The Cognitive Animal

Empirical and Theoretical Perspectives on Animal Cognition

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1 The Inner Life of Earthworms: Darwin's Argument and Its Implications

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I have been interested in the scientific knowledge of animal life and in how presuppositions, structures of argumentation, and language express and shape that knowledge. The ways of describing animals have varied in behavioral science according to the interconnected play of underlying assumptions, theoretical frameworks, and the kind of language that has been deemed permissible for portraying their lives. Mind is unavoidably implicated in different descriptions of animal life because the way in which behavior is understood and described always speaks to the question of animal mind, whether deliberately, implicitly, or by omission. This is the major theme of my work *Images of Animals: Anthropomorphism and Animal Mind* (2000). In this essay, I address the connections between assumptions, forms of scientific inquiry, language use, and animal mind by discussing Darwin's argument for the inner life of earthworms.

In his last work, *The Formation of Vegetable Mould, through the Action of Worms with Observations on Their Habits* (1881/1985), Charles Darwin investigated the impact of earthworms on the geological and biotic environment, and devoted part of his study to worm behavior and intelligence. He introduced the latter topic by expressing his wish "to learn how far the worms acted consciously and how much mental power they displayed" (Darwin 1881/1985, p. 3)—a formulation that turned out to be incongruent with most ensuing twentieth-century behavioral science. The question of whether animals act consciously has been regarded as problematic: ontologically problematic in that the existence of conscious action has been subject to doubt regarding many (and sometimes all) animals; epistemologically problematic in that conscious action has been regarded as not lending itself to scientific inquiry; and semantically problematic in that "conscious action" has warranted the pejorative and dismissive label of anthropomorphism. That Darwin researched conscious action in animals so genealogically distant from human beings was an anomalous action in the trends that came to govern behavioral research. The fact that he argued that earthworms exhibit intelligence was apparently discomfiting; the silence of behavioral science regarding Darwin's argument for worm intelligence speaks volumes.[1]

Darwin made a bold argument about the inner life of earthworms. I use the expression "inner life" here to capture something more comprehensive than "mental life" or "cognitive ability." These latter terms tend to allude to processes such as thinking, deliberating, or judging, whereas "inner life" includes a subjective viewpoint. In Darwin's portrayal, the inner life of worms is indeed a cognitive world—a world about which worms form judgments. The inner life of worms also includes their subjective world—a world of perception and work that they experience, rather than vacantly sleepwalk through. Darwin delivered both aspects of inner life—cognition and subjective experience. I discuss both these aspects here and after examining Darwin's depiction of the behaviors, intelligence, and experience of worms, I draw some conclusions that are pertinent to the question of animal mind in science today.

The Intelligence of Worms

Earthworms plug the openings of their burrows with leaves and petioles. This behavior was Darwin's main interest, and he began by asking why worms do this, surmising several purposes: to keep the burrows free of water and dirt, to provide protection from predators, and to block cold air currents. He then undertook observations and experiments to examine how earthworms handle leaves and other objects. He found that the pattern of plugging was too regular to be random, yet he also recognized that the pattern was too variable to be strictly instinctive. Darwin was ultimately compelled to admit that earthworms use judgment about the best way to pull leaves into their burrows—that they feel the shape of the leaves prior to grasping them. Darwin described this capacity of judgment based on the tactile sense as showing "some degree of intelligence" (1881/1985, p. 91).

By examining hundreds of leaves used by earthworms, Darwin found that most of the leaves were drawn in by their tips and only about 10 percent were pulled in by their stalks (petioles). He concluded that the pattern of plugging the burrows with leaves was not random. After distinguishing more carefully how worms handled different types of leaves, Darwin found that they drew broad-based leaves in particular almost invariably by their tips—only 4 percent were grasped by their stalks. "The presence of a foot-stalk," he observed, "which might have tempted the worms as a convenient handle, has little or no influence in determining the manner in which [broad-based] leaves are dragged into the burrows" (1881/1985, p. 66). Darwin's explanation was that handling a broad-based leaf by its stalk would be unwieldy, for as the worm pulled the leaf into the burrow, its broad base would encounter the ground abruptly, offering resistance that would be relatively difficult (although not impossible) to overcome (1881/1985, p. 68).

