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Natural Selection and the Nature of Communication

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One of the deeply satisfying things about an evolutionary approach is that one can start at the causal foundations of a topic and work from the ground up to build one's way into a systematic map of some particular conceptual territory. This is especially true of communication, many of whose principles emerge so naturally from the theory of natural selection that the process feels almost effortless. The key insights emerge from an examination of the logical and causal inter-relationships among the following concepts: entropy, order, replication, natural selection, replicative order, frames of reference, replicative entropy, replicative work, function, evolved design, regulation, cybernetics, computation, information, learning, inference, and finally, communication and meaning.

SOME PHYSICS ESCAPES THE REALM OF ENTROPY

The vast expanses of the universe are overwhelmingly populated by phenomena embodying eddies of ever-increasing disorder, salted with only the rarest of exceptions. The domain of phenomena that biological evolution applies to—life—is exceptional. Life consists of the set of physical systems that cause the assembly of (near-duplicate) physical systems (Dawkins, 1976; Williams, 1966). To qualify as self-replicating, these systems must, in their turn, maintain the same capacity for self-replication in the offspring-replicant as in the parent. This means that some of the components of the regulatory system that constructs descendant physical systems must in some fashion reliably transmit something crucial: the capacity to further replicate the inherited design *into* each new descendant. Such components are, by definition, called the genetic system of the organism. By evolved design, the genetic system conserves and transmits the information necessary to construct descendants, and this with great and necessary accuracy. Nevertheless, through inevitable physics, entropy injects random changes into this otherwise conserved, design-replicating information as it passes from generation to generation. (*Mutation* is nothing technical: It is simply the Latinate synonym for *change*.)

Hence physics poses an unsparing problem: How is the existence of life forms at all consistent with a physical world that is pervaded by a tendency to move randomly over time from the far rarer, less probable, more organized states (should they come to exist) to the far more

probable, far less organized arrangements? Even more puzzling, how can populations of organisms often move uphill against entropy toward more ordered configurations, as they clearly have? Plants and animals flare out as remarkable departures from the rest of the physically normal entities, such as Kuiper Belt objects, solar convection cells, lunar impact craters, particle clouds driven by Martian wind storms, gamma ray bursts scouring the surfaces of planets, and rippling planetary auroras. What sets all organisms—from ash trees and buckthorn to kestrels and radiolarians—apart from all other expressions of the physical universe is that their designs are spectacularly unlikely arrangements of highly calibrated relationships. Life forms reliably achieve inconceivably highly ordered states—and specifically, order that is highly functional with respect to replication. We will scrutinize what *functional* means in this framework, after a longer look at the question posed by the omnipresence of entropy.

It is true that neither our planet nor its organisms are closed systems, because these systems allow interactions between their internal elements and the environment. Thus, thermodynamic entropy can still increase globally (consistent with the second law of thermodynamics) while (sometimes) decreasing locally in populations of organisms lucky enough not to starve or go extinct. Being open systems permits, but does not explain, the high levels of organization and energy concentration found and deployed in life. Nevertheless, as highly ordered physical systems, organisms should tend to slide rapidly back toward a state of high disorder, because disordered states are so much more probable than ones consistent with survival (much less reproduction).

As the physicist Erwin Schrödinger wrote in his book *What Is Life?* (1944/1992), "It is by avoiding the rapid decay into the inert state that an organism appears so enigmatic" (pp. 69–70). Indeed, each organism does decay into an inert state, but instead of doing so in the milliseconds that chemistry makes reasonable, this decay is fought off in an evolutionarily near-perfected rearguard action for days, weeks, months, or years. From one perspective we should all be extinct, but enough lineages escape from terminal entropy through the operation of the defining property of life: replication. Replication paired with entropy itself in the form of mutation (design copying errors) jointly interact to provide the platform out of which the entire four-billion-year tower of elaborating life fountains upwards toward the farthest reaches of high order.

So how is this very high order achieved? Given that random physical processes introduce differences that modify the otherwise conserved design of these physical systems, it is inevitable that at least some will change the operation of the replicating systems in a way that is material to their exact methods of self-reproduction, and hence to their rate of reproduction in a given environment. By far the most probable outcome is that random changes to conserved design would cause the system's ability to replicate to degrade (a case of harmful mutation). This is because successfully carrying out replication requires immensely well-organized, and hence improbable, causal machinery carrying out a dizzying array of exacting processes. If design degradation were all that happened, then replicators (however they came into existence) would decay into increasingly noisy and drifting chains of parents and descendants, until each chain terminated through an inability to complete all the necessary cause-and-effect steps of an offspring assembly.

Given opportunities provided by a large enough set of successful replications, a small residual subset of these changes in inherited design will be accidentally generated that improves the physical system's replication-promoting organization—that is, that constitutes increased replicative order. What does this mean? Improved design features are defined by having the consequence of multiplying themselves over generations. This happens because the favorable design change interacts with relevant, cross-generationally enduring properties of the world in a

systematic, repeating, nonrandom method to cause net increases (positive feedback) in the subsequent frequency of their genetic basis. As these modified, better-designed organisms cause themselves to become more numerous, they increase the order to be found in the world—one mystery we are trying to explain. Conversely, design features that cause net decreases in their gene frequencies become less numerous and eventually disappear (negative feedback on bad design), which can also (potentially) increase the order in the world, as material shifts from constituting the less well-organized to being utilized by the better-organized. The better-ordered design self-amplifies and displaces the less-well-ordered design. It is exactly this attribute of physically self-caused differential replication of the better-designed that densely populates the world with (in Darwin's awed phrase) "endless forms most beautiful and most wonderful"— forms manifesting high *replicative order*, whose lineages often tend to become even better organized over long stretches of cross-generational time.

NATURAL SELECTION AND REPLICATIVE FUNCTIONAL ORDER

Natural selection drives the escape from entropy into the world of functional replicative order. It is essential to be clear on precisely what specific type of natural order evolution uniquely produces, namely, *functional replicative order*. One could imagine the world manifesting many types of things that might seem to embody complex functionality—lakes of wine, hedges of bread, watches synchronized with the orbital period of Titan, mountains in the form of houses complete with electricity, air conditioning, and running water. But, these are so inconceivably improbable that natural physical processes (as opposed to intelligently directed processes) obviously never produce them. More importantly, if we use an intuitive human framing derived from our evolved theory of mind system, *functional* means having properties that assist an agent in reaching its valued goal. Using this definition, nothing can be objectively functional per se, absent a frame of reference that specifies an agent and goal. Lakes of wine would be useless to a crater or a whale. However, in the domain of self-replicating physical systems, there are refracted conceptual counterparts corresponding to *agent* and *goal*, namely, *organism* and *replication*. These license a special, biologically restrictive conceptual analog to the intuitive concept of function. Making these substitutions, we can see that the only kind of organized functionality evolution produces (at rates higher than chance) is *replicative functional order*, that is, functionality to be found in sets of characteristics in an *organism* whose interactions contribute (through however many intermediate steps) to systematically causing enhanced *reproduction* (in a specific lineage) over multiple generations.

Because reproduction-promoting characteristics are the only (naturally occurring) characteristics that cause their own increase in frequency, they constitute the only (naturally occurring) kind of functionality that proliferates through time and space. Obviously, intelligent organisms such as humans can artificially produce functional systems, because they constitute agents with valued goals—and predicting the behavior of this animate world is why we evolved our intuitive concepts of *agent* and *goal*. This process is physically self-executing and requires no actual goals, agents, or values, although the evolutionary process might eventually produce them as computational elements in some lineages. This emphatically does not mean that organisms are, in reality, agents (although some may be), much less agents whose represented or teleological goal is replication. It means only that organisms are assemblages of devices whose functional organization was tailored by selection based on whether, under typical ancestral conditions, they caused replication. Moths fly into flames because their organization implements its outputs, not because they are seeking reproduction. It is a seductive and common error, even

among biologists, to think of organisms as agents with the goal of reproduction, instead of considering the actual cause-and-effect design of their behavior control machinery. We are designed by evolution to (mis)interpret organisms in terms of our evolved concepts of *agent* and *goal* because (1) humans (and some other species) sometimes operate partly as agents with consciously represented goals; (2) the behavior of many more organisms can be partly predicted by projecting this interpretation to them; (3) the fact that humans make material arrangements (such as tools), and behavioral arrangements (such as a hunt) to pursue valued goals allows the evolved concept *goal* (*function*, *purpose*) to help provide a useful explanatory framework for them, using what Dennett calls the intentional stance (Dennett, 1987).

Understanding the centrality of replicative functional order leads to a very stark, logically spare framework, fundamentally free of all of the rich, life-like, animate, and mental features we implicitly are inclined to imbue the world with. From a human perspective, organization that causes an increase in the probability of successful gene propagation (the multiplication of some molecular sequences over others) is a very bizarre, humanly meaningless, and restricted kind of functionality. Yet, it is the only complex functionality ("adaptations," "mechanisms," "useful" traits, "beneficial" traits, "favored" traits, etc.) that will non-arbitrarily characterize systems found spontaneously occurring in the natural world. Adaptations or devices that manifest replicative functional order execute *replicative work* for the organism—that is, they tend to move the organism along mechanistic paths that bring it closer to a life history of realized reproduction. The various sub-theories of natural selection, such as kin selection, sexual selection, foraging theory, the theory of animal conflict, and theories of cooperation and communication, can be used to understand why the architectures of organisms have the designs that they do. Replicative functional order is the only kind of functional order that is objectively present in undomesticated organisms (i.e., caused to be present in organisms).

