AVIOLOGY

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Abstract:
As a consequence of activities aimed at exercising and developing biological structures and functions within a social framework, humankind has travelled the path from imaginative constructions to rational-cognitive processes. The accumulation and critical selection of knowledge have led to the understanding that the human being is not unique in origin, attributes or capacities, but is merely a living creature that inhabits, like all others, instinctively and unwisely, a rather small rocky body held in the reins of an ordinary star.

At the present moment, after knowledge has revealed that the multitude of attributes once imagined to belong exclusively to humanity are, in fact, attributes of living matter in motion and becoming, human beings continue to struggle to preserve the last remaining item in that set: articulated vocal language.

Keywords:
Songbirds; articulated vocal language; communication.

The path traversed by humanity – from the imaginative constructions arising from activities of exercising and developing biological structures and functions to rational-cognitive processes – has caused each step to pave the way toward understanding that the human being is neither unique in origin, structural-functional attributes or any other respect, nor special by destiny, nor supreme as the purpose of some creation. Rather, it is merely one living creature among others, passionately and unwisely inhabiting a rather small rocky body held in the reins of an ordinary star. At this moment, after knowledge has led humanity to understand that the multitude of attributes it had imagined as belonging exclusively to itself were, in reality, attributes of living matter in constant motion and transformation, human beings still struggle to preserve the last of these alleged exclusivities: language.

It may be of interest to ask what the human being actually is once stripped of those attributes through which it believed itself to be unique. Yet a deeper understanding of humanity may perhaps be gained through a more profound knowledge of other living creatures.

Human beings appear convinced that mammals are more richly endowed than any other class of animals and that an impassable divide exists between themselves and all other species. Such beliefs arise from a mixture of arbitrary hierarchisation and disregard for attributes, and, of course, from the application of humanity's preferred procedure: the double standard. Since these convictions rest neither upon extensive nor rigorous bodies of research – of a kind capable of producing and validating relevant and reliable results – they are not merely temporary prejudices but rather the outcomes of a millennia-old anthropocentric mode of thought. Following the animistic period, this mode of thought generated a cluster of conceptual and ideological variants concerning Divinity, which, after taking special care of a "supreme" creation – Man – was cast into the labyrinth of relativistic and subjectivist wanderings, where it was devoured by its own creation and transformed into a metaphorical emanation. Universal principles and ordinances continued to be imagined as divine in nature; yet man became the measure of all things and the agent that determines or modifies everything through the mere action of his mind.

In reality, beyond God or Nature, many species – passerines, for example – may display highly important and specialised traits absent in mammals. They may possess common or corresponding attributes at comparable levels and, in some respects, birds may even be more highly evolved than mammals – occasionally even more so than many human beings. The fact that presumed superiority is not absolute demonstrates in itself that the factor responsible for enduring existence is evolutionary in nature; a species cannot be said to have been "gifted" unless the endowment encompasses all its individuals and extends to all relevant attributes.

Leaving aside the evident fact that numerous animal species possess characteristics at levels of performance that render ridiculous the sub-mediocre level at which humans possess them – if indeed they possess them at all – it may be observed that among the corvids (ravens, crows, jays, magpies), psittaciforms (notably the African grey parrot and certain cockatoo species), mimids (thrush species), Paridae (tits and chickadees), Sturnidae (starlings), Falconidae (falcons) and pelecaniforms (such as cormorants, the "sea ravens"), there exist numerous individuals displaying abilities that appear unexpected, astonishing and ultimately incredible to the non-evolutionist. In species-specific ways, these birds are capable of remembering places, moments, objects, events, both of others and of themselves; manipulating objects; managing quantities; learning behaviours; constructing and using tools; progressively accumulating knowledge; solving difficult problems; planning and anticipating actions; recognising human language; engaging in

complex social interactions; hunting cooperatively; and even testing others – including humans – all with remarkable precision.

Yet human investigation of these species still remains at a relatively rudimentary stage.

Although many of the species mentioned above are capable of conducting complex communicative processes, those that communicate by means of an articulated vocal language comparable to that of humans are "songbirds" (suborder Oscines) belonging to such families as the Fringillidae (finches, canaries, goldfinches), Mimidae (mockingbirds), Passeridae (sparrows), Alaudidae (larks), Sylviidae (warblers, reed warblers, mountain leaf warblers, reed birds), Troglodytidae (wrens), Paridae (tits and chickadees) and Turdidae (nightingales, thrushes, robins).