Darwin followed up this line of investigation by examining how worms handled leaves whose tip and base were the same width. The majority of such leaves were still drawn by their tips, but now nearly 30 percent were grasped by their stalks—seven times more than was the case for broad-based leaves. The large discrepancy between broad- and narrow-based leaves drawn in by the foot-stalk, Darwin indicated, was not accidental. The fact that worms "break through their habit of avoiding the foot-stalk" (1881/1985, p. 68) for leaves that are easier to pull into their burrows by the base suggested to him that worms formed judgments about the different shapes of the leaves and acted at least in part on the basis of these judgments.

The idea that the worms judged the shape of the leaves was further supported by Darwin's observations involving Rhododendron leaves, which have the peculiarity of curling around the midrib shortly after falling to the ground. Examining over two hundred fallen Rhododendron leaves—and before looking at what worms actually did—Darwin figured that the most efficient ratio of drawing them would be two-thirds by their base and one-third by their tip. Turning to his subjects, he found an almost exact match between his estimated base-to-tip ratio and the one executed by worms. "In this case," Darwin concluded, "the worms judged with a considerable degree of correctness how best to draw the withered leaves of this foreign plant into their burrows; notwithstanding that they had to depart from their usual habit of avoiding the foot-stalk" (1881/1985, p. 70).

It is impossible to go into all the details and nuances of Darwin's experiments, which include how worms handled pine leaves, various petioles, and artificial "leaves" that Darwin constructed from paper. His extensive observations led to the explanation, however "improbable" as he tactfully put it, that worms "show some degree of intelligence" (1881/1985, pp. 90–91). Darwin did not define "intelligence" in exact or technical terms,[2] yet its meaning emerges clearly in his meticulous study. For Darwin, the earthworms' ability to judge shape was the most significant indication of intelligence. He directly observed worms feeling the shape of leaves before grasping them. The connection between judgment and intelligence is stated clearly in the summary remarks of his study of worm habits:

> If worms are able to judge ... how best to drag [an object] in they must acquire some notion of its general shape. This they probably acquire by touching it in many places with the anterior extremity of their bodies which serves as a tactile organ. It may be well to remember how perfect the sense of touch becomes in a

man when born blind and deaf, as are worms. If worms have the power of acquiring some notion, however rude, of the shape of an object and of their burrows, as seems to be the case, they deserve to be called intelligent; for they can act in a manner as would a man under similar conditions. (Darwin 1881/1985, p. 97)

It is interesting that Darwin's reasoning was strengthened through analogy to the human case. He reminded his audience that when a person's tactile sense is the sole sensory modality, it becomes acute and capable of fine discernment. And he suggested that if a person used touch to assess the shape of an object and thereby determine how to manipulate it effectively—as worms did—this same act would indisputably be viewed as intelligent.

Darwin used "intelligence" as a distinct explanatory category, but not one that excluded supplementary accounts. He noted that plugging holes "is no doubt instinctive in worms" (1881/1985, p. 74), for they do not need to learn the behavior. However, instinct could not explain *how* worms actually handled leaves (including the leaves of plants foreign to their habitat), and their behaviors were not "so unvarying or inevitable as most true instincts" (1881/1985, p. 93). In the case of leaves that were just as easily drawn by their stalks as by their apex, the worms' persistence in grasping the apex was explained by their "having acquired the habit" (1881/1985, p. 68). So while Darwin argued that worms exhibit intelligence, he presented a composite view of their performance: Worms possess an inborn drive to plug their burrows; their intelligence consists in acting on the basis of the shapes of objects; yet over time, they acquire habits according to which they tend to behave.

Darwin realized that "worm intelligence" would be an oxymoron for skeptics and even for a commonsense viewpoint: "This will strike everyone as very improbable," he wrote (1881/1985, p. 98). Concern to sustain credibility is reflected in the scrupulous way he gathered, assessed, and presented evidence. Darwin also endeavored to preempt certain objections: He noted that little is known about the nervous systems of "lower animals," implying they might possess more cognitive potential than generally assumed. He included examples of "insect stupidity" (my term) perhaps intended to show that his discovery of worm intelligence did not express a sweeping conception of invertebrate capacities. And finally, Darwin averred that he had been initially dubious about the possibility of intelligence in earthworms, but his a priori doubts were swept aside by observational and experimental results. His discovery of intelligence was unbiased; it was not a romantic or tenuous interpretation imputed to their actions. His insistence on this point was not simply for credibility. "Some degree of intelligence appears," he remarked, "a result which has surprised me more than anything else in regard to worms" (1881/1985, p. 35). Darwin was genuinely taken aback by his discovery.