Replicative order can be conceptually benchmarked through considering the matrix of physically and developmentally possible changes in the design of the organism and analyzing the change each would make in the rate of replication for the design given the prevailing conditions. As used here, *design* simply means the replicative order in the organism built and conserved over generations by natural selection, together with its systematic by-products. Greater effective design for reproduction (given a specified environment) constitutes higher replicative order, and reduced design for reproduction represents lower replicative order.

REPLICATIVE ORDER AND FRAME OF REFERENCE

Functional replicative order is a special kind of objective physical order, and is different from other kinds of order. Its recognition allows us to understand the causal architectures of organisms in a powerful new way that link together observed design features to evolved function, enduring environmental conditions, and ancestral event populations. It has been by bringing the causal framework centered on replication into focus that the door to understanding the engineering principles underlying the naturally selected architectures of organisms has been opened, including their systems of communication. On all different scales, organisms necessarily consist of suites of interlocking mechanistic devices, each organized according to some cause-and-effect arrangement designed (tailored) by the feedback processes inherent in natural selection to bring about outcomes which, taken in combination with the outputs of the other devices, increase the probability of a lifespan of successful replication. We can understand the reason that each of these devices (adaptations) has the characteristics it does by understanding how these characteristics interact functionally to cause the solution of their associated adaptive problem.

These design features make replicative functional sense, and understanding their replicative function—how they solve their adaptive problem—makes sense of why their architecture has the organization that it does. That is why inventorying and breaking down the set of evolutionarily recurrent tasks each species must solve, over a life-history of successful reproduction, is central to understanding a species. Like a particularly shaped key fitting into a particular lock, it is the highly ordered mesh between adaptive problem (including task environment) and adaptive problem-solver (adaptation) that allows us to recognize and understand the functional organization of the architecture.

George Williams (1966) called observations of these improbably well-ordered relationships between the design features and the adaptive problem *evidence of special design* that the system was built by natural selection for solving the adaptive problem. (The evidence is particularly compelling when the design features of the adaptation are predicted in advance, and are then discovered based on those predictions. This happens, for example, when the predictions lead to the construction of experiments to detect the existence of previously unknown mechanisms and design features; e.g., Kurzban, Tooby, & Cosmides, 2001; Lieberman, Tooby, & Cosmides, 2007; Sell, Tooby, & Cosmides, 2009.) Like all scientific claims, the claim that something is an adaptation involves an analysis of probability: whether the reliably developing features of an organism constitute a mechanistic adaptive solution to an adaptive problem that is too good to have arisen by chance (too well-coordinated with the problem-space, too effective, too precise, too economical, too reliable, etc.; Williams, 1966).

For example, the water-soluble protein crystallin is found in the cornea and the lens of the eye and has the extraordinarily rare property—for a protein—of increasing the refractive index while not obstructing light (Jester, 2008). Nearly all possible proteins are opaque. Not obstructing light is the lock and crystallin is the key. An extremely long search through ancestor-descendant protein sequences along a decreasing gradient of light obstruction would have been necessary to evolutionarily discover such a transparent protein out of the dense jungle of far worse alternatives.

This coordination represents a specific kind of objective physical order—replicative order—traceable to the hill-climbing process of encounters of replicated subcomponents and their variants with ancestral cause-and-effect event populations. It is an objective physical property, but a property of a particular species or lineage. That is, an increase in the replicative order of one species can represent a decrease in the replicative order of another—such as host and parasite, or predator and prey. Or they can both increase, as in symbiotic relationships. The point is, replicative order is specific to a frame of reference defined by the design of an organism in its environment.

Organisms exploit the distinct and clashing kinds of orders inherent in different physical frames of reference, including replicative order and replicative entropy. Order, replicative or not, must always be defined with respect to a frame of reference. The frame of reference (e.g., books spatially arranged alphabetically by author) categorizes the state of the described system (the physical order of the books on the bookcase) to the degree that it is in correspondence with the kind of order defined by the reference frame. Books on a bookcase can be organized by author, title, topic, or—in the case of an eccentric friend—color. That is, what is orderly (versus what increases disorder) depends on your metric or frame of reference (books arranged by author would be disordered according to the color frame of reference but ordered according to the alphabetical-by-author frame). So, for example, the initial formation of the Earth involved accretion, impacts, and the sorting of its chemical constituents by density, so that the heavier metals sank to the core, the less heavy materials migrated to the mantle, the lighter solids floated up to form the crust, with water on top, and gases emerging to form the atmosphere as

the lightest, topmost layer. Now, from the reference frame of chemical homogeneity and density, the Earth spontaneously became more orderly, not less. Yet, at the same time it moved toward greater thermodynamic entropy or energy dispersal (and by that frame of reference moved toward being less well-ordered). As this example shows, whether something is categorized as migrating from greater to lesser order, or the reverse, depends on the frame of reference one chooses to view the dynamics from. Of course, causation—what happens—is objectively determined by physics, and the analyst's choice of reference frame will not change that. But different causal systems—and what one wants to understand about them—may make different reference frames relevant, and opens diverse engineering possibilities both to human engineers, and—of more relevance here—to natural selection functioning as an engineer.

It is indispensable to recognize that the upward climb toward replicative order against what we will call *replicative entropy* references kinds of physical order and entropy that are fundamentally different from either thermodynamic order and thermodynamic entropy, or informational order and Shannon entropy. Replicative order and replicative entropy are proprietary concepts that emerge specifically from the logic of natural selection, and not from thermodynamics or information theory. The concepts of a lineage's replicative frame of reference and its replicative order will turn out to be fundamental to understanding both the evolution of communication and the evolution of meaning.

Organisms can exist only because evolution exploits the potentiality inherent in deploying different entropic frames of reference and their different types of order and marshaling how they interact to accomplish different and complementary kinds of replicative work. That is, what is naturally increasing disorder (moving toward increasingly probable states) for one frame of reference inside one physical regime can be harnessed to decrease disorder and perform replicative work with respect to another frame of reference coupled to another physical regime. For example, ordinary gaseous diffusion, a typical kind of increasing disorder, can be used throughout the body as something that performs replicative work, increasing replicative order. Oxygen in the lungs diffuses across membranes into capillaries, falling toward more probable high entropy states, and hence increasing disorder with respect to statistical mechanics. However, from the frame of reference of replication-promotion, this same process is decreasing order—just a different kind of physical order. Hemoglobin, trapped on one side of the capillary membranes, binds to the oxygen, which carries it to tissues, where dropping pH lowers the binding affinity, causing the oxygen to dissociate and diffuse into the cell; there it is burned, to provide the energy driving the system, including breathing in oxygen, pumping the blood, manufacturing hemoglobin and capillary membranes, and so on. The increasing disorder of gas diffusion is harnessed by natural selection to increase replicative order (resurrecting ATP so it is available for energy). More generally, natural selection picks out and links different entropic domains (e.g., substrates, enzymes, membranes, cells, assemblages) that each impose their own proprietary entropic frames of reference locally. When the right ones are associated with each other in the right way, they interact to perform replicative work. They do this through harnessing various types of increasing entropy (like gas diffusion) to decrease other kinds of entropy in ways (regenerating ATP) that are useful for the organism. The correct flow of energy and substrates allows the organism not only to successfully self-assemble against other kinds of disruptive buffeting but also enact steps to achieve extremely high replicative order (an adult healthy phenotype, successfully engaging over time in an ensemble of actions that increase the probability of reproduction).

When not looking at all the complementary frames of reference, life's Herculean triumphs of self-ordering seem like the action of some miraculous life force—something like Escher's watermill driven by his perpetual closed loop waterfall. The body, as well as intimately

associated parts of the environment, consists of an interpenetrating patchwork quilt at all scales—one that weaves these heterogeneous domains into interactions that perform replicative work together, while preventing their distinct disordering gradients from disrupting each other (too much).

GENETIC AND ENVIRONMENTAL INHERITANCE

Evolution coordinates the two parallel inheritances each organism receives—the genetic inheritance and the inheritance of environmental regularities—that interact to cause development. Adaptive problems—that is, the statistical set of cause-and-effect relationships in the world that, over evolutionary time, pushed a species' genes from their initial appearance as rare mutants to near universality (or stable high frequency polymorphism)—can be called the species' *environment of evolutionary adaptedness*. The mutation-selection-new mutation-further selection process requires time to push designs very far toward increasingly effective solutions to adaptive problems. The need for many generations means that species' designs necessarily embody organization—sets of organic devices—that constitute functional responses to the temporally long-enduring structure of the world, rather than unpredictable transient events. That is, something does not qualify as an adaptive problem—even if it kills an organism—if the particular events that affect replication do not occur in persistent enough sets over the species range to durably drive genetic change. For selection to build a complex adaptation—an adaptive problem solver—the adaptation must see the world (define the boundaries of the distribution of events it functionally responds to) in terms of large categories of long enduring conditions or continually recurring instances.

Our evolved architectures make bets based on the long-term evolutionary average properties of the members of the categories they evolved to respond to. For example, the majority of snakes are harmless. However, the cost of severe injury or death from the deadly minority selected the design of the snake phobia system so that (at least initially) fear is evoked to all members of the category *snake*, rather than to the subcategories that are actually dangerous, yet harder to discriminate. Hence, the granularity with which our adaptations evolved to categorize the world is large, approximate, and ancient in scale. Accordingly, our cognitive architectures are more likely to be equipped with conceptual primitives such as *snake*, *mother*, *meat*, *enemy*, *fruit*, *night*, *blade*, *fire*, *mate*, *stranger*, *storm*, *scream of terror*, and *sweet*, rather than (obviously) *Czech*, *dove*, *candle*, *waiter*, *arquebus*, *intertextuality*, and so on. (This principle will be significant in dissecting the evolved foundations of meaning.) Even at this early stage of knowledge, converging lines of evidence indicate that there are computational entities, "conceptual primitives," that reliably develop in all normal humans as part of evolved interpretive systems that inhabit our psychological adaptations, even though we do not know all of their formal properties, nor almost anything about how they are neurally implemented or their genetic basis (Barrett, 2015; Boyer, 2018; Carey, 2009; Pinker, 2007; Tooby & Cosmides, 1992; Tooby, Cosmides, & Barrett, 2005).