Communication among songbirds occurs both within and between species, serving a multitude of purposes and employing a wide variety of modes that rely primarily on visual signals (through alterations in appearance, displays, chromatic effects, morphological and postural modifications, as well as dances and gestures, that is, body language) and acoustic signals (encompassing a rich diversity of sounds, from mechanical noises produced by body parts or external objects to calls and "songs").

In fact, the designations *songbirds* and *song* (when referring to the acoustic streams produced by these birds) are only partially justified. Birds can indeed sing (just as humans can, although often with considerably greater "virtuosity"). As in the human case, the suprasegmental features of sound production (sound duration, pitch, dynamic and musical stress, intonation, rhythm and so forth), together with the continuity of the acoustic stream, may create the impression of song.

Observation of the capacities for articulated vocal language production in both oscine birds and humans, together with examination of: (a) the genetic, anatomical-physiological, neural, behavioural and social substrates and components; (b) the high degree of specialisation of the structures through which the process is realised; (c) the specialised development of the processing structures; (d) molecular behaviours; (e) the structure of vocalisations; (f) the features of vocal communication processes; (g) the characteristics and parameters of practice and training; (h) the evolutionary pathways and mechanisms involved; and (i) the associated behaviours, reveals that the communication systems and processes of oscine birds and humans display profound and striking similarities, ranging from correspondence to genuine commonality. Indeed, the vocal mode of communication employed by songbirds not

only occupies the same level of complexity as that of humans, but the articulated vocal language of songbirds constitutes the closest known analogue to human articulated vocal language.

Biology, environment, sociality. The development of vocal communication behaviours in both birds and humans presupposes the existence of innate auditory templates and a sensitivity to conspecifics or socially proximate individuals, together with motor programmes and processes of instruction, memorisation and selection involving both innate and learnt models. The imitation that emerges requires a high degree of accuracy, while learning must continue into adulthood. All of this occurs within the context of an effective interaction between biological endowment and development, on the one hand, and environmental influences on the other.

The foundation of the acquisition and exercise of such an attribute is biological in nature. Vocalisations are grounded in the expression of gene networks, in functional states and modes operating at molecular and anatomical levels and in a cerebral architecture characterised by cortico-striato-thalamic loops and direct projections from cortical neurons to the brainstem motor neurons that control the vocal organs.

Since the motor patterns responsible for acoustic streams are precisely coordinated and modulated through somatosensory feedback, the mechanism of sound production requires the acquisition of complex motor skills. These include neural control of the effectors involved in the vocal production system responsible for generating species-specific sounds: the intricate coordination of respiratory muscle groups, vocal-organ musculature and cranio-mandibular muscles, together with the relationship between the neural pathways and nuclei governing these muscles, all directed toward the optimal and efficient operation of the sound-producing organs.

At the same time, like humans, birds possess innate capacities that adequately support the accurate perception and proper learning of the sounds that they will later employ in generating acoustic streams. Gradually accumulated auditory experience requires social interaction and exposure to the adult communicative system. Exposure to calls (sounds referring to dangers, advantages or group movements) and to song (for which dedicated vocal organs and forebrain neural circuits exist) – both produced by parents or by adults involved in rearing the young – leads to the perception, acquisition, subsequent memorisation and learning of an extensive repertoire of vocal signals. These processes require categorisation and specialised memory mechanisms capable of continual updating, thereby providing the basis upon which vocal imitation develops.

The orientation of juveniles toward the acoustic signals produced by organisms in their environment in general, and especially toward the vocalisations emitted by their conspecifics – from whom they acquire simple syntactic patterns and referential elements relevant to communication – demonstrates that the activation of their biological endowment cannot occur in the absence of early practice. This fact is of crucial importance both for auditory perception, for the processing of learnt vocalisations and for the development of vocal behaviour. The outcomes achieved are proportional to the frequency, intensity and quality of practice, particularly that undertaken during the critical or sensitive period, a process unfolding under the influence of environmental conditions, the principal and overriding determinant.

