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Abstract:
This article traces the contributions of mirror neuron theories in neuroscience to debates on literature and related theories of mimesis or, as Erich Auerbach defined it, the representation of reality. The “ensemble” descriptor used for the visualization technologies on which we currently depend to chart the neuronal firing in the human brain is also an apt term for an additional translational issue between structure and what one might call the philosophical domain. The most carefully established data of brain activity is empirically confirmable on the micro level. Moving from it to the so-called “higher order” or more complex issues of meaning and use by humans, not least in cultural life, requires in effect a translation from micro evidence to ensemble evidence. Within the neurosciences, such translational processes are objects of seduction and suspicion at once. Yet an “ensemble” principle is not only active in brain mapping evidence, but in the “single brain” to “social brain” evidence field for neural mirroring. The brain in isolation represents only a slice of the field of the dialogic brain, the brain performing social cognition of others, the

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brain bringing the other's existence into the individual's embodied space through the individual's internal simulation. This essay moves from the concept of the social brain to the suggestion of an ontological priority of representation in the mirror neuron paradigm. Is literature itself a relative of brain mirroring processes, and thus a form of biomimesis? And if we recognize literature and other representational processes as a part of "the human ensemble," should we also recognize the capacity of literature and other art forms to mimetically influence our performance of physiological being?

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Literary Biomimesis: Mirror Neurons and the Ontological Priority of Representation

Deborah Jenson and Marco Iacoboni

Mirror Neurons and the Problem of the Ensemble

Often the discoveries that change our understanding of the human—as process and product—are translated through the animal. This is certainly the case with the mirror neuron paradigm. In the laboratory of Giacomo Rizzolatti in Parma in the late 1980s and early 1990s, researchers heard and saw the same class of neurons in the F5 area of the frontal lobe of macaque monkeys firing when the monkeys themselves executed an action, such as grasping an object, and when the monkeys observed lab staff grasping an object. It gradually dawned on the researchers that a unique alignment of execution and perception was at stake: an internal, physiological, mimetic tracing of another's experience. After this preliminary and almost subliminal evidence, they carried out rigorous neurophysiological experiments to verify it (di Pellegrino, et al. 1992). In 1996, they first used the resonant term "mirror neuron" in the journal *Brain* (Gallese, Fadiga, Fogassi and Rizzolatti). The crafting of research results over the second half of that decade evolved into a paradigm of specifically human language, "mindreading," and imitation[1]—long before the capacity existed to do direct single cell studies of the same empirical phenomena in humans. In 2010, single cell studies of neural mirroring—with important variations from the anatomical regions specialized in mirroring—in human surgical patients undergoing treatment for epilepsy were finally achieved, in a study by Roy Mukamel, et al. The current article traces the contributions of mirror neuron theories in neuroscience to debates about what has been framed as among the most "human" of social areas: literature, and related theories of mimesis or, as Erich Auerbach defined it, the representation of reality.

It should be acknowledged from the outset that the mechanics, politics, and philosophical orientation implicit in using mirror neuron research to explore a historically human-associated field like literature and mimesis will exert a consistent undertow on our project here. To begin with, there are the concrete technical obstacles to exploring the brain in general, and the human brain in particular. Monkey research, generally on members of the macaque family, involves brain surgery to insert electrodes that do the single cell recording that remains the gold standard of the most compelling empirical evidence on brain mechanisms. Brain mapping, through fMRI (functional magnetic resonance imaging) and other visualization techniques, remains a visualization of the ensemble activity of many neurons, rather than single neurons. Inasmuch as single cell studies are conducted with animals and ensemble activity is the hallmark of much translation of single cell research to actual human brains, it is not easy to cross-test ensemble visualizations in humans and animals. It is difficult to arrange for

[1] On this paradigm see pp. 4-5 below.

unanesthetized animals to lie still for a long period in a loud, cramped machine, yet results from awake animals carrying out normal behavior are far more useful than results from anesthetized animals. It can be difficult to adapt technology to the study of animals of different sizes; imaging neuronal activity in animals as small as songbirds is a challenge in brain mapping studies, although single-cell neural correspondence in the form of auditory/vocal mirroring has been recorded by Richard Mooney and others (Keller and Hahnloser 2009; Prather, et al. 2009; Prather, et al. 2008). Our closest relatives, the great apes, unlike the monkeys in question in mirror neuron studies, often fall between the cracks of both ensemble and single cell approaches. Researchers will not conduct the more invasive electrode-based testing on chimpanzees or other apes for the same reasons that they will not do so on humans; at the same time, the sheer physical size and strength of apes makes the movement-based challenges of brain scanning all the more acute, although a few researchers have managed to bridge this divide (see for instance Hopkins, et al. 2010) by using PET (positron emission topography) scans, which can provide a very gross metabolic trace of what the animal was doing before the scan. In short, technology, as well as species-based differences and the research protocols geared to them, adds layers of translation to scientific inquiry into the human brain.