There is, of course, no such thing as genetic determinism: All developmental outcomes are the disruptable, dynamic, joint product of gene-environment interactions (Tooby & Cosmides, 1990c, 1992, 2015). Yet, species reliably reproduce their designs across generations just as if there were such a thing as genetic determinism—even seemingly sometimes across tens of millions of years. How can this paradox be resolved? It is commonly overlooked that the developing organism not only receives a genetic inheritance, but also receives a predictable second inheritance logically parallel to the genes—the set of enduring, ancestrally recurring environmental regularities

the genes evolved to depend on for development and successful functioning. These are "inherited" simply by persisting as an encompassing envelope of conditions from one generation to the next. This includes everything stable about the species' local world that would negatively affect development if it were changed: the laws of chemistry; the typical temperature range; the reliable initial presence (for mammals) of the mother; the patterned shifts in the spectral composition of terrestrial illumination over the day that our color vision assumes; the stereotypical vocal signals for one's own species (other members of the species constitute a critical part of the environmental inheritance); milk (for mammals); typical species that function as food (e.g., eucalyptus leaves for koala bears); for humans, an adult language community—indeed, one that conforms to Universal Grammar (assuming the correctness of the Chomskyan account); the array of species-typical facial expressions of emotion; the fact that the size and strength of adversaries predict their ability to inflict costs; and perhaps tens of thousands of other aspects of the world (Tooby & Cosmides, 2015).

It is the evolutionarily tuned interaction between these two paired inheritances—a genetic inheritance and an environmental inheritance—that causes the (largely) species-typical design to develop along its functionally coordinated trajectory. Each genetic or environmental element is shaped by ancestral event populations—the summation of incredibly numerous actual individual physical events in the past that filtered some genes over others. For convenience, we term the inheritance of environmental regularities the *environment of evolutionary ontogeny*. This turns out to be a subset of the environment of evolutionary adaptedness, as conceptualized through the lens of the task of successful development.

THE COEVOLUTION OF GENOME AND ENVIRONMENT

Over evolution, natural selection selects not only the genome but also the species' environment of ontogeny. Successful self-assembly is the first adaptive task faced by every organism, and it represents an enormous hill-climbing achievement by moving from a single cell toward amazingly improbable fine-grained arrangements of (often) massive quantities of matter (e.g., trillions of cells). It must be accomplished in the face of the world's continuous change, chaos, and disruption, which constitute ongoing entropic onslaughts to the realization of the organism's replicative order. Obviously, each individual (surviving or not) reflects the compromised intersection of ordering and disordering processes, so perfection or optimality is not to be expected—simply large departures toward functionality from random disorder.

The key to understanding how these challenges are so often surmounted lies in recognizing how natural selection picks the elements of the species' environment as well as the genes that make up its genome. Every time selection picks out a gene, it is also picking out aspects of the environment that the gene's downstream phenotypic consequences interact with. One genetic alternative might make the offspring imprint on the mother's appearance as a guide to mate selection; the alternative might not, and so (for this purpose) the mother's appearance in the second case would not be part of that offspring's environment of ontogeny. That is, the species' developmentally relevant environment becomes different depending on which gene was selected. Selection, by picking one gene over others, constructs the species' environment of ontogeny out of the total superset of total environmental conditions. It also picks out how the developing organism interacts with that aspect of the environment. So, the environment does not just appear unanticipated at the conception of each individual, as a new sculptor might show up, shaping the clay in some individually idiosyncratic way according to her unique vision. Instead, whether and in what way the specific aspects of the environment affect development

have been highly engineered by its long and intricate history of ancestral interactions with the evolving genome in past environments. It matters in what ways the particular environment the individual encounters resembles the species' evolved environment of ontogeny—that is, resembles the environment the species evolved in, and therefore the environment its replicative functionality evolved to "assume."

This, surprisingly, makes the lineage's environment just as much a product of natural selection as the genes are. Indeed, natural selection acts *through* genes by retaining or subtracting mutations (or established alleles). But selection goes further, by acting *on* the relationship between the genes and the organism's developmentally relevant environment, so that their interactions are coordinated to produce the species' functional architecture. Over evolutionary time, selection will sift for genes that pick out certain aspects of the environment based on whether they are useful, stable, and organizing for the successful realization of the organism's design. In effect, that is, selection asks, do these aspects of the environment assist in transforming the *latent replicative order* present in the genes into the *expressed functional order* of the potentially replicating phenotype? At the same time, evolution will select against genes that open development to disruption from other aspects of the environment that do not usefully contribute to development. Hence, development is (imperfectly) hardened against the kinds of regularly experienced environmental (and genetic) variations that diminish replicative order. Indeed, developmental adaptations are not only hardened against variation, but are also often designed to harvest environmental "information" present in that variation so that the resulting adaptations are positioned to richly articulate with details of particular environments in ways that perform replicative work. Of course, novel environmental features might disrupt development in completely novel ways, because the genome has not been selected to be prepared for them (Tooby & Cosmides, 1990c, 1992, 2015).

One answer, therefore, as to why organisms can successfully rebuild their designs across generations despite the ever-changing, disordering nature of the world is that things only change (or not) with respect to a replicative frame of reference; natural selection, acting over evolutionary time designs the replicative order in the lineage so that its replicative frame of reference minimizes the degree to which the flow of events is experienced as change rather than continuity. Heraclitus claimed we never step in the same river twice, but the argument here is that developmental adaptations are anti-Heraclitan in design: that is, they were sampled until ones were found that experience the water as being the same, time after time. This helps explain why, say, species-typical anatomical features, or, the facial expressions of emotion (e.g., anger) appear as if they were genetically determined when there can be no such thing. In fact, what masquerades as genetic determination is joint co-determination by the evolutionarily tuned interaction of the inheritance of genetic regularities and the enduring parallel inheritance of environmental regularities. If you change the developmental environment outside of the envelope of conditions defined by the evolutionary environment of ontogeny, then a different phenotype emerges diverging from the species-typical phenotype. If you change it enough, the organism, lineage, or species ceases to exist.

The coevolution of the genome and the environment allows the evolution of developmental adaptations that circumvent the bandwidth limitations of the genome. The consideration of the role that the environment of evolutionary ontogeny plays in development allows researchers to understand how adaptations can encompass enormous bodies of information about the organism's environment, despite the limited bandwidth of the genome itself. Natural selection only cares, so to speak, that the phenotype be caused to develop an organization that solves its adaptive problems, without caring whether the information necessary for this comes from the genes, from the environment or (as always) from their interaction. So, evolved order is not just "in"

the genes or "from" the genes, and environmental order is not just "in" or "from" or "determined by" the environment. Developmental questions are never a matter of genes "versus" the environment: Genes enable the method by which particular aspects of the environment are caused to participate in the integrative interactions that produce a phenotypic and computational product of (potentially) remarkable complexity, poised to do incredibly subtle and sophisticated replicative work. The information "from" the environment is assigned evolutionary meaning in the process of co-constructing and organizing the behavior-regulatory adaptations. For example, to take a simple case, a perceptual construct may be assigned the coupled meaning (conceptual primitive) "food" in evolutionarily pre-organized data structures accessed by the appetitive system. In opening the architecture to environmental inputs, the system is not escaping evolved organization, but is further realizing it on ever-increasing and ever more precisely articulated scales.

Hence, it is important to fully appreciate that natural selection, in effect, stores information impartially in the environment just as well as in the genome, so that their integration in the developing organism—say, in the brain—always embodies evolved organization and not just "genetic" or "environmental" effects free of each other's "influence." This evolutionary functional developmental framework is not nativist (although it incorporates aspects of nativism); or environmentalist (although it incorporates aspects of environmentalism); instead, it recognizes that every aspect of every organism is the joint product of an evolutionarily-coordinated gene-environment co-regulated developmental system.

Given that everything develops (from the original zygote), adaptations should be conceptualized as having two functional modes. Researchers generally focus on what can be called the executive mode, in which adaptations are executing their evolved functions (e.g., prudent snake avoidance; successful food choice; successful predator evasion; incest avoidance). What often escapes attention is their organizational mode, in which they are operating in a fashion that assembles them and organizes them to be better positioned to execute their function (turn-taking in motor practice of evasion and chase; sampling potential foods). A great deal of what appears to be nonfunctional behavior when viewed from an executive mode perspective (e.g., play fighting, babbling) seems plausibly to be adaptations operating in a self-organizational mode (Cosmides & Tooby, 2000; Tooby & Cosmides, 2001). One face of aesthetic motivation appears to be the product of adaptations operating their organizational mode, motivating the organism to interact with aspects of the world in ways that increase the power and acuity of the mind's functionality.

Over evolutionary time, a lineage can discover new stores of organization that are reliably present in the environment, and hence available to be exploited once adaptations (in their organizational mode) become tailored by selection to transmute them into replicatively useful somatic or neurocognitive structure. Such stores offer the opportunity for species to evolve adaptations whose designs guide the developing organism to exploit them to become better organized to perform replicative work. For example, the hedonic reward signal of chase play or play fighting, together with the cognitive/decision-making architecture it is a part of, guide the organism in activities that harvest environmentally dispersed fragments of information into developed perceptual motor skills, skills of concealment, exploration of the environment for refuge and evasion paths, etc. Consequently, as the organism plays, it develops a far greater competence in predator detection and evasion, there to be executed when menaced (Barrett, 2015; Symons, 1978).