Consequently, on the basis of a set of biological constraints and under the influence of social factors involving interactions between heredity and a culturally structured environment, the social behaviour of vocal communication emerges through the use of perceived auditory signals. The articulatory gestures gradually produced and practised become organised in a modular and hierarchical manner across multiple levels (notes, syllables, more extended sequences corresponding respectively to phonemes, syllables, words and utterances). Ultimately, highly adapted to their respective environments and ecological niches, birds possess the competence necessary for acquiring, practising and developing a biological and social behaviour that functions as a stage within an interactional-transactional process and is capable of adaptive and progressive evolution. Moreover, they are able to transmit this behaviour culturally. As a consequence of the level and degree of development of their brains, this behaviour comes to exhibit attributes such as sociality, behavioural complexity, categorisation, mentalisation, ritualisation, multisensory integration, perceptual syntax etc.

The critical period. The occurrence of biological development, its exercise and even the acquisition of social behaviours of all kinds takes place within the limits of critical or sensitive periods. The perception, production and learning of vocal behaviour likewise achieve optimal levels only during a sensitive period in which outcomes depend jointly upon the organism's biological capacities and environmental influences. In the absence of such a period, or once it has passed and concluded, the window of opportunity may remain partially open – together with some possibility of realising latent potential. Nevertheless, the efficient unfolding of the relevant processes becomes progressively more difficult.

In essence, such a period is characterised by a sensory stage – in which the organism perceives and memorises those elements that occur frequently in its

environment (thus giving rise to auditory imprinting upon the song characteristic of the inhabited geographical area) – and a sensorimotor stage, during which information provided by auditory feedback is compared with the memorised model and the production of sounds begins. In this manner, acoustic streams gradually acquire organisation and plasticity, until the resulting song no longer depends upon auditory feedback.

On the basis of auditory and visual experience, representations of sounds are formed during the initial part of this period and are subsequently translated into the motor programme that reproduces them. Endowed with the capacity for imitation – made possible by motor learning guided by auditory information – young birds begin to acquire the ability to produce sounds, to coordinate their auditory and vocal organs and, through a form of production comparable to babbling (subsong), to perceive the relationship between context and particular vocalisations. Such rudimentary forms of expression exercise the audio-articulatory organs and contribute to the formation of the phonatory apparatus.

At this stage, moreover, the effects of practice upon the receptive organs, the structures responsible for producing acoustic streams, the brain and neural circuits are especially powerful. Practice trains all participating components, demonstrating that the information acquired during this period is crucial for normal development; to a large extent, it determines lifelong performance.

As will become apparent, an extraordinarily important consequence of this exercise is that, owing to their plasticity and their capacity to manifest themselves behaviourally, neural and behavioural networks undergo architectural reconfiguration. Their connectivity patterns are modified in ways that are functionally efficient with respect to the process under consideration, thus contributing to the transition from this stage to the one in which sounds resembling those previously perceived are produced.

Learning constitutes a cognitive task that requires a high degree of specification. This process is supported by genetic factors and rests upon a localised and well-structured neural system.

It has been shown that, being constrained and defined by various predispositions and capacities, the processes involved in acquiring vocal sound production are activated early in life – as a consequence of perceiving environmental vocalisations and receiving auditory feedback – and that the acquisition of vocal behaviour depends heavily upon auditory information obtained through contact with an adult member of the same species and immediate environment (a parent or caregiver, who is perceived and imitated). Imitative learning therefore requires that juveniles hear both others and themselves. Young birds develop capacities for

categorial perception and display a marked sensitivity to the statistical distribution of stimuli – traits that lead to the optimal learning of sounds that are well represented statistically within the environment.

Because birds, like humans, possess the ability to modify innate vocalisations according to an imitated vocal model (that is, through vocal learning), sensory experience shapes the development of song during the sensorimotor learning stage. Distinct from other forms of similarity arising from common origin, chance, ecological convergence, repertoire selection or related processes, and essential to the acquisition and transmission of diverse cultural phenomena, mimetic vocalisation gives rise to behavioural modification in the receiver as a consequence of perceiving the resemblance between a model and the result of its imitation.

Subsequently, species-specific vocalisations are processed within specialised neural circuits, from which information is extracted and used for the refinement of the individual's developing song. Since imitation is fundamentally a compromise between the model and the imitator's internal tendencies and capacities for producing a particular outcome (even when everything is imitated, the result gradually assumes the characteristics of the imitator), it requires time for an individual pattern to emerge. As vocal learning progresses and intensifies, selectivity toward the sounds of the bird's own song develops. This selectivity appears and increases as the bird learns to produce a stable, adult song. It is strongest in relation to current vocalisations, because the neurons involved analyse the degree of auditory feedback during singing and thereby maintain vocal production within certain limits. In this way, sensory experience becomes internalised and is subsequently employed to shape vocal productions and enhance learning efficiency. All of this activity depends upon the action of mirror neurons, a mechanism that adjusts production and performance through feedback guided by the imitated model. Reinforced experience modifies motor commands and such modification constitutes learning.