The "ensemble" descriptor for the evidence revealed by visualization technologies aptly evokes an additional issue of translation between structure and the philosophical domain. The most precisely established data of brain activity are empirically confirmable on the micro level. Moving from this level to the so-called "higher order" (or more complex issues of meaning and use by humans), not least in cultural life, requires in effect a translation from micro evidence to ensemble evidence. Within the neurosciences, such translational processes are at once objects of seduction and suspicion. Translation from single cell to more abstract issues rooted in ensemble evidence means not only moving from one field of technique and representational modality to another but also diversifying the goals of the experimental processes.

The diversification of the field of interpretation within the neurosciences also raises the question of the politics and the conceptual ramifications of transdisciplinarity. All intellectual endeavors are situated within a field of implicit or explicit claims about the brain. This creates a healthy dialogic tension between neuroscience and the study of topics including consciousness, memory, imitation, and emotion in the humanities. Yet humanist analysis of the descriptive dimensions of empirical science—the meeting point of experimentation and the words to describe it—frames neuroscience results within a historical ensemble of culturally evolving discourses. The humanities-related exploitation of neuroscience concepts often involves not only a movement from one vocabulary to another, one side of campus to another, but also a movement from empirical inquiry to critique of empiricist epistemologies. Conversely, the increasingly philosophical allure of neuroscience deterritorializes the study of cultural forms and products of human cognition, such as arts and literature, from a humanities niche to a broader transdisciplinary field of diverse inscriptions and readings.

What one could metaphorically call an "ensemble" principle is not only active in the species discontinuity and technological diversity of brain mapping evidence and its interpretive fields, but in the "single brain" to "social brain" evidence field for neural mirroring, from its very first monkey-to-human observational circuit. The relatively new field of "social cognition" or "social neuroscience" involves movement from the study of

the brain *qua* brain to the study of intellectual processing that cannot be precisely mapped on the level of the single human brain. The methodological rationales of mirror neuron researchers have been central to the millennial genesis of this self-consciously delimited field of social neuroscience, which continues to investigate single cell circuitry, but with a mandate to map social cognition and its larger role in the constitution of singularly human degrees of refinement in reading the intentionality of others. A recent volume in the field explains the mandate of social neuroscience to move from a single brain focus to a research ensemble of interactive brains:

> [Social neuroscience] emphasizes the importance of understanding how the brain and the body influence social processes, as well as how social processes influence the brain and body. In other words, social neuroscience is a comprehensive attempt to understand mechanisms that underlie social behavior by combining biological and social approaches. (Harmon-Jones and Winkielman 2007, 4)

An additional emerging field of "cultural neuroscience" also explores the brain in regard to more historically and regionally defined ensembles (Losin, Dapretto and Iacoboni 2009; Losin, Dapretto and Iacoboni 2010). In this nascent field, the interdisciplinary collaboration between neuroscientists, social scientists, and humanities scholars seems indeed necessary to plumb the ensemble of intelligence that undergirds culture.

University of Parma researcher Vittorio Gallese, in his 2004 "From Mirror Neurons to the Shared Manifold Hypothesis: A Neurophysiologic Account of Intersubjectivity," framed the focus of neuroscientific research on the individual brain as solipsistic: "Solipsism implies that focusing on a single individual's mind is all that is required to define what a mind is and how it works" (180). For Gallese, "the social dimension" of our neurobiological life is so determining that "all levels of interaction that can be employed to characterize cognition in single individuals must intersect or overlap to enable the development of mutual recognition and intelligibility" (180). The brain in isolation, in other words, represents only a small portion of the field of the "dialogic brain," i.e., the brain performing social cognition of others, the brain bringing the other's existence into the individual's embodied space through the individual's internal simulation. Gallese's approach to an interpersonal brain can also be described as a critique of "sub-personal" brain studies. The mirroring brain optimally would be studied not only by the monkey observing the researcher, but by human subjects observing other humans (Dapretto, et al. 2006; Iacoboni, et al. 2004; Iacoboni, et al. 1999), and even by the researcher observing the monkey (Buccino, et al. 2004), monkeys observing monkeys, researchers observing researchers, or any other non-solipsistic relation of research subjects and researching subjects. Indeed, a recent trend in brain imaging studies on mirroring involves the participation of more than one subject, and even the analysis of how activity in one brain is reflected by activity in the other brain (Schippers, et al, 2010).