Others' minds are a particularly pivotal source of information embedded in the environment. For example, the brains of the local population of adult macaques contain useful information about the magnitudes of the local ecological risks of venomous snakes. Macaques

recalibrate their initial fear of snakes by watching conspecifics display fear expressions toward snakes (Mineka, Davidson, Cook, & Keir, 1984; Öhman, 2009; Öhman & Mineka, 2001). The fact that the snake phobia system is designed to reset parameters based on others' fear levels frees the fear system from the potentially unrepresentative prison of individual experience—an incipient form of culture.

From the point of view of each child entering the world, the stores of information in minds of the pre-existing members of the social group are a reliably recurring aspect of the environment. Humans, of course, have taken the mining of information to be found in the minds of others to remarkable zoological extremes. Indeed, humans have evolved an entire suite of adaptations that propelled us into what we and others have called the cognitive niche, a way of life involving the intensive capture and use of detailed local information, based on a dramatic drop in the individual cost of acquiring information (Pinker, 2010; Tooby & DeVore, 1987). In the cognitive niche, humans use unprecedented amounts of socially accumulated local cause-and-effect information and expertise, enabling (among other things) tool use and the contingent improvisation of tactics for highly productive ecological exploitation. This has allowed humans to multiply across nearly all terrestrial habitats, successfully diversifying into a remarkable number of subsistence practices.

The computational architecture underlying the cognitive niche includes adaptations supporting information pooling in the social group (culture); the evolution of specializations for the low-cost transfer of (largely) propositional information from mind-to-mind (involving the evolution of language and innovation in other aspects of communication); mind-reading adaptations enabling striking advances in inferring the contents of others' minds (involving theory of mind, pragmatic implicature, epistemic vigilance, scope syntax, etc.); adaptations for causal reasoning supporting tool use, environmental manipulation and instrumental action ("intelligence"); and a rich set of adaptations for cooperation, exchange, and interpersonal negotiation (moral and socioemotional adaptations; Cosmides & Tooby, 2000; Mercier & Sperber, 2011; Pinker, 1994; Sperber & Wilson, 1996; Sznycer, Al-Shawaf, et al., 2017; Sznycer, Tooby, et al., 2016; Sznycer, Xygalatas, Agey, et al., 2018; Sznycer, Xygalatas, Alami, et al., 2018; Tooby & Cosmides, 1992, 2008, 2010; Tooby & DeVore, 1987).

COMMUNICATION AND SYSTEMS OF EVOLVED MEANING

Innovations in communication lie at the heart of the human information-intensive cognitive and behavioral revolution. These innovations create and support the immeasurably enriched human inner worlds that constitute our species' strange existence. This is because low-cost, high-bandwidth communication spreads the costs of acquiring individual pieces of information across all the individuals in the social group (or communicating population), radically lowering the *per capita* cost of information (Tooby & DeVore, 1987). This reduction in price fueled striking increases in the quantity that can be cost-efficiently used. Moreover, the payoff of discovering new information is not just reaped by the discoverer (as it would be without communication), but also by kin, cooperators, and descendants, explaining the evolutionary increase in the human lineage in the motivational intensity of curiosity, exploratory imperatives, and life-long propensities to play.

Traditional approaches to the social and human sciences (blank slate views, or the Standard Social Science Model) have reasonably foregrounded culture, language, learning, intelligence, rationality, and sociality as central to human uniqueness (Tooby & Cosmides, 1992). However, we want to briefly caution that the traditional conceptions—the implicit and often explicit

models of what these are like computationally—contain some assumptions that need to be revised, especially that (1) the dominant learning architectures are prepared to face all contents equally; and (2) they contain no reliably developing content native to their systems. This contrasts, for example, with Chomsky's (1957, 1959, 1975) arguments that for the human cognitive architecture to be successful in acquiring the syntax of the local language, it needed a specialized language acquisition device. Specifically, its principles of language induction contentfully reflected in some form correct limiting assumptions about universal grammar—that is, grammatical patterns and principles characteristic of all human languages. In the terms used here, the linguistic environment of evolutionary ontogeny included the cognitive architectures of language-competent speakers. Species-typical universals characteristic of these computational architectures (what Chomsky called *universal grammar*) selected for language learning adaptations that presume that the local language conformed to universal grammar, a step which made this cryptographic-like decoding problem (the child inducing the local grammar) computationally possible (Chomsky, 1975; Pinker, 1989, 1994; Tooby & Cosmides, 1990b). This was the strongest early case study indicating "learning" was not what cognitive and psychological scientists had thought it was for almost a century—a powerful but content-free system that could solve any learning problem without needing any content-specialized computational principles built in. On the blank slate view, the human mind was conceptualized as something like a tape recorder or video camera (or blank slate)—the mechanism of recording added no signal of its own; the only content was supplied by the external environment. This was Aristotle's theory that, in Aquinas' distillation, "There is nothing in the mind that was not first in the senses." Plato famously argued that the mind was full of innate ideas derived from past lives.

It is important to identify two related, mutually reinforcing arguments which, rightly or wrongly, summarize key points of departure of an evolutionary functional view of the mind from the Standard Social Science Model paradigm for the behavioral sciences (including the psychological, social, neural, and allied biological sciences). The first is that evolution would not have produced a blank slate mind, because it would have been hopelessly computationally inefficient, having to consider endless sterile possibilities while starving or being eaten by predators, etc. (Tooby & Cosmides, 1992). The second is that evolution would not have produced a blank slate mind, because (as Chomsky argued in the case of language) the organism faces a diverse number of adaptive problems that must be solved but that are computationally intractable to a blank slate mind, because the necessary information is not out in the environment (Chomsky, 1957, 1959, 1975; Tooby, Cosmides, & Barrett, 2005; Tooby & Cosmides, 1992). For example, Hume famously pointed out that one cannot derive an ought from an is, which means that for every domain where the definition of biological success is different (e.g., foraging, mating) the organism must have values or definitions of biological success supplied to it from its architecture (Tooby et al., 2005).

The field of evolutionary psychology is largely based on the recognition (or some argue, misconception) that the human neurocomputational architecture is full of replicative order in the form of neural programs that are functionally specialized just like the language acquisition device is. These programs cover an enormous range of adaptive problems and functional activities: child rearing, foraging, navigation, altruism toward kin, negotiating welfare tradeoffs to social others, forging group identity, participating in collective actions, resolving conflicts of interest cost-effectively (managed by the anger system), effort-allocation, alliance detection, preventing infidelity, incest avoidance, mate choice, sexual motivation, status management, collective aggression, animacy detection, food evaluation, cooperation, exchange, friendship, coalitional action, and so on (for an overview of the logic, see Tooby & Cosmides, 1992, 2015; for reviews of the field, see Buss, 2015).

On this view, each of these functionally specialized programs contains their own evolved proprietary computational architecture. While the computational specifics of particular adaptations are becoming increasingly resolved as research progresses, our neuroscientific ignorance about how exactly information-processing is neurally implemented makes modesty appropriate. Nevertheless, these programs appear to have conceptual primitives (*mother*, *food*, *conditional exchange*, *goal*, *agent*, *harm*, *kinship*, *contamination*, *sexually attractive*, *own-offspring*, *enemy*, *ally*, *us*, *them*, *health*, *sickness*, etc.); interpretive frameworks (which link primitives into systems with specialized inference engines, including often motivational triggers); specialized inferential elements (pollution by contact, cheater detection, grammar-morphology induction, alliance cue signals alliance group, strength predicts dominance, playface initiates pretend play, seeing is knowing, etc.); motivational programs (punitive sentiment toward free riders; erotic attraction; familial love, etc.); value-concept gradient systems connected to specific motivation and emotion programs (setting, e.g., the magnitude of fear related to closeness to spider; the magnitude of the sacrifice one is willing to make for the welfare of a specific known other; magnitude of rivalrous dislike given the magnitude of the threat of loss or displacement; the magnitude of hunger); and so on (Buss, 2015).

If one accepts that there is a rich, evolved set of content-specialized programs in the human mind, then this raises the question of how the contingent elements of each individual's life become correctly mapped into these pre-existing cognitive structures so that they can perform their evolved functions. Each adaptation faces the problem of binding or attaching represented local contingent facts to its appropriate evolutionarily meaningful conceptual or regulatory proxies: The grammar system must detect that specific words in the local language are *verbs*. The kin detection program must attach a perceptually defined person-representation to a kinship index—i.e., who is your *sister*?, what is the *name* of the *stranger*?, what substances around you are *food*?, what faces are *enemies*? Systems for binding ontogenetic specifics have distinct methods specific to the nature of the interpretive problem, but in general these subcomponents can be called psychophysical front ends associated with programs for assigning meaning and motivational tags. This *face* is your *mother*; this person who supported you in the argument is on *your side* and is your *ally; you* are both *members* of your *coalition*, and in *conflict* with *them*, the *opposing coalition*. This is the world our brains construct for us, in interaction with local inputs.

Each ancestral human was born into a particular place and situation full of contingent specificities: These trees, my mother, my sister, this fig in the hand, this snake on the branch, these utterances, these facial expressions, these tools, this set of band-mates, these neighboring groups, and so on. If *verb* is a part of universal grammar, then instances of verbs must be recognized in the lexicon as verbs. Evolutionary theory suggests that genetic kin constitutes a special category of persons that the actor benefits from treating altruistically, and benefits by avoiding them as sex partners. To perform these functions, the kin detection and motivation system must discover and map which familiar others are genetic kin. Research indicates humans have such an evolved program for detecting genetic kin; it uses the cues of seeing one's mother care for a newborn, and length of co-residence during childhood to bind regulatory magnitudes of *genetic kinship* (the higher the index, the more sexual desire toward them decreases and altruism increases) to particular people (Lieberman, Oum, & Kurzban, 2008). Similarly, an alliance detection program uses behavioral cues of alliance observed in one's social world to sort people into one or more alliances (Kurzban, Tooby, & Cosmides, 2001; Pietraszewski, Curry, Petersen, Cosmides, & Tooby, 2015). For an adaptation to be activated and guide behavior, this process must happen for every active psychological adaptation. Therefore, the mind experiences and represents the person's situation and flow of experiences at two levels simultaneously: The first

level is the world of unique particularities; in the second level, these particularities are clothed in or mapped to meaningful evolved categories (predator; beloved child; weapon), and weighted with motivational magnitudes (close family member; desirable game animal; annoying free-rider). In aggregate, the current activation of these programs provides the organism a *situation representation*—something the organism always needs, so that she always knows how to act in the present moment.