The entire complex of processes continues to unfold both ontogenetically and phylogenetically, throughout the individual's lifetime and across successive generations. As a result, equilibria are continually lost, transformed and renewed.

Ultimately, by possessing and implementing a wide variety of motor strategies drawn from an extensive repertoire of possibilities, oscine birds learn their songs from a broad range of sounds generated in accordance with the characteristics of the species' articulatory apparatus and, above all, with those of the particular community to which they belong. The definition of these sounds occurs gradually through statistical and phonological-computational processes, while individual features emerge in relation to the capacity for categorial discrimination. Categorisation itself is context-dependent and gives rise to the ability to distinguish

among the songs of geographically segregated populations. Furthermore, the fact that birds successfully classify and correctly assign sequences that they have never previously learnt demonstrates that they possess syntactic knowledge of grammatical rules that are independent of context. In other words, they exhibit the fundamental capacities necessary for learning both a finite, simple grammar and a complex one – a conclusion corroborated by neural processes analogous to those observed in humans.

From a neural perspective, the subcortical localisation of structures responsible for sensorimotor integration and the control of finely coordinated movements indicates that birds have evolved brains characterised by the specialisation and hierarchical organisation of the various functional areas involved. Within these brains, auditory and motor centres interact closely with one another and with higher control centres.

Functionally, the neural networks developed by birds are analogous to the corresponding regions of the human brain (Broca and Wernicke). These networks are situated in regions broadly comparable to the corresponding areas of the human cortex and the basal ganglia. Involved in both perception and production, these cerebral regions and those responsible for learning display common organisational patterns, including the activation of language-related areas that are lateralised to the left hemisphere – a region that undergoes substantial development during language acquisition and continues to expand as linguistic mastery increases.

The mechanisms underlying learning, auditory integration and vocal integration are likewise similar to those observed in humans. Thus, just as speech does, birdsong reflects the executive influence of the telencephalon upon respiratory and vocal activity. Ultimately, the mechanisms through which neural networks make higher-order functions and complex behaviours possible originate at the level of local neural circuits.

Indeed, from the perspectives of anatomical, histochemical and functional organisation, the neural structures that enable birdsong and human speech (particularly with respect to learning and production) display remarkable similarities. In both species, neural activation during the actual communicative process is especially intense in the areas associated with acute perception, faithful imitation, learning and memory. (Since the brain forms distinct representations of the song of the parent or tutor and of the individual's own song, it is evident that auditory recognition and vocal production are served by separate cerebral regions.)

The fact that the regulation of birds' song-related behaviour occurs within cerebral areas involved in vocal and social behaviour – and that dopamine receptors associate communication with the reward system – indicates that evolution has

developed and selected song in birds in order to transform this capacity and subsequently this activity into a communicative system of major social importance. Particularly suggestive in this regard is the fact that song quality constitutes a reliable indicator of biological quality, encompassing genes, neural organisation, auditory and vocal systems and the capacities for perception, imitation, production, learning etc. In this way, the recipient – whether the singing bird itself or another individual – partially determines patterns of neural activity, the recipient's responses influencing both song production and the characteristics of the song itself.

Another highly salient and relevant fact concerns the brain. Since practice possesses the capacity to produce modifications ranging from organs and physiology to behaviour, the progressive and cumulative ontogenetic and phylogenetic exercise – of the attribute under discussion and of its associated anatomical components – has resulted in the specialisation, hierarchical organisation and complex interconnection of avian neural areas. Motor and auditory centres have come to interact closely, while control over lower vocal-motor regions has been retained even in birds that do not engage in vocal learning. Moreover, as a consequence of a complex process of co-evolutionary feedback, following the neural events and processes that first enabled vocalisation – and within the broader context of the importance of learning and memory – the information thus acquired came to influence the motor network responsible for vocal production. Through neuronal interconnection, mechanisms evolved that, especially during learning and particularly during early critical periods, retain information regarding the sequence of activation of neuronal groups, together with all the implications arising therefrom. Ultimately, the processes of perceiving, producing and learning vocal sounds brought about sensorimotor transformations of the brain, such that songbirds developed specialised networks for the perception, production and learning of song, as well as for the vocal control of the structures involved in vocalisation.