In justifying the multiple or dialogic-brain focus of this particular research area, mirror neuron researchers—especially those in Italy or with ties to the Parma group—have raised questions about intersubjective experience and its representations that resonate not just with the humanities, but, to a remarkable degree, with the longer history of humanist philosophy. From what Gallese calls our "embodied experience of the world" (2004, 180) and "the identity we experience as individual organisms, the sense marking our uniqueness among other beings" to "the identity we experience in other social individuals, the sense of 'being like you'" (180-81), or the "we-centric" process of social development, mirror neuron researchers formulated new ways of interrogating how we know that we are. How do we know that others are? How do we understand and act on the separateness or the mutual constitutiveness of the individual organism and the social world? Limited as we seem to be by the physical boundaries of our own organic being, how do we know to value the experience of those outside of ourselves? Is understanding itself, as philosopher Mark Johnson has suggested, a form of simulation? (2007, 164). Can we direct or limit the imitative genesis of knowledge? When is a simulation not just a copy, but an innovation, even a product of genius?

Reading Books, Reading Minds, and Embodied Representation

Researchers in the humanities typically explore the above questions using literature or other media and arts—material texts—as transcriptions of the social brain. Even in the "linguistic turn" of the twentieth century, in which semiotics reframed texts as potentially internal to mental processes and perception rather than external, the notion of their secondary nature, their deferral and difference-*différance* in the French neologism coined by Jacques Derrida—from ontological existence remained crucial. Cognitive processing of signifying entities/relationships was held to turn on the implicit contrast between one arbitrary sign and another in the conventional chain of their associations within alphabets or discourses. (In Terry Eagleton's quick summary, "'Cat' is what it is only by fending off 'cap' and 'bat,' but these other possible signs, because they are not constitutive of its identity, still somehow inhere within it" [2008, 111].) By contrast, in social neuroscience, the ability to read—whether to read behavior or the "mind"—does not rely on external or material traces, or even on secondary processing of signs in their relationship to referents, but on behavioral and physiological existence itself—although the exact mechanisms and consequences of this reading are subject to increasingly fine-tuned debate.

As the humanities move beyond anchoring canons of cultural forms and products—"great works" that have become increasingly subject to critique as nationalist and elitist hierarchies of human perception, expression, and technology—such concepts of inevitable reading of behavior and mind are potentially regenerative. In the place of fixed selections of great works, neuroscientific theorizations of imitation and representation are compatible with the transition—virtually required by the contemporary dominance of "new media"—to comparative and global understandings of forms and products of the intellectual ensembles that underpin human culture. Such transitions are, of course, not new; they represent an endless metamorphosis of the role of "humanities" in the evolution of culture. In a famous scene in Victor Hugo's 1836 novel *Notre-Dame de*

Paris, print culture was poised to "kill" the earlier signifying technology of the cathedral, which, with its stained glass visual narratives, its verbal sermons delivered by preachers, and its visceral reach toward an emblematic sky, had accommodated the largely illiterate "readers" of a metaphysical world. The printing press and the banal paper and ink micro-product of the published book—a portable *speculum mundi* or mirror onto the world—allowed for the preservation and dissemination of meaning on a more individualized scale, within collectivities oriented toward the fundamental social mobility of alphabetic literacy and canons of literary rather than ritual knowledge. Although Hugo's affective and dramatic representation of the cathedral in *Notre-Dame de Paris* paradoxically contributed to the self-justifying power of the printed novel, it also serves as a reminder that the privileging of print culture has contributed to the marginalization of the cultural forms and products of many other societies and histories. In the context of cognitive neuroscience, literature, whether preserved in print or in other media, emerges with renewed force as a sophisticated projection and recording of consciousness, yet the intellectual ensemble of the social brain cannot always be mapped within the history of print culture, or within the epistemological terms of the regional intellectual histories that have privileged print culture.