Understanding the reality of these interpenetrating systems of evolved meaning throughout our species' neurocomputational architecture is crucial to understanding the nature and operation of human-to-human communication. To understand fully why, it is necessary to take a step back and explore the relationship between the perspective that emerges from the theory of replicative functionality, and Shannon's (1948) separately developed theory of information and communication, embedded in Weiner's (1948) conceptualization of cybernetics.

EVOLUTION, REPLICATIVE ORDER, AND SHANNON'S THEORY OF COMMUNICATION

Evolution provides a framework that grounds Claude Shannon's theory of communication and Norbert Weiner's science of cybernetics in replicative order. A key question is how Shannon's theory of communication, and especially information theory, relates to the evolution of life. To answer this, we need to identify exactly when information entered the world, where it exists, and how it exists (leaving aside the different meaning of information in quantum mechanics). For Shannon, information is a concept analytically embedded in his theory of communication. "The fundamental problem of communication is that of reproducing at one point, either exactly or approximately, a message selected at another point" (Shannon, 1948, p. 379). This model posits two entities, the source and the receiver, which are already coordinated on a pre-existing set of possible messages. In any particular instance of communication "[t]he significant aspect is that the actual message is one selected from a set of possible messages" (Shannon, 1948, p. 379; see also Shannon & Weaver, 1949). At the risk of stating the obvious, it follows that information in Shannon's sense only comes into being with respect to the existence of a source and receiver sharing such a set of pre-established messages. In the nonliving physical world, there is feed-forward causation and causal structure, but no shared sets of messages, and so no information in Shannon's sense.

With the emergence of life with its replicative order, things no longer merely happen; instead, a new kind of physical order, replicative order, differentially accumulates. Replicative order in the design of organisms is designed to bring about some outcomes (those doing replicative work) over other outcomes. Living order benefits from, and is selected to accumulate, organization for the targeted regulation of functional processes, including behavior. With the passage of evolutionary time, it is easy to see that the design of an organism might evolve regulatory elements designed to exercise control over other functional subsystems—elements which benefit by such regulation. General cells evolve into nerve and other cell types. Within the organism, it is easy to see how the system benefits from components which send, and other components that receive, evolutionarily coordinated messages from a pre-existing set, such as a pain receptor in the foot triggering muscle contraction. Although we have been culturally and technologically shepherded by our digital tools towards thinking increasingly in terms of Alan Turing's conception of computation, Norbert Weiner's proposal of a more inclusive field of cybernetics is a more illuminating framework. He defined cybernetics as "the scientific study of control and communication in the animal and the machine" (Weiner, 1948). Fitting regulation

(control), information, communication, and then computation together inside an evolutionarily informed cybernetics puts them together logically and historically in the wider scientific landscape of the evolution of the physical universe.

Although we now associate information with computation, and often consider computation in its most general and abstract form with mathematical analysis taken independently of real-world consequences, much is lost (as well as gained) with this Turing-style framing. Adversaries in war naturally tried to defeat others' understanding of one's codes by injecting maximum unpredictability into the signal. For this reason, computational approaches to encryption and hence decryption are designed to minimize fallible assumptions about what the incoming signal might be. Decryption—depending on the detection of the deviation from noise—pushes for computational generality in a way other engineering problems do not. The resulting implicit and often explicit model of a computational system, generalized to be ready for anything is, we argue, fundamentally misleading for understanding the emergence and nature of natural computational systems.

In contrast, Norbert Weiner was recruited to work on the problem of fire control systems in anti-aircraft guns. Such particular engineering problems are intrinsically computationally specialized, wherein the actual embodiment of the guns, the properties of ammunition, the dynamics of the targets, and the atmosphere manifest regularities that can be treated as a stable background; the computational elements developed to solve the fire control problem can implicitly presume these regularities in their computational implementations. This vastly simplifies the computational problem of inputting or estimating the remaining open parameters (target speed, altitude, wind direction, temperature, air pressure, distance) that must be integrated for the target to be hit. (Interestingly, Claude Shannon started his career at Bell Labs also working on fire control systems.) In approaching control problems, Weiner did not need a general-purpose computational system that implemented a totally flexible conceptualization of the situation. Instead, the methods required for regulatory guidance of a system to the goal are the residual set of those not already solved by the regularities of the task environment and the system embedded in it. "Representation" of the total situation can be largely dispensed with. These often allow elegant minimal hacks to solve a specific engineering problem. For example, to catch a baseball or intersect with any other projectile, you only need to move to keep the object at the same point in your visual field—you do not need a computation of the ballistics of the projectile and yourself with respect to a three-dimensional environment. (We suggest that, despite the apparent flexibility of human intelligence, the reality of natural computational systems is far more analogous to fire control systems than to Turing machine implementations on von Neuman architectures; Tooby & Cosmides, 1992.)

As a consequence of the evolutionary accumulation of replicative order in living systems, adaptations for systems control that perform replicative work evolve computational and signaling systems. In these systems, information comes into being with the evolution of coordinated sets of messages between senders and receivers internal to the organism. Replicative order provides frames of reference with respect to which information exists, rather than just physical causation. Hence, information in Shannon's sense first enters the world embedded in evolved regulatory systems. Natural computation enters the world as specialized regulatory elements designed to solve particular adaptive problems for the organism (at all scales—even single-celled organisms have large numbers of regulatory information-processing elements; Bray, 2011). All exist within frames of reference provided by the replicative order of the respective species or lineages involved.

It is important to recognize that information per se in Shannon's sense does not exist in the external physical world. Physical causation exists in the external world, but information does

not. There is no pre-existing objective parsing of the world into an exhaustive set or superset of messages. Despite how our senses present the world to us, the world simply exists as an endless uncarved flow of physics, and each cause-and-effect relationship is just an infinitesimal part of the limitless ocean of unparsed structure. (It is important to note that DNA involves communication in Shannon's sense, and is both information-bearing and also computationally system-regulating—merged in one superlatively functionally ordered replicative system. DNA replicates and enters or forms a new cell, which constitutes the transmission of a message written in a code both within and between individuals. It also is the source of regulation for the cell, or a cascade of larger entities.)

In contrast, whereas information does not exist in the non-living world, the precursors to information—the raw material out of which information is extracted—obviously do exist. This allows us to be more precise about what learning is (in the broadest possible sense) and how information in our brains about the world is produced through interaction with a world—a world that merely contains precursors to information but not information itself: An organism benefits by regulating its behavior in functional accordance with selected aspects of the actual state of affairs in the external world (it needs to detect and flee predators; identify and eat foods, etc.). Hence, the regulatory architecture evolves to detect those states of the world that the regulatory system needs to discriminate and differentially respond to implement functional regulatory responses (i.e., perform replicative work). Brains are infinitesimal compared to the magnitude of the world, so brains evolve to cost-effectively assay those limited aspects of the world that might be useful to coordinate their behavior in conjunction with. It throws away or does not detect the rest.

Learning can be defined in the least restrictive way as the assessment of states of the world that one or more regulatory systems in the organism developed to discriminate in order to perform replicative work. Under this broad definition, even perception is a form of learning. The replicative order of the organism (usually in interaction with prior developmental processes) provides a computationally implemented frame of reference designed to interpret these input assessments. These computational systems interpret them in terms of the functional regulatory outputs they enable (i.e., flight driven by the detection of a predator; mastication driven by the recognition of a food). In fact, a set of information carried by signals to a target in a regulatory system coevolves with an interpretive system that frames physical patterns as information. That is, information is physical (as Shannon and other information theorists emphasize), but exists only with respect to an interpretive system in an organism—a system that provides a frame of reference (derived from replicative order) that makes the information meaningful to the regulation of the system (and other subsequent computational steps the organism might be designed to make). It is always important to remember that information only exists with respect to an interpretive system, and natural interpretive systems only came into existence as aspects of evolved organisms. Of course, multiple organisms (especially of the same species) can and commonly do share the same interpretive systems in terms of their abstract properties (such as object recognition, predator detection, social hierarchy, or phonological processing). These are shared in the sense that each member of the species (or a developmentally coordinated group) has its own instantiation of the interpretive system (e.g., a local dialect's phonemic boundaries) that is paralleled in others. Those who share interpretive systems will therefore interpret external situations in the same way. As we will see, this sharing of interpretive systems—and hence potential coordination—between individuals are important, because they are what allows Shannon's theory of communication to be applied to communication between organisms.