From a genetic perspective, the phenomena observed during the ontogeny of birds and humans are similar with respect to the genes involved, their activation, the modes through which such activation occurs, the behaviour of the genes and structures concerned and the effects resulting from their interactions. Thus: a) The FoxP2 gene is involved in song learning and song plasticity (in humans, FOXP2 performs comparable functions related to language); b) The expression patterns of FoxP1 and FoxP2 overlap during song production (just as those of FOXP1 and FOXP2 do in humans). Both sets of genes participate in the formation and functioning of neural circuits that employ sensory feedback, thereby serving the voluntary and sequential learning of orofacial gestures; c) The brain regions in which FoxP1 and FoxP2, and respectively FOXP1 and FOXP2 are expressed, constitute

crucial nodes in the control of motor-circuit systems involved in motor planning and execution. These genes contribute to the sensorimotor integration that supports vocalisation and other learnt complex motor behaviours.

More generally, from the earliest ontogenetic stages onward, the expression of the aforementioned genes is strikingly similar in birds and humans, both in relation to the brain regions in which they are expressed and with regard to their effects at the molecular, structural and functional levels.

Vernaculars, dialects and bilingualism. Just as human language is realised through particular languages, birdsong is species-specific. Yet, like human languages, it exhibits considerable intraspecific variation. Being products of concrete organs belonging to concrete communities whose members are born, develop, practise and live within specific environments – environments whose determining influence is immense, indeed in a certain sense total – calls and vocal signals possess a biological basis. As products of diverse environments, birds cannot transcend a certain degree of uniformity. All belong to the suborder *Passeri* (Oscines), yet their characteristics differ sufficiently to permit classification into families, genera and species. Furthermore, intraspecific differences among individuals are not only sufficient to individualise them but also to situate them within distinct intraspecific groups. The acoustic production of these organisms likewise possesses both biological and group-specific determinations. Consequently, through learning and coexistence – processes marked by imitation – traits, behaviours and products inevitably acquire social and subsequently cultural characteristics, though in varying degrees. Thus, the production of calls and songs becomes increasingly specialised and divided according to community-specific patterns – what, in human terms, would be called *vernaculars* and *dialects*.

At the same time, however, because learning permits the diffusion of behaviours, capacities and techniques across space and time – a process that naturally unfolds most strongly within communities and populations, particularly within species, though to a certain extent also between species – the resulting capacity to generate and sustain culture does not operate in isolation from events occurring beyond the boundaries of a given community or population. This means that, like humans, birds possess a cultural behaviour that manifests itself across multiple spatial contexts (and perhaps, to some degree, temporal ones as well). Their cultures are capable not only of achieving a degree of homogenisation within certain limits but also of accommodating one another, subsequently evolving and being transmitted through such interactions. This process does not occur indiscriminately or under all circumstances. Fundamental to it is membership in a common community; only thereafter do contacts with other communities (both intra- and

interspecific) produce significant effects, contacts to which individuals and groups are inevitably exposed.

Thus, signals (alarm calls and contact calls) are employed in both intra- and interspecific interactions. Birds respond not only to the alarm signals of conspecifics but also to those emitted by birds of other species with which they share the same territory. This means that they are capable of learning and incorporating the signals of other species. The processes of imitative learning may yield results so enduring and accurate that – particularly when such signals are frequent in the environment – the calls of one species may be reproduced by birds belonging to another. This constitutes the avian equivalent of bilingualism in humans and such borrowed signals may even become integrated into the vocal repertoire characteristic of the recipient species. Indeed, birds may imitate species-specific songs with such fidelity that the variation introduced by the imitator can be smaller than that found among members of the species from which the song originates (a phenomenon explainable by the fact that a faithful imitator employs motor patterns essentially identical to those of the model).

Moreover, because the vocal learning of a particular pattern requires auditory feedback – even if only to distinguish one's own vocal emissions from those present in the environment, thus making it possible to identify discrepancies between what is produced and the memorised template acquired from a model – conditions such as life in noisy colonies or habitats shared by multiple bird species emitting diverse signals and possessing distinct songs (especially in environments affected by substantial acoustic pollution) create a significant potential for communication difficulties. One means of compensating for such difficulties consists in the introduction of redundant sequences and the modification of specific parameters of signal production, thus increasing both signal quality and, consequently, signal complexity. In this context, it has been observed that certain neurons respond to disturbances introduced during playback but not to perturbations affecting naturally perceived song, while other neurons respond to disruptions of perceived song but not to either correctly produced song or faulty playback. This demonstrates that auditory areas of the forebrain detect incongruities between feedback and mirrored feedback deriving from an internal model of song, whether belonging to the bird itself or to its model. On the other hand, the repertoires of neighbouring species may overlap in certain sequences. In such cases, song tends to revolve around thematic sequences characterised by similar transitions while remaining extensive and distinctive.