Originally, mirror neuron research was synergistic with cognitive psychology paradigms of "mindreading," but it subsequently diverged over the problem of logical inference and conscious representations. Gallese, at a conference in Tucson in 1998, had forged a collaborative relationship with the Rutgers cognitive scientist and philosopher Alvin Goldman, a main figure in the area of "simulation theory" or "enactment imagination" that had already existed for a number of years. Gallese's 1998 article with Goldman connecting mirror neurons to the longer history of simulation theory, "launched" the mirror neuron phenomenon in its more cross-disciplinary and public form. Goldman, in *Simulating Minds*, writes that one of the most salient social characteristics of humans is the ability to engage in reading one another's minds. "People attribute to self and others a host of mental states," he notes, as do all organisms capable of responding to or predicting others' behavior; "but *having* a mental state and *representing* another individual *as* having such a state are entirely different matters. The latter activity, *mentalizing* or *mindreading*, is a second-order activity; it is mind thinking about minds" (2006, 3). For Goldman, imitation, as "behavioral duplication of an observed action, whether of its goal, means, or both," is developmentally necessary to mindreading. The imitation is "extended," "deferred," and "attempts to enact in one's own mind a target's mental states or processes" (196). These positions are increasingly incompatible with those of mirror neuron researchers, who are focused on the reading of behavior without the link of logical inference and extended or deferred mental duplication.

As Gallese commented in an unpublished 2010 interview with Deborah Jenson at Duke University, Goldman's interpretation of minds reading minds through representational processes should be complemented by a more direct approach to others' behavior.[2] Theory of mind research relies on what Gallese sees as a potentially tautological imaging of the activation of brain areas during elicited mindreading behavior—a lighting up and charting of brain regions not unreminiscent of phrenology. Given such technological limitations of the capacity to document the physiological

[2] [Editors' note: see also the interview with Gallese by Wojciehowski in this volume.]

mechanisms leading to the activation of a given brain area during mind reading tasks, Gallese focuses on simulated behavior rather than on cognitive representations of the other's mind. He sees the intense mimeticism of social cognition as grounded in the variety of the motor palette, even when the motor experience yields such ostensibly abstract matters as the agent's sense of being the owner of a performed action, or the observer's self-disambiguation from the agent. Although Gallese notes that the mirror mechanism is not able to provide us with the reasons that might underlie motor intentions, he does feel that embodied simulation is a functional mechanism in social cognition. "We map the actions of others onto our own motor system," Gallese argues, "creating a mutual resonance of intentionally meaningful sensory-motor behaviors, but not specific mental state inference."

The discourse of "mentalizing" or mental state inference is thus filtered through the motor system in mirror neuron research, yielding a corresponding emphasis on imitation—not on imitation as a copy of an original, but imitation as an executory contagion. The term "mentalizing" remains largely foreign to the study of literature and the arts, and merits critical historicization for its early nineteenth century origins denoting a kind of sublimation of baser instincts, a determination to live in a cognitive/spiritual sphere sharply demarcated from the assumed coarseness of corporeal life. (The next major wave of the meaning of "mentalizing" emerged in discussions of Zen philosophy in the mid-twentieth century, where it was used critically to connote "living in one's head" as an obstacle to meditative practices.) But the term "imitation," central to mirror neuron research, is of course a dominant term in translations of the classical notion of mimesis. Historically, mimesis is a key conceptual portal to the vast array of representational forms, practices, and cultures that make up the field of the humanities and arts. In practice, Gallese stated in the interview, both Theory of Mind research on cognitive representations of others' experiences and mental states, and mirror neuron "intercorporeity" as mimetic appropriation are profoundly relevant to the contemporary study of mimesis. But mirror neuron research has been particularly important in recalling a startlingly developmental side of imitation with which ancient philosophers appear to have been quite comfortable, as demonstrated in Aristotle's famously oblique precept in the *Poetics* that humankind is a mimetic animal (Gans 1993, 8).

Mimesis as Imitation: Definitions Ranging from the Fake to the Essence of the Human (Animal)

As Stephen Halliwell notes in *The Aesthetics of Mimesis*, even before Plato, mimesis referred to categories as distinct as visual resemblance, behavioral emulation, impersonation, poetic or musical expression, and metaphysical conformity between natural and immaterial realms. "The common thread running through these otherwise various uses," according to Halliwell, "is an idea of correspondence or equivalence" (2002, 15). In the mirror neuron paradigm, mimesis is a developmental intercorporeal synergy. Imitation need not have an external or performative dimension, like mimicry, or a material product, like a painting: even without physical miming or linguistic or artistic

representation, one imitates the behavior of others on a neurological level, and one's ontological being is inseparable from that motor apprehension.

In both humans and primates, there is a window of infantile development in which mirror neurons are thought to lead to a direct motor response. Pier Ferrari and other Italian researchers, again at Parma, continuing the foundational work of Meltzoff and Moore in the 1970s, documented intensive and automatic imitative activity by newborn rhesus macaques (Ferrari, et al. 2006) between three days and two weeks of age, correlating to an imitation phase of roughly three months in human infants. This phase shows that monkeys are "imitation ready" on an evolutionary scale, even if they do not yet learn from imitation the way humans do.