In Shannon's conceptualization of communication, there is a shared set of messages, and the problem is one of reconstruction in the receiver of the message that was sent. In an evolved

system of sending and receiving within an organism, this needs to be analyzed somewhat differently: There must be a principled mapping between the message sent and an interpretation in the receiver, but the receiver does not need to reconstruct the "same" message—just the useful next step in the usefully managed regulatory process. In murine rodents, olfactory cues to cats trigger predator evasion, but the receipt of the signal by the behavioral system is triggered evasion, not the reconstruction of a smell template (Kinderman, Siemers, & Fendt, 2009). The point here is that the organism's regulatory system provides (1) a frame of reference that (2) assesses some physically detected signal in order to (3) characterize some external state of the world that (4) discriminates it from other states of the world, in terms of (5) an interpretation that (6) the regulatory system uses to produce or improve behavioral (or physiological) regulatory outputs. So, more precisely, natural information only exists in the world paired with or relative to an interpretive system—a system that provides a frame of reference that gives an interpretation to the informational substrate that turns the substrate into information. These (naturally occurring, as opposed to artificially built) information-interpretative system pairs exist only inside organisms (or between organisms), as a result of the organisms' replicative order.

In the case of evolved instead of artificial communications systems, the properties of the receiver's communicative and interpretive interface are the lock (the recurrent adaptive problem) that the sender's signal production interface evolves to unlock. Likewise, the properties of the sender's signal production interface are the lock that the receiver's communications and interpretive system evolves to unlock. At its simplest, when conflict is absent, senders evolve architectures capable of being understood by receivers, and receivers evolve architectures capable of understanding—each constituting an adaptive problem for the other and each coevolving to constitute an adaptive solution to the adaptive problem posed by the other.

Shannon separates off the question of meaning from the analysis of physically instantiated information, a useful and prudent step, given that it takes an evolutionary framework to tackle the question about what natural systems of meaning are in evolved organisms like humans. Here, however, we suggest that scientific progress on questions concerning the nature of meaning—at least specific types of meaning—can be facilitated by considering how each specific type of information generated in one part of the architecture is used by other components as inputs, intermediate computational products, or regulatory outputs in other functional parts of the system: all to drive replicative work. Meanings in our architecture are not Shannon-information decoded from messages sent; instead, meaning systems emerge in evolved human psychological adaptations as they assemble themselves in their organizational modes. For example, *mother* may have propositional linkages in the conceptual and language systems, but it is also linked in implicit regulatory ways to motivated proximity management, welfare trade-off valuation, as triggers of kin detection for her other children, and many other systems which are quite functionally specifiable but fall outside a lexical database (Bowlby, 1969; Lieberman, Tooby, & Cosmides, 2007; Tooby et al., 2008; Tooby & Cosmides, 2008). Meaning is generated by the programs in our brains that evolved to serve our regulatory systems. However, precisely because we are not unitary agents pursuing the goal of reproduction but assemblages of quasi-autonomous programs, we embody large, diverse sets of evolved, haphazardly developed interpretive frameworks that assign affect-laden meanings.

COMMUNICATION AND LEARNING

Communication between different organisms is based on learning—that is, adaptations designed to detect states of the world. Natural communication first evolves within organisms. Obviously,

however, eventually communication evolves between different organisms (more precisely, as we will see, between subcomponents of different organisms). It is not, though, always appreciated that the driver of the evolution of inter-individual communication is located in the learning systems and associated interpretive systems of the receiver. That is, the organism evolves to capture those types of information from the world that assist it in improving its different systems of behavior regulation (foraging, mating, alliance, aggression, predator evasion, etc.). That is, it evolves learning systems that correspond to what it needs to know. The world happens to supply the great majority of what the organism needs to know, but the world per se was not generally selected to supply it.

The designs of the learning systems (such as its specification of the states of the world it benefits from registering, discriminating, and interpreting) evolve to match the organism's learning problems. However, for a subset of what the organism is designed to assess, there are payoffs to the supplier of assisting the receiver in capturing this information. In most cases of learning, there are information seekers ("receivers") but not information senders. Here, we are not speaking about the intentions of the sender (whatever that might mean), but whether selection has shaped the monitored organisms to assist in delivery of informative signals to the information seeker. So, we have information seekers, which attempt to capture information that is useful to them; there are incidental information suppliers, which the seekers evolve to capture information about and from. For example, trees are opaque, and therefore animals avoid colliding with them: They supply the information about their locations, but they do not send it, because they have not been selected to make supplying this information easier.

Of course, there are organisms that benefit when the information seekers receive information about them. They become subject to selection pressures that modify their designs to more readily supply this information to information seekers. In this case, we have finally arrived at what is describable as inter-individual communication, with actual information, actual senders (those designed to supply information), and actual receivers (those designed to capture this information). The characteristics of the adaptations for sending are driven by the characteristics of the receiver—that is, what states of the world the receiver is designed to capture. With the emergence of this system there is genuine inter-individual (as opposed to within-individual) communication of information. Having come so far, it is still important to recognize that this is only unidirectional communication, from the sender to the receiver, and not bidirectional communication. Such unidirectional situations are common. For example, toxic organisms, such as certain species of butterflies, are brightly colored; potential predators benefit by being warned before they sample toxic foods; toxic prey benefits by not being sampled. Prey evolves to signal toxicity to predators, but predators are not (in this case) selected to send any corresponding signal back.

Finally, among many animal species there is the evolution of full reciprocal or bidirectional communication. Under some circumstances, both parties benefit from capturing information from the other, and both are selected to supply it. These systems of communication may or may not share a full set of messages between sender and receiver, but that do not mirror the sender's message. What can serve as a substitute for Shannon's shared set of messages is a set of messages potentially sent by the sender, matched with a set of functionally useful interpretations derived by the receiver—interpretations that do replicative work for the receiver. The butterfly has warning coloration, but the avian predator does not also have warning coloration as a possible return signal; what the avian predator has is a weighting on prey choice by appearance that causes it to avoid the butterfly—that is, that gives a regulated functional response to the signal.

In contrast, in the case of human language, there is the full Shannon communication system, wherein the sender and receiver share a set of messages and the receiver reconstructs

the message sent by the sender. Moreover, language is typically bidirectional (but obviously can be unidirectional, in which language production is in one of two individuals only, so that an aphasic or a very young child may understand the speaker but not be able to speak in turn). It is arresting that the form of communication that seems so easy and natural to us should in fact have such an extensive set of layered properties, and should be at the upper end of the evolutionary process.

With no hope of its being acted on, we gently suggest that it might be useful when discussing evolved communications systems, to sometimes use the term supplier rather than sender, since the supplier has not always been shaped by selection to send signals; instead, in many cases the source happens to supply to observation the precursor or information substrate to what becomes transformed into information when interpreted by the information-seeking interpreter and regulatory system. So, one has suppliers and seekers rather than senders and receivers.

CONFLICT AND DECEPTION AS FEATURES OF INTER-INDIVIDUAL COMMUNICATION

Conflict is a ubiquitous feature of inter-individual communication. Signaling theory and the evolutionary dynamics of communication are still debated, and papers outlining key issues are readily available, so we will not extensively review these issues (Dawkins & Krebs, 1978; Grafen, 1990; Krebs & Dawkins, 1984; Maynard Smith & Harper, 2003; Searcy & Nowicki, 2005; see also Chapter 4 by Reid, Zhang, Anderson, & Keblusek, in this volume). For those unfamiliar with these issues (but familiar with the nature of social life), it will come as no surprise that the primary dynamics arise from the fact that different replicators have different fitness interests, and so are often selected to pursue conflicting agendas, generating conflict, and over generations antagonistic coevolution. Organisms (typically animals) for reasons already described may be selected to produce signals that supply information to information seekers. Because fitness interests are rarely perfectly aligned, inter-individual communication is challenged by the possibility that signals may sometimes be deceptive. If signals of a given type are never accurate, then information seekers will evolve to disregard them, and there will cease to be communication in that channel. Hence, the only signals that animals stably monitor are ones that continue to have some information in them. The question is what keeps signaling honest under conditions where senders are benefitted by supplying signals that are sometimes honest, sometimes not. Of course, there is ongoing selection in the information seekers to distinguish honest from deceptive signals.

One theory is that, under the right envelope of conditions, the honest signals are costly to send. If the signals are costlier for deceivers than for honest signalers (for example, because the honest signalers are in better condition (Grafen, 1990; Zahavi, 1975), then this can place a limit on the invasion of deceit into a system of honest signaling. According to this view, for example, only the healthiest peacocks can afford the largest and most colorful tail (Zahavi, 1975). Index theories propose, in contrast, that in many cases of communication, the nature of what is being assessed cannot be faked by virtue of the causal pathways involved: For example, if what is being advertised is a low level of mutations, and the mutations express themselves if they are present, it is not matter of cost to distinguish low- from high-quality genotypes (Maynard Smith & Harper, 2003). The apparent *joie de vivre* of a male whale breaching the water and falling back is explained on this theory by the fact that the sound of his impact is strongly physically correlated with his size, and therefore with his aggressive formidability—something hard to assess otherwise in the visually challenging underwater murk. It is a satisfying complement to

index theory that the causal structure of the world is such that organisms often cannot help but supply information simply by pursuing their replicative activities. Information seekers evolve to track whatever useful information may be supplied in such observations, which sets the stage for a gradualism of the seeker focusing on, and developing more sensitive detectors for those physical indices which reliably convey information in a difficult to fake way.

Often, evolutionary dynamics of signaling for a set of organisms can be sorted out by asking the following series of questions: What sets of information does each set of organisms benefit by observing? For each set of organisms and each body of information, who is benefitted by the truth being revealed? Who is harmed by the truth being known? Who knows which players would be helped or hurt? Who is in a position to release or broadcast the truth (about a given set of information)? Who is in a position to clarify or obscure the truth being known? What are the costs and benefits for each player of changing the knowledge states of others, and their own? For example, in a system of sexual selection, a high quality male might benefit by his mate quality becoming known to local females, while other males might be harmed. Other females might benefit from discovering his mate quality, whereas his present mate might be harmed. In contrast, if senders and receivers (such as mothers and offspring) are both benefitted by the truth being known (i.e., is there a predator?), then signals might evolve to become very reliable, and highly trusted. If a young male who has been rapidly increasing in strength knows he has become relatively strong, then he can advantageously recalibrate others by arranging a display (like chimpanzee tree-branch shaking) that advertises his strength. Using these questions, communications dynamics for any given situation can be broken down and analyzed. They apply to illuminating the dynamics of rivals, cooperators, those like potential mates engaged in consequential choices, predators, prey, parasites, allies, outgroup members, and mixtures, and the distribution of camouflage, the economics of display, and numerous other questions. The basic principles are nearly self-evident: The agents who benefit by knowing the truth are in favor of transparency; those harmed will discourage displays, produce anti-information, and attempt to increase noise.