The capacity of individuals to transcend the boundaries of their own communities is not the product of behaviour operating merely within the limits of ordinary and habitual conditions; rather, it represents an extension of adaptive capacities acquired and practised within the community itself. For this reason, the

fact that neurons respond to a wide variety of changes, including subtle and weak ones, and that perceptual thresholds vary among geographical populations cannot be attributed solely – or even necessarily primarily – to cultural causes. Genetic factors are never absent, even when their influence is difficult to isolate, variable in magnitude and occasionally ambiguous or apparently elusive in its manifestation. Differentiated through syllabic variation and syntax (and very likely also through subtle morphological variation), the songs produced by populations belonging to the same species and variety, yet occupying different territories within a broader geographic range, exhibit geographical variation. The roots of this phenomenon, however, extend beyond culture alone. Research and experimental evidence indicate that variation in song syllables correlates with variation in allele frequencies, while similarities in allele frequencies prove independent of geographical distance. Consequently, differences among songs from distinct geographical areas cannot be explained exclusively by cultural processes; at a fundamental level they are related to gene frequencies, a conclusion strongly supported by analyses of genetically heterogeneous populations in which song meanings differ accordingly.

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In the preceding discussion, insufficient emphasis has perhaps been placed on the fact that, in reality, the phenomena described occur in precisely the same way or in ways remarkably similar in both birds and humans. The orientation of the genetic substrate, the developmental tendencies of the audio-articulatory organs and the neural system, the preferred modes through which communities function efficiently, the inclination toward vocal communication through articulated vocal language and the modes of practice, development and evolution of the communicative instrument itself (in both those oscine species that have excelled in this direction and in our own species) are extraordinarily similar and, in some respects, virtually superimposable. From an evolutionary perspective, such correspondence can only be attributed to convergent evolution.

In itself, this observation renders unnecessary the effort to portray the human being as fundamentally unique. From a strictly scientific standpoint, one may adopt a variety of perspectives and criteria of classification and hierarchy, both with regard to the diverse endowments of animals and to the species that possess them. It becomes apparent that many animals display specialised biological, social and behavioural traits, some shared, others distinctive, which have been selected and refined to such a degree that they may confer particular advantages upon individual species. Yet all of this reveals nothing more than the manner in which environments have acted upon those species and the ways in which they have utilised the

equipment with which those environments endowed them, first in response to external demands and then in response to internal requirements and tendencies.

Accordingly, human language is unique within the animal world. Yet so too are countless other animal and plant structures, functions, capacities and attributes. Such uniqueness does not imply that any of them constitute a structure, function, system or behaviour without parallel or correspondence elsewhere in the living world. In the case of language, the relevant structures (from receptive to productive and subsequently processing mechanisms) preceded the novel uses to which they were later recruited. Responding to pressing necessities, these uses appropriated existing structures in part, without eliminating their previous functions. The exercise of the fundamental communicative function led to the emergence and development of cognitive functions and, in turn, generated new structural demands. Next, the exercise of the structures and the function was naturally followed by the construction and exercise of the resulting system and behaviour. The actions of all components contributed to their mutual instruction and to the co-evolution of structure, function, system and behaviour. Step by step, the genetic component underwrote the entire complex process while itself remaining subject to necessity, extending its own limits whenever alternative means of accommodating these four dimensions proved inadequate to satisfy vital needs.

If complex attributes such as language cannot be explained in this manner – as outcomes of adaptive and evolutionary states, dynamics and processes unfolding through time upon existing foundations that became progressively amplified and integrated – then one must conclude that they possess the power to render a species fundamentally unique. Such a conclusion implicitly entails the belief that these attributes did not arise through evolution. It thus commits us to the view that they were somehow bestowed by a supernatural agency, whether as a partially formed and functional gift, as a special act of creation or as any other product of the imagination, in every case the result of a magical or mystical process.

(English translation by Oana Voichici)

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