Cognitive psychologist Merlin Donald—the innovator of a "mimesis paradigm" in psychology that has been in many ways folded into the mirror neuron phenomenon—argues in *A Mind So Rare* for a crucial cognitive and developmental dimension of mimesis:

> Mimesis is still the elemental expressive force that binds us together into closely knit tribal groups. Of all our human domains, mimesis is closest to our cultural zero point. It is also closest to emotion. Mimetic capacity has huge emotional ramifications because it involves both the conscious elaboration and the suppression of emotion.… In its purest form, [mimesis] is epitomized by four uniquely human abilities: mime, imitation, skill, and gesture. These are direct offshoots of the expansion of the human executive brain system. (2001, 263)

Especially visible in earliest development is what Donald calls "kinematic imagination": "The cognitive core of mimesis is kinematic imagination, the ability to envision our bodies in motion" (271). Donald sees the family itself as a small theater-in-the-round of kinematic dramas: "Early in development, the child connects with a mimetic social network ruled by custom, convention, and role taking. The family is a small theater-in-the-round, featuring a series of miniplays, in which each member must assume various roles" (266).

Later in life, when the firing of mirror neurons is not so directly followed by motor response, the precise relationship between sensory input and motor representation remains oblique, as Catmur, Walsh, and Heyes noted in a 2007 study on Sensorimotor Learning. In effect, when we experience the firing of mirror neurons in response to someone's hand movements, we are learning about that kind of action. Many scientists therefore believe that mirror neuron experience is key to our social, linguistic, and cognitive development. Leonie Welberg summarizes,

> The "mirror properties" of the mirror system are not completely innate. Rather, they can be trained, through sensorimotor experience, to transform observation into action. These findings imply that insufficient social interaction and consequent inadequate sensory experience might affect the

> development of the mirror neuron system, for example, in children with autism. (2007)

Indeed, some researchers are now hypothesizing that autism is a sort of copying disorder—a failure to copy—as in this 2001 assertion by Williams, et al.:

> We focus…on an imitative disturbance involving difficulties both in copying actions and in inhibiting more stereotyped mimicking, such as echolalia. A candidate for the neural basis of this disturbance may be found in a recently discovered class of neurons in frontal cortex, 'mirror neurons' (MNs). These neurons show activity in relation both to specific actions performed by self and matching actions performed by others, providing a potential bridge between minds. (Williams, Whiten, Suddendorf and Perrett 2001)

Researchers are currently working on strengthening this bridge between minds in various disorders on the autism spectrum by providing imitative therapies (Ingersoll 2010).

Imitative faculties in humans have always been associated with animals, in complex ways. The tensions of monkey-to-human conclusions on the science of imitation plague mirror neurons through the omnipresent witticism "monkey see monkey do." When one really thinks about it, "monkey see, monkey do" is one of those loaded phrases. On the one hand, it appears to establish a subtle but definitive distinction between primates and humans: it implies that monkeys are not human because they are imitative rather than rational; that you will not find monkeys musing the Cartesian dictum *cogito ergo sum*, "I think therefore I am." On the other hand, the monkeys in question are actually veiled representatives of humans, since as in all proverbial expressions, the cautionary experiences of animals and objects, from tortoises to kettles, contain discrete commentary on the pitfalls of the human condition. In this case, mimetic monkeys represent what humans should avoid: a life of conventionalism and lemming-like imitation of their peers, of unthoughtful and automaton-like behavior. The mimetic monkeys are analogies for humans making monkeys of themselves, leaping before they look, parroting rather than speaking, etc.

And the expression comes not just at the expense of the dignity of monkeys: its a-grammatical formulation—not the plural monkeys see and monkeys do, nor the singular monkey sees and the monkey does—arguably shows the ethnocentric bias of mimicry of a colonized speaker, who has only incompletely grasped the principles of grammar in the languages of Western colonialism. Darwin himself had queried whether a heightened mimetic faculty was "'common to all men in a savage state'" (quoted in Taussig 1993, 75). Since the period of the Reformation, Western culture has traditionally encoded the mimetic as the primitive, and displaced it onto the "others" of colonial expansion, yielding the category of "mimic men" as in V.S. Naipaul's 1967 novel by that name. New postcolonial nations have had to engage very actively with the legacies of being branded as imitators, as was particularly clear in the case of the first self-emancipated republic of

former slaves, Haiti, beginning in 1804. Charges that the conquerors of colonialism had failed to conquer originality led Haitian thinkers to celebrate the imitative bases of cultural intelligence generally, as in the following quote by Louis Joseph-Janvier: "Imitation is not so simple.… What is civilization, in the end? Pastiche or copy. Everywhere. All civilization consists in an exchange of imitations, more of less appropriate, intelligent, and opportune" (quoted in Jenson 2011, 336). Frantz Fanon contextualized a more pathological "game" of "appropriating the white world" for the colonized subject (2008, 19). "Monkey see, monkey do" obliquely gestures to a divide that extends from the human and the primate to the rational and the imitative to the colonizer and the colonized.