It is important to note that neither costly signaling theory nor index theory of honest signaling seem well positioned to explain the two major human cases of human communication: language, and the (often involuntary) expression of emotions. It does not seem to require more calories to tell a lie or to move a deceptive set of muscles in your face than to tell the truth. Nor does it seem the truth is compelled by physical necessity (as with the sound of the whale's impact). We have suggested that in these cases another principle is at play (Tooby & Cosmides, 2008). The argument is that what keeps these signaling systems honest is the relative downstream consequences of broadcasting true versus untrue information among close cooperators over time (Tooby & Cosmides, 2008). This analysis operates more strongly the longer a piece of information is used in the group. Some pieces of information once released will be used repeatedly. It seems plausible that an individual can anticipate how that item of information will be used the first time, in circumstances she can foresee. But second and subsequent uses may be harder to anticipate. The average return on releasing versus withholding information will be, other things being equal, given by the average degree that others take the releasers' values into account in their decision-making. Antagonists will use accurate information to the detriment of an individual, while close cooperators will often use information in the interest of the information source. The argument is that rather than attempt costly strategic analysis of the payoff of every piece of information that might or might not be broadcast, some categories of information on average will have a positive expected return if released, because you are broadcasting to those who place a high weight on your welfare. If so, evaluative information, for example, signaled by certain emotional expressions such as happiness, disgust, fear, and so on, will allow

others to better take into account your welfare when they act, by knowing your values. This model not only predicts emotional signaling's most surprising characteristic—its automaticity—but it also predicts that people will be more emotionally expressive, the more they are together with people they know and like. In contrast, the more they are with people who are antagonistic, or strangers, the more shy, reserved, impassive, and withdrawn they should be.

The explanation for why language is reliable against invasion by deceit may rest on two factors, one similar to the argument for the automaticity of emotional broadcasting. The most basic point is that there is no problem explaining the reliability in communication where there is a reliable harmony or convergence of interests among the communicators. Indeed, humans evolved in small, closely related, highly interdependent groups, which is consistent with the high level of cooperation, and intensive communication mandated by the hominin entry into the cognitive niche—a way of life that depends on high levels of information sharing. Also, it is not an overstatement to say that humans evolved to be nearly obligately group-living in our mutual interdependence. Cross-cultural evidence shows that humans on every inhabited continent, and in small-scale societies as well as developed societies, track in a detailed way the specific values of others in our community. We feel strong shame when we are seen to violate their values (Sznycer, Al-Shawaf, et al., 2017; Sznycer, Tooby, et al., 2016). We feel strongly attracted to winning approval by publicly upholding our group's behavioral evaluations (Sznycer, Xygalatas, Agey, et al., 2018; Sznycer, Xygalatas, Alami, et al., 2018). Thus, our pre-existing plateau of cooperation, based on our obligate small group-based ancestry, is a first-tier explanation for our levels of deceit being lower than they could be.

Second, the kinds of complex propositional information transmitted linguistically often carries its own credibility tests in the way with which it meshes, or fails to mesh, with the immense stores of information we already have. As Mercier and Sperber (2011) and others have written about in enormous detail, humans have a large set of adaptations for epistemic vigilance that are deployed when processing others' utterances (e.g., Mercier, 2020; Sperber & Wilson, 1996). Indeed, we have argued that humans come equipped with what might be called a scope syntax, which is necessary for the human entry into the cognitive niche, because in our information-drenched way of life, individuals are bombarded with vast amounts of information of varying and hard-to-evaluate truth value; that is, our minds need systems for evaluating, and quarantining sets of information so that undetected false representations will not, by inferential propagation, spread incoherence or falsehood throughout one's knowledge bases (Cosmides & Tooby, 2000).

LANGUAGE ACQUISITION INVOLVES EVOLVED SYSTEMS OF MEANING

Language acquisition involves evolved systems of meaning and situation representation. Chomsky's argument about the poverty of the stimulus, and the computational or learnability problems posed by syntax had an immediate and decisive impact on the development of the cognitive sciences (Chomsky, 1957, 1959, 1975; Pinker, 1994; Skinner, 1957). The pre-theoretical commitment to the computational generality of learning systems, especially human learning, meant that almost all attention became stalled at the debate between what one might call (as a convenient name rather than a sophisticated or fair theoretical characterization) partisans of blank slate learning, versus Chomskyans, who focused primarily on syntax. Conveniently, the syntaxes of various specific languages had a formal structure that could (perhaps optimistically) be characterized as at least well enough to test whether, say, finite state grammars could succeed at acquiring them (as they could not).

What few people realized at the time was that Shannon's theory of communication indicated that arguments analogous to Chomsky's about learning syntax applied with even more of a vengeance to learning the semantics of languages. Cryptography is possible only when cryptographers have *a priori* statistical knowledge about a pre-existing set of incoming messages drawn from a shared set. The child's task is parallel to the cryptographer's. The child's task of discovering word and sentence meanings involves isolating, out of an infinite (or indefinitely large) set of possible meanings, the actual meanings intended by other speakers. The less information the child (or cryptographer) has about likely messages, the more messages the child must receive to converge on answers. At the limit, if any message is possible—the system is completely general—then even an infinite amount of information would not allow the child to converge on the local meanings of words. If the utterance "Do you want some soup?" could just as well mean "Martin Luther told me he stole Gaius Marius's dignity when he found a hole in his atomistic argument" or "I hope the clouds sing tomorrow" as it could mean "Do you want some soup?," then the developing child is in trouble.

Fortunately, natural selection, unlike philosophers and psychologists, would never allow the evolution of such a fatally crippled system. Culturally, we are all attracted to the idea of a mind free of content because it (falsely) invites the idea that such a mind would leave us free to think anything without limitation. (However, such an architecture would actually prevent us from thinking.) The developing child, in order to be able to solve the adaptive problem of learning the meanings of words, must reliably have in her evolved cognitive repertoire enough interpretations she shares in common with competent speakers that she can guess at the likely meanings of the utterances she hears. Even more fundamentally, from an information-theoretic point of view, the more general the architecture, the more possibilities it has to compute over—the higher its starting entropy—and the more inefficient it is. Our traditional expectation that brains should be general purpose is upended: Natural selection as an engineer would move brains in the opposite direction, collapsing unnecessary or inefficient dimensions.

As discussed, our evolved psychological architecture must necessarily be permeated with evolved systems of meaning as components or aspects of adaptive specializations that regulate our behavior adaptively (theory of mind; theory of objects; skeletal tool core knowledge; social exchange logic; the logic of aggression; the logic of alliance; child-caretaking; food concepts and motivations; pretend play; syntactic core knowledge; spatial representation; causation, core emotion expression interpretation with the ability to understand the associated evaluative signals; and so on). These systems of meaning supply the interpretations that must be shared between the learning child and speakers necessary for the child to acquire meanings: communication depends on a shared list of messages Moreover, these systems of meaning do something even more basic: All organisms, in order to generate behavior more or less appropriate to their circumstances, have to construct an ongoing situation interpretation (even if it is the emotion mode of confusion—which motivates the suspension of action and attempts to rebuild coherent representations). So, the child herself must always be generating situation representations, which is the central element of constructing what Sperber and Wilson call the mutually manifest between two communicators, as well as the ground of the acquisition word meaning. Situation representation and its sharing are, it turns out, also crucial to understanding the social assignment of meaning in group processes.

Before turning to that final issue, it is important to identify, on the topic of learnability and computational tractability, the relationship between Shannon's theory of information and communication and the efficient design of regulatory and computational architectures. If a human engineer or evolution is building a regulatory system, it obviously needs to be as computationally powerful as necessary to solve its adaptive or control problem. This means its data

structures, frames of reference, and interpretive system need to be as large as necessary to accommodate the number of states to be discriminated and differentially responded to. So, for every dimension in the adaptive problem or task environment that needs bandwidth, one might expect (given cost-performance tradeoffs) for the architecture to have sufficient capacity. This corresponds to what people intuitively call "flexibility" in the cognitive architecture.

Reciprocally, however, for dimensions that have never been needed, one would expect (if somehow they came to exist) for selection (or the canny engineer) to remove them for efficiency and cost considerations. Unencountered dimensions of "flexibility" should have been stripped out or never built, and their occurrence should not be expected to be more than accidental or as a by-product aspect of our cognitive architectures. Evolved systems have only encountered past conditions, so there is no selection to prepare them for all possible conditions, even ones never encountered, or encountered so rarely it would not pay to dedicate resources to the possibility. So, in this sense one expects dimensions of capacity or flexibility with respect to evolutionarily recurrent problems (or their structural isomorphs), but not to Turing generality. In this respect, our minds should bear what Darwin called the stamp of their lowly origins. This is not as depressing as it might sound, because as Chomskyans are fond of pointing out, combinatorics can generate very large outputs from finite elements. Also, it bears pointing out that these capacity issues are somewhat independent of the other deeply contested claim: That our neurocomputational architectures are imbued with large amounts of contentful computational structure, which reconstruct in our minds large systems of evolutionary saturated or evolutionarily inflected meaning. This is no longer as controversial as it once was, when many anthropologists are documenting universal moral sentiments, universal emotion programs, core knowledge systems, and so on.

