cognition. How narratives participate in the formation and dissolution of patterns in the embodied brain's interactions with the world is the right question to ask if what we have is not a logically ordered, formally structured mind but a bushy brain that is an ensemble of relationships that get fixed over time but are open to a future of variation. Those interactions are the means by which stories help the brain negotiate the tension between pattern and flexibility thanks to the play of their concordant discordances.