Recent research in the neurosciences demonstrates, however, that it is erroneous to identify the human with the transcendence of imitation. Yet is probably erroneous to identify the human with any single quality or quantity at all. Historically, no sooner is an area or marker of human function qualified as "uniquely human," than animal scientists confirm its presence among animal populations as well. An "only us" methodology is inherently suspect of harboring human-centric bias that allows us to view the world according to static anthropomorphic criteria. Any area of human capacity celebrated as confirming what is best about the human—say, in the past, rationalism, or consciousness of consciousness—turns out to be involved in excluding, or dividing and conquering, human populations by the measure of their circumstantial performance of this capacity cum standard. Definitions of what is human traditionally have had a way of separating out the rational principle from the chaff of what seems to fall away from it. When people's bodies are particularly strongly determined as *physical*, through markers like pregnancy or disability or differences of skin color, or when people come from societies less historically invested in rationalist traditions, they may not be welcomed into the community of what French philosopher Blaise Pascal called "thinking reeds" (2001, 120) on equal terms; "thinking reeds" have often used other "thinking reeds," redefined as empty vessels, as slaves. The making of the human is not about finding accurate measures of something corresponding to the human, not even about highlighting values targeted as human, but about understanding the histories and epistemologies framing human communities, their needs, their pitfalls, their futures.

Mirror Neurons and the Ontological Priority of Representation

Mirror neurons suggest a kind of ontological priority of representation. Representation is internal, it is physiological. As such, literature itself is reframed as a kind of biomimesis, so ancient that it now appears to us completely aligned with culture rather than nature: an imitation of neurobiological technologies of executory representation and motor intersubjectivity.

Biomimesis, which now routinely informs pragmatic and empirically oriented fields such as biomedical engineering, features inspiration as a design principle. As Phillip Ball notes in his 2001 article "Life's Lessons in Design," "There is such a long and colorful history of engineers, scientists, and artificers gaining inspiration from nature that one could be forgiven for thinking that all the best ideas have been spoken for." Biomimesis

was, Ball explains, "as much an aesthetic as a practical pursuit," with the Eiffel Tower inspired by bone structure, the Wright brothers inspired by the sight of vultures swooping, etc. In the contemporary moment, biomimesis increasingly imitates or integrates designs from the living world at the molecular level, leading to the nanotech adoption of design principles not in the form of visible models like the vulture's swoop, but in processing and recombination mechanisms, economy and/or sequential substitutability of solutions, and so on.

The specific lexicon of biomimesis was launched with Warren McCulloch's 1962 discussion of "the imitation of one form of life by another" (393) and Ronald Breslow's subsequent extension of the term (which he believed was his own coinage) to molecular "mimicry" of enzymes in chemistry (1972). As a 1978 energy technology treatise succinctly noted,

> The term 'biomimetic' is a compound of *bio* meaning life or living organism (from the Greek *bios,* life) and mimetic, showing mimickry [sic] (from the Greek *mimesis,* to imitate): hence *biomimetic,* a method or procedure based on or derived from a living organism by imitation or mimickry [sic]. A 'biomimetic' technology, then, is predicated on a translation or abstraction of a process used by a living organism for a similar end. (Hill 1978, 500)

In recent years, the politics of the biomimetic correspondence have undergone thorough analysis, with, as Hub Zwart argues, the goal to "reintegrate the technosphere into the biosphere (mutual pervasiveness of technology and nature)" (n.d. 17). Peter Sloterdijk has coined the term homeotechnologies to describe the collapse of the nature/technology (or allotechnology) divide in the sustainable embedding of biomimetic innovations.

Literature is so imbued with aesthetic connotations that it generally eludes conceptualization as a technology. And yet when one considers the capacity of narration to allow readers to simulate large expanses of chronological experience in a brief reading episode, or of poetry to condense complex messages through metaphor and metonymy, or of rhythm and rhyme to create mnemonic prompts via sensory reinforcements of meaning, or of fictional characters to serve as avatars of readers' affect, its sophisticated mechanisms become clear.