COMMUNICATION AND HUMAN COALITIONS

For individuals to act together in a group toward shared goals, the members must be coordinated with each other—something that depends on communication. Coalitions are sets of individuals interpreted by their members and/or by others as sharing a common abstract identity (including propensities to act as a unit, to defend joint interests, and to have shared mental states and other properties of a single human agent, such as status, prerogatives, and aggressive power). Underneath is a set of programs that evolved out of pre-existing individual social adaptations, but that also now induce us to form, maintain, join, support, recognize, defend, defect from, factionalize, exploit, resist, subordinate, distrust, dislike, oppose, and attack (other) coalitions. Communication is central to this entire social system, because while an individual is in total control of her own behavior, a set of individuals can only act jointly to the extent they are dynamically communicating and coordinating. This depends on a shared situation interpretation of what they are doing, and a joint motivational commitment to carrying out joint actions.

Most species do not and cannot see and feel about the social world in this way. Among elephant seals, for example, an alpha can reproductively exclude other males, even though beta and gamma are physically capable of beating alpha—if only they could coordinate. The fitness payoff is enormous for solving the constellation of regulatory and motivational problems inherent in acting in groups. Beta and gamma get no matings in a world without coalitions, whereas if they were capable of teaming up, they could drive off alpha and each get half of the matings. Two can beat one, three can beat two, etc., and so once the computational machinery evolves to act in groups, solitary animals are wiped out, and the species becomes a set of contending coalitions rather than struggling individuals. We are descended from some of the vanishingly few

species to have solved these problems by evolving coalitional instincts. In this transformed world, power shifted from the solitary alphas to larger numbers of the cognitively coordinated non-alphas. This gave rise to the human world of politics, coalitions, ingroups and outgroups, factions, and war; our ancestors lived in a world where other groups expanded at their expense, or shrunk as a result of their group's collective dominance. Humans, with our high levels of ingroup cooperation and closeness have our pluses as well, compared to most other species— especially in times of peace. But our minds, even in peacetime, are saturated by the shadows of factions, allies, menaces, and the joy of moving collectively against our adversaries.

The first set of interpretations that our minds construct is intersubjective agreement on the existence of a set of groups. To be successful in the landscape of groups, you need to represent their existence. They exist to the extent to which individuals ally themselves with each other, so public acts of individual alliance are interpreted in our minds in ways that construct a map of our world as being populated with groups or alliances. Significant research shows that humans have an automatic alliance detector that takes individual acts of alliance, and produces group representations. For example, the propensity to categorize by race is one output of these system, and so seeing race in the social world is a function of the extent to which acts of alliance cross or maintain racial lines (Kurzban, Tooby, & Cosmides, 2001; Pietraszewski, Cosmides, & Tooby, 2014).

During our evolution, reproductive resources were often limited, in a zero-sum fashion. Organisms, such as humans, evolved adaptations that take advantage of opportunities to capture enhanced shares of these resources, leaving more copies of these design features than those without lacking adaptations as well-designed. Individual competition exists, but has been largely displaced by coalitions, because coalitions with their greater power in the last analysis tend to determine final outcomes. Coalitions form and compete in a collective, zero-sum fashion for status (relative entitlement to determine outcomes). In more developed areas, government institutions have largely pre-empted violence as the final determiner, but politics becomes the way to govern peaceful societies. In any case, the evolved adaptations still populate our minds with coalitional motivations, constructs, and emotions.

Humans have an evolved, group-directed motivational system that is designed to link individuals together to act as a unit to enhance their status, or initiate aggression in the interest of seizure, exploitive supremacism, or self-defensive deterrence (Tooby & Cosmides, 1988, 2010; Tooby, Cosmides & Price, 2006; Wrangham, 2019). The system is volatilely sensitive to contagious coordination in other group members, as the increases or decreases in the number of individuals who act together volatilely change the power of the group. Indeed, ad hoc mobs may materialize to strip victims of their property, homes, or lives.

Individuals, factions, and groups have two primary avenues of social negotiation: (1) threatening or inflicting harms to the target (aggressive formidability in the Asymmetric War of Attrition); and (2) conferring or threatening to withhold benefits (conferral power). Groups' divisions of social or material resources are determined by representations of status (formidability/conferral power) in the brains of two sets of agents (set A and set B). Where these representations are mutually consistent, there is no (overt) conflict, and these relationships are exhibited in flows of acts that are expressed in welfare tradeoffs between members of the two groups. The expected welfare tradeoffs between the two groups can be mutually consistent and mutually manifest. For example, in the American South under Jim Crow Laws in the 1930s, the relative status of whites was high, and blacks was low, and whites expected black behavior to reflect this. They enforced this by violence and other sanctions. Welfare tradeoffs are proportionate to relative status of the two sets (e.g., social dominance). In such a world, the acts of one or more individuals towards one or more members of another group are interpreted as communicating the relative status of the two groups.

When the weight placed on the welfare of one or more members of the ingroup is perceived as being too low (i.e., less than what the agents implicitly compute they can enforce given their joint formidability or power to withhold or confer benefits), then this becomes the internal trigger for the anger program. The emotion of anger evolved to orchestrate the agent's (individual or group) bargaining behavior during conflicts of interest (Sell, Tooby, & Cosmides, 2009; Sell et al., 2017). The function of the anger system is to leverage through prospective or actual bargaining actions (harming, or withholding help) to recalibrate upward the weight the other party places on their welfare. When groups enter the picture, anger potentially becomes an entrained part of group psychology. Coalitional psychology includes evolved circuits designed to link together the emotion programs of the individuals co-participating in the coalition. The status of the group is a public good shared among them that they all benefit from or suffer from. It is important to recognize this is not a model of rational agents or irrational agents, or of justice-seeking. The communication going on need not be conscious, and need not be directed at each other as agents under executive control. The motivational system involved is designed to assess things such as the formidability of the group, the formidability of the individuals from the other group, and then trigger motivations based on automatic assessments. As people who have been involved in mobs might recall, perhaps it makes sense to say that signals are being sent from computational subsystems inside one or more individuals to subsystems inside other individuals, within and across groups.

Groups negotiate relative rank and entitlement through (1) registration of cues (number, formidability, cohesion, etc.); (2) broadcast signals (expressed anger or outrage, menace); and (3) actions that communicate the intention to incentivize the other party (through directing violence, rioting, withholding or destroying valued things, etc.) until one or both sides recalibrates sufficiently. This is the point where a new equilibrium of mutually consistent welfare tradeoffs is reached (co-registered by all concerned). Permanent, durable groups (like individuals) should be imputed to have a relatively stable bargaining power, implicitly based on their numbers, cohesion, aggressive skills, and ability to grant or withhold benefits. Because of demography, health, maturation and other factors, groups need to assert their deterrent power through managing challenges, or invite attack.

Events in which one or more members of one group injure the welfare of one or more members of another group (defined here as an *outrage*) are implicitly viewed by all aware of them as proposing a change in the intergroup welfare tradeoff relationship—a new precedent that reflects the new relative power of the two groups. This helps to explain something that could be abstractly seen as strange—why should conflict between two individuals come to involve all the individuals of the two groups? This is because group status is a public good that applies to all members of a group. If the group cannot defend member A, then it equally cannot defend member J. Should this new welfare tradeoff precedent be accepted, this would reset expectations for future interactions between members of the two groups to the detriment of one and the benefit of the other. If the group whose member(s) have been injured feels stronger and entitled to more deference than the proposed welfare tradeoff implies (with its potentially undeterred mistreatment precedent), mutual awareness by ingroup members of the outrage mobilizes others to come join a coordinated aggressive action to attempt to reset the other group's welfare tradeoffs toward the ingroup. Here the messages sent back and forth between the two groups are easily and mutually interpreted because everyone shares the same evolved interpretive system. Often these messages are not even articulated—or even lexically accessible.

Typically, outrages and the joint attention they summon trigger collective responses, and so representations of outrages and grievances function as group-mobilizing resources, and are nurtured, embroidered, and exaggerated for their utility in advancing the group's interests,

including in subordinating outgroup members. They trigger cohesion, turning uncoordinated individuals into joint actors.

For this reason, representations of outrages are group resources. Outrages by the outgroup provide a threat to the public good of the ingroup coalition's status entitlement representations; this advertises the possibility of a massively increased payoff for a coordinated group response. Because it is normally difficult to get individuals to set aside competing agendas within groups, yet group power increases with coordination, outrages (real or fabricated) become a resource ingroup individuals strategically deploy to mobilize joint action they (as individuals) benefit from. Nearly all wars are precipitated (rather than caused) by outrages, as well as many social movements (Hitler staged an invasion of Germany by German officers wearing Polish army uniforms immediately before invading Poland; Nazi irregular government power was greatly increased after the Reichstag fire; the Civil War in the United States began after southern troops fired on Fort Sumpter; the modern civil rights movement was significantly triggered by the torture and murder of the boy, Emmett Till, etc.).

CONCLUSION

Having built all this way from first principles, it is important to recognize the centrality that communication plays in cognitively populating the world with motivated groups, often in conflict. Moreover, it is not just communication in general that is involved, but specialized systems of communication that are serving their evolved functions. Consequently, it is important to recognize that groups can only exist because specialized adaptations exist that interpret the world so that we see events in terms of the actions of groups, even when it would be just as accurate to see mere individuals. These groups can only exist because specialized communication links—linked not between individuals, but from subsystems within individuals to other subsystems in other people. These communication links provide us with interpretive systems that impose an evolved set of functions on our choices, shepherd us into acting in groups in highly conflictual ways, activate largely pre-existing content that evolved to be native to our psychologies, and that provide us with a shared hallucinatory reality not often to our good.

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