A World of Experience

While Darwin did not set out to find intelligence in worms, it is also clear that he was open to such a possibility. This openness is visible in his posing the question ("how far the worms acted consciously and how much mental power they displayed"), and in his readiness to accept worm intelligence once other explanations were ruled out as insufficient ["one alternative alone is left, namely, that worms, although standing low in the scale of organization, possess some degree of intelligence" (1881/1985, p. 98)]. Darwin's openness to the possibility of awareness (where it is often offhandedly dismissed by modern *Homo sapiens*) is also evident in his implicit portrayal of earthworm life as a world of experience.

This perspective is vividly discernible in Darwin's depiction of earthworm living quarters. In discussing how worms constructed and inhabited their burrows—the tunnels, openings, and chambers—he used the descriptive terms of architecture and home, thereby accenting the skill and life of worms. Darwin's language contributed two significant dimensions to the portrayal of their inner life: It presented structures constructed by worms as products of work, rather than fortuitous outcomes of passive movement; and it presented worms as inhabitants of spaces that possessed features engineered for utility, comfort, and security.

The burrows Darwin studied were often several feet in depth and their walls were lined with worm castings, deposited initially as "voided earth, still soft and viscid" and then spread out as the worm traveled up and down its hole (1881/1985, p. 111). The consequent thin film of dried-out castings provided the burrow with structural support and protected the worm's body from rough walls. "We thus see that the burrows are not mere excavations," observed Darwin, "but may rather be compared with tunnels lined with cement" (1881/1985, p. 112). The idea of "cemented tunnels," inviting comparison with human labor, suggested a space constructed through (and for) action as opposed to a passively created "mere excavation."

Darwin also examined how worms created basketlike structures, held together with leaves, miscellaneous objects, and castings, that protectively enveloped the mouths of their burrows. Worms that he kept in pots formed these structures using pine needles, fragments of other leaves, glass beads, and bits of tile—formations he described, again inviting analogy with human work, as "plastered with viscid castings" (1881/1985, pp. 112–113). Underscoring the skill involved in its construction, he described one case in detail:

> The structures thus formed cohered so well, that I succeeded in removing one with only a little earth adhering to it. It consisted of a slightly curved cylindrical case, the interior of which could be seen through holes in the sides of either end. The pine-leaves had all been drawn in by their bases; and the sharp points of the needles had been pressed into the lining of voided earth. Had this not been effectually done, the sharp points would have prevented the retreat of the worms into their burrows; and these structures would have resembled traps armed with converging points of wire rendering the ingress of an animal easy and its egress difficult or impossible. The skill shown by these worms is noteworthy and is the more remarkable, as the Scotch pine is not a native of this district. (Darwin, 1881/1985, p. 112)

Darwin noted that while the worms were innately inclined to construct these protective basket structures, the effective manipulation of various objects suggested that the worms' handling of materials per se was not innately obtained, at least not in full.

The admiration Darwin expressed for the worms' "noteworthy and remarkable skill" intimates his admission of what might be called "implicate authorship." The care involved in this particular construction was, Darwin suggested, above and beyond what instinct could explain. The detail of pressing the pointed pine needles into the sides of the cylindrical interior so they could not injure the worm's retreating body was potentially akin to an effective precaution rather than a blindly enacted behavioral pattern, since the pine was not a native tree. By "implicate authorship," I am referring to behaviors that suggest the possibility of an aware agency, for (1) they cannot be completely accounted for by extant concepts or frameworks of behavioral science and (2) they clearly have a rationale or purpose. As Darwin put it for this case, if pressing the needles had "not been effectually done, the sharp points would have prevented the retreat of the worms into their burrows."

According to Darwin, the worms often rested within these baskets, absorbing warmth without exposing their bodies. So in addition to noting their protective function for worms, he observed how the baskets were lived in—how body, habit, and comfort fittingly intersected within their configuration. "Worms often remain ... for a long time close to the mouths of their burrows, apparently for warmth; and the basket-like structures formed of leaves would keep their bodies from coming into close contact with the cold damp earth. That they habitually rested on the pine-leaves, was rendered probable by their clean and almost polished surfaces" (1881/1985, p. 114). Darwin thus saw a dimension of experience in their use. The basket structures were not only potentially deliberately constructed, they were also utilized and lived in, providing places where the worms could rest, find warmth, and be cushioned from the dampness of the earth (and, he indicated elsewhere, be somewhat protected from predators).