In neurological mirroring, the coincidence of execution and observation—the physiological reproduction of external stimulus—reframes mimesis within the fiber of being. The notion of the return in mimetic *re-presentation* is called into question by the motor simulation of the field of observation. If literary or artistic or performative representations double and extend basic neurobiological mechanisms, then the difference between presentation and representation is minimized, and mimetic processes are grounded socially, intellectually, cognitively, and physiologically; what Auerbach calls the literary representation of reality would be simply a relatively alienated, aesthetically codified, technologically adapted version of a human virtual capacity. It also suggests a

basic need for a new paradigm of representation and human mimeticism in the biological and philosophical dialogues of the new millennium.

If literature can be seen as a form of biomimesis, it is also important to note the capacity of literature and other art forms to mimetically influence our performance of physiological and cultural being. Christopher Prendergast writes, "if a generalized human mimetic activity founds artistic mimesis, it is also the case…that the forms of literary practice themselves actively furnish or influence, though in complex and diffuse ways, some of the models for the imitative practices of everyday life" (1988, 24). Uses of age-old literary techniques in advertising and propaganda are evidence of the capacity of mimesis to train experience.

The notion of an ontological priority of representation contrasts with the extraordinarily influential Platonic depiction of representation as several times removed from the truth, as mere copies or simulacra, or as texts representing our linguistic mediation of a world beyond our specifically cognitive access. In Plato's allegory of the cave, human beings are chained in an underground den from childhood onward, prisoners of a screen—the cave wall—on which an optical illusion of reality is projected by shadows and echoes of people walking by carrying objects such as figures of animals. The poor prisoners do not recognize that their lives are fixed on representations—"imitations three times removed from reality" (2001, 370)—rather than a world of light beyond the mouth of the cave. Their verbal interactions designate illusions, rather than giving names to reality. Adapted to their confinement, to leave the cave and look beyond the mouth to the day outside would be to experience the pain of unaccustomed movement by cramped bodies, and of sudden exposure to blinding light. The cave of representation is the lower world; direct access to higher truths characterizes the upper world.

The stern warnings about virtual reality-like experiences of representation in the *Republic* commemorate, according to Maryanne Wolf in *Proust and the Squid*, the anxieties of Plato's teacher Socrates about "transition" in the late fourth century B.C.E. "from an oral culture to a literate one and the risks it posed, especially for young people." This transition to a literate republic foreshadows our own contemporary "concerns about the immersion of children into a digital world" (2007, 70). In effect, a new technology of representation, even one as seemingly tame in our own day as text, brought to the fore the problem of how humans process and relate to virtual fields of experience. Do representational technologies inform us, or manipulate us? Do they bring what is out of reach into our ken, or distract us from an urgent present? What does it mean for societies when authors of representations supplant familial or cultural authorities in the competition to persuade the young?

Despite the condemnation of the superficiality of mimesis in the parable of the cave, in numerous other passages of the *Republic*, representations and imitation have a potent phenomenological impact. In general for Plato, the problem with mimesis is not that it is a shadow, but that humans become its shadow puppets. Socrates nudges his listener to condemn the avatar-like assumption of characters' identities by either producers or receivers of texts, to see the dangers represented by the fact that "this assimilation of himself to someone else is an imitation—either by voice or by gesture, of the person whose character he assumes" (2001, 92).

The Republic's ostensible condemnation and interdiction of representation is thus actually well suited to analysis of the stakes of simulation, virtual experience, and literary forms and products, in the cognitive sciences. Although Socrates situates representation in relation to "actions that the imitations copy," in other passages imitations are not mere copies, temporally secondary and physically external, or even three times removed from the truth, but the opposite—they "become second nature in body, voice, and mind." Because of the capacity of mimesis to create an experience of second nature, Socrates proposes banishing the sensory persuasions of poetry from the republic, and forbidding the representation of the denizens of the lower strata of civil society. In the theatrical domain, future legislators should "not act the part of either male or female slaves," or of "a woman who is suffering, grieving, or weeping, and certainly not one is sick, or is in love or in labor" (2001, 95). The *Republic* contextualizes representations as important but threatening mechanisms in socially contagious development and cognition.

In Plato's idea that imitations become second nature, we see that second nature is socially constructed to a large degree, but that it feels like nature, anchored in body, speech, and thought. The mimetic faculty is, according to anthropologist Michael Taussig, "the nature that culture uses to make second nature" (1993, 70). This second nature conforms in many ways to the logic of biology, but it is adaptable, educable, and socially produced. The neuroscience discovery of the mirroring mechanism shows both the physiology and the plasticity of "second nature." Representation in the mirror neuron paradigm is not simply a case of imitation that is far from reality, or imitation as what Hegel called "but a presumptuous sport" (2009, 80); it is a fundamental human processing structure in our encounters with others. Representation is not what is external and secondary: it is physiological and developmental, and entangled with our sociality. For Aristotle, as Halliwell says, the importance of mimesis lies in "the 'world-like' properties of artistic representation—its depiction…of things which *could* be the case—with its production of objects that possess a distinctive, though not wholly autonomous, rationale of their own" (2002, 152).

In the literary humanities, it has become somewhat difficult to engage with the complexities of the classical or the anthropological conceptions of mimesis, because in the late twentieth-century post-structuralist philosophical field, mimesis became a metonym for a naïve belief in the transcription of a static, capturable reality. Taussig complained in the 1993 *Mimesis and Alterity* that in poststructuralist literary theory, "mimesis has become that dreaded, absurd, or merely tiresome Other, that necessary straw-man against whose feeble pretensions poststructuralists prance and strut" (44). Such critiques of an allegedly transparent mimetic equivalence between representation and reality were especially common in discussions of "Western logocentrism," or the centering of Judeo-Christian culture around a divine presence/absence of the *logos* or truth.

When the problem of the difference or deferral of self-presence and meaning between representation and referent is reframed as a problem of a social motor field, the

connections between the mirror neuron paradigm and earlier conceptions of mimesis become clearer. In effect, if your experience is in my body, the inescapable problem of mimesis is simply that my body must also be in your experience in order for you to engage with it cognitively, even when you engage with the idea rather than the physical reality of my body.

However, even if the mirror neuron paradigm suggests that we are susceptible to cognitive privileging of models within our direct experience, the capacity to abstract from a model is obviously of primary importance in the plasticity of human cognition. As cognizant individuals we can imagine worlds beyond the reach of our own senses, essentially conferring self-like sensory experience to others. We do not rely on first-person narration in representations in order to comprehend them, but can step out of the platonic brain/cave and process the cognitive abstractions and multiplicity of free indirect discourse, omniscient narrators, and other devices of focalization that bypass the individual's sensory access to the external world.

Or at least we tend to think we can. A more nuanced view of the matter might be that we navigate laboriously between sensorily confirmed experience and the models we have processed of others' experience. Recent cognitive psychological analysis of readers' relationship to fictional characters and their narrative focalizers suggest that even in texts populated by a crowd of characters, readers do adopt the position of a given character, who comes to represent something of an avatar for them, despite the absence of first-person narrative positioning of that character. (Readers—and perhaps especially teachers of readers—may not be conscious of this tendency in themselves or others.) Such character adoption stances, not specifically linked to first-person narration, have been tested through a number of experiments, including spatio-temporal orientation to fictional objects within the fictional character's purview, recall of sentences describing events from the adopted character's point of view, speed in attribution of emotion to the adopted character, and formation of literary empathy specifically in the form of role-taking (Coplan 2004). This research implies that our neurobiological apparatus remains keenly involved in how we see beyond our individual noses. Perhaps it is not enough to philosophically dismantle egotistical perspectival principles; perhaps to a certain degree, despite our undeniable capacity to become extraordinarily versatile readers, we have a tendency to be prisoners to representations, whether oral, textual, or digital, relating them to ourselves and adopting/deploying them as avatars of our positions and needs. This is the same intersection theorized by Freud in *Group Psychology and the Analysis of the Ego*, when he noted that "A path leads from identification by way of imitation to empathy, that is, to the comprehension of the mechanism by means of which we are enabled to take up any attitude at all towards another mental life" (1921, 108 n.2). Or, as V.S. Ramachandran put it, "You cannot have 'free floating' qualia without a self to experience them" (2003). Accessing other mental lives from the confines of our own cognitive apparatus is no simple thing; yet mirror neurons allow us to do exactly that. Perhaps Socrates had a point that the virtual is powerful stuff in the self-imagination of the republic. Mimesis may be the problem, but it can be fought against with every cellular activation of our social intelligence—for which mimesis is also the training ground.

The neuroscience investigation of mirror neurons and the study of mimesis in the humanities reveal surprising symmetries, with a human ensemble evoked around

ensemble evidence, and ontology and mimesis merging through mirrors in the brain. Which one is the constructed reality? To pick up the trope attributed to "Saint-Real" in Stendhal's *Le Rouge et le noir,* is it the brain or the novel that is a "mirror we carry along the road" (1884, 153)?

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