Darwin completed his study of earthworm living quarters by examining how burrows "terminate in a little enlargement or chamber" (1881/1985, p. 114). The floors were lined with small stones and seeds and in Darwin's pots, by glass beads and bits of tile carried down by the worms from the surface. During the winter, the worms curled up into balls (singly or in numbers) in their padded chambers, their bodies buffered from the soil. Darwin maintained that "the sole conjecture which I can form why worms line their winter-quarters with little stones and seeds, is to prevent their closely coiled-up bodies from coming into close contact with the surrounding cold soil" (1881/1985, p. 116). With his intimate description of these "chambers" and "winter-quarters," Darwin again presented a view of burrows as experienced abodes.

Darwin's language of lived-in space describes a "phenomenology of mind" through the presentation of an experiential world; it does not focus on cognitive processing, but is partial to embodied, interactive, and material manifestations of awareness in the world (see Abram 1996; Crist 2000). The created landscape of worms' lives, as depicted by Darwin, implies a mind at work, for the cemented tunnels, cylindrical baskets, lined chamber floors, and plugged burrows are designed constructions that cannot be fully comprehended by scientific concepts that eschew mind, in particular by that conceptualization of "instinct" which equates it with thoughtless enterprise. [On the ubiquity of this conception of instinct in behavioral science, see Griffin (2001/1992).] Indeed, Darwin was cognizant of this particular use of the idea of instinct, writing that "the instincts of even the higher animals are often followed in a senseless or purposeless manner" (1881/1985, p. 95). The actions of worms could be understood as driven by instinct—by an urge unbacked by deliberation or planning—but neither the diversity and the details of construction nor the form of life that the constructions afforded were encompassed by the idea of instinct. There was something more. And this something more was not emphatically asserted by Darwin, but pointed to with restrained awe.

Concluding Remarks

Darwin's portrayal of the inner life of earthworms challenged basic assumptions of science and common sense about what sorts of organisms are capable of intelligence and what are not, and about what sorts of organisms are able to experience life and what are assumed to be little more than animated robots. In admiration of this bold thinker, it is fair to state that without much fanfare, but in a gentle and measured manner, Darwin simply did not abide by these assumptions which are, after all, far from self-evidently true. He found mind—both cognition and subjective experience—where it was presumed not to exist.

How is Darwin's study relevant 120 years later? To return to the introductory comments, his study brilliantly shows that the question of "conscious action" in animals is not inherently problematic: not ontologically problematic because it is not rational to presume, prior to inquiry, that the existence of conscious action is unlikely, even among invertebrates; not epistemologically problematic because once the question of conscious action is allowed to be posed, the scientific imagination finds fascinating ways to address it; and finally, not semantically problematic because writing off "conscious action" as anthropomorphism commits the deeper (in my view) fallacy of anthropocentrism. Such dismissal rests on the presumption of an unbridgeable gap between the ostensibly "highest" of animals (humans) and most other organisms (not to mention worms).

And now to some lingering questions. Did Darwin actually prove the operation of intelligence in worms, or their possession of an aware experiential perspective? Not in any incontestable sense; more important though, he opened the door to such possibilities, engaging in intriguing observations and designing ingenious experiments on the way. Does it matter whether earthworms are intelligent or experience their world? I would submit that what matters is that scientists be allowed and encouraged to pose these questions about worms and other animals. It is hoped that following their cue, commonsense views that are flippantly dismissive of such forms of awareness in the world will be discarded. Why is this desirable? The most significant reason today is the need to awaken and deepen our sense of wonder about the living world. For the erosion of this wonder—encouraged, in part, by the dominance of overly mechanistic models of animal behavior in the twentieth century—is internally connected to the gathering speed of the human onslaught on the natural world, and to its darkest corollary, the sixth extinction.

Notes

1. Exceptions are Yerkes (1912), Ghiselin (1969), Graff (1983), and Gould (1983, 1985).

2. See Ghiselin (1969, p. 201). While Darwin cited George Romanes' criterion of deducing intelligence "only when we see an individual profiting by its own experience" (1881/1985, p. 95), he neither endorsed nor applied it as a stringent criterion. Darwin sent relevant pages of the manuscript about worm intelligence to Romanes, asking him to comment. Romanes replied "that there may be intelligence without self-consciousness" (cited in Graff 1983, p. 11).

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