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Solving Psychological Problems in Four Dimensions:

Heuristics for Integrating the Social and Biological Sciences

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Abstract

Psychology is the science of the individual yet it draws on higher (social, cultural) and lower (biological) levels for its explanations and, in fact, often divides along these levels. We propose a heuristic framework designed to highlight the conceptual commonalities across all areas of psychology. We suggest that psychological problems can be arrayed along four dimensions: level of organization, cause, perspective, time span. We argue that recognizing these dimensions is necessary to tackle complex multidimensional problems (nature-nurture debate, mind-body problem). Indeed, the fissures that are taking place nationally in many psychology departments along one or more of these dimensions make it difficult to adequately address multidimensional questions, and thus jeopardize psychology's pivotal position between the social and biological sciences.

Four Dimensions of Explanation

      The social and biological sciences are plagued by a number of classic controversies (e.g. nature vs. nurture; mind vs. body) that, despite the continued attention they receive, remain unresolved. Moreover, these controversies spawn books for the lay public, written with political agendas and biases in the guise of scientific dialogue (Hernstein and Murray, 1994; Jensen, 1969). The purpose of this paper is to suggest that some of these controversies are more apparent than real – that they arise from a failure to make distinctions within the questions asked. These distinctions, if drawn, would make it clear, not that there is more than one answer, but that there is more than one *question* involved. Rather than having to choose among questions (and answers), we suggest that each of the questions, and its answer, are essential to contribute to our understanding of a phenomenon – the trick is situating these questions and answers within a systematic grid that permits, indeed encourages, comparison.

      In the social and biological sciences, the most interesting and challenging topics are embedded in a complex multidimensional system. In an effort to simplify a problem, making it tractable for empirical research, scientists often focus on a single dimension, with each discipline moving its own emphasis to the foreground. Doing so, however, invariably makes implicit and often unintended changes in assumptions along the other dimensions of the system. Our goal is to help make explicit these implicit factors and processes, and thereby provide a set of fundamental principles for studying and understanding multidimensional systems. We also suggest that psychology, situated at the interface of the social and biological sciences, is ideally positioned to tackle multidimensional problems of this sort.

      We present here four dimensions along which problems in the social and biological sciences can be arrayed. These dimensions are not exhaustive – there are undoubtedly others that could also be useful. The concepts underlying the dimensions are not even new – each concept has been suggested before and written about, often extensively. Indeed, two of the dimensions cover the same territory mapped by Aristotle in his *Physics* (Aristotle, 1970 ca. 350 B.C./1958). The contribution of this paper is to view these concepts as dimensions and to draw these dimensions together into a single fundamental scheme that can be applied to a wide range of problems in the social and biological sciences. The scheme is a foundation on which to build explanations of multidimensional systems. One virtue of the

scheme is that it often allows us to see systematic reasons for cross-disciplinary and within-disciplinary misunderstandings and controversies. The four dimensions that comprise our analytic system are the following:

(1) <u>Level of organization</u>. Phenomena in the social and biological sciences can be described at several levels, from the molar to the molecular. An essential decision that a scientist must make in carving out a phenomenon is to determine the most appropriate level for that phenomenon. We suggest a heuristic – the concept of "robustness" (Wimsatt, 1981, 1985) – that can be used to guide this decision. However, we note that the level of analysis most appropriate to a phenomenon is also affected by the other three dimensions along which it has been situated by the scientist, either consciously or, more often, unconsciously.

(2) <u>Cause</u>. The question most frequently asked about a phenomenon is its cause.[1] Hidden here are two queries – the "how" and the "why." The "how" question explores the mechanism that underlies a phenomenon (the interaction of closely antecedent events, structures and processes that make it happen). The "why" question explores the function of a phenomenon (the events that follow it and lead to its recurrence, its survival in an iterated selection process, ultimately its purpose).[2] Controversies can arise because one scientist pursues the mechanism of a phenomenon, while another pursues its function. Answers to these two types of causal questions are usually quite distinct yet not contradictory.

(3) <u>Perspective</u>. A phenomenon can be described from the point of view of its participants (the subjective, or first-person, perspective) or from the point of view of uninvolved parties (the objective, or third-person, perspective of an observer). In many disciplines, the subjective perspective is considered suspect, an unscientific epiphenomenon of the brain. In other disciplines, the objective perspective is considered either unattainable or bereft of true meaning. Both perspectives are necessary ideals toward which we strive and are important to fully resolve such controversies as the mind-body problem. Indeed, we argue that certain phenomena are actually constituted in terms of the subjective perspective, so that the observer may be inextricably integrated with the phenomenon itself and only have casual power from this perspective.

(4) Time. All phenomena occur in time. When carving out an area of study, a scientist (either implicitly or explicitly) situates a phenomenon within a time span. It may be relatively short, often focusing on processing at a given moment in time (momentary time span); somewhat longer, a span covering an individual's life course or a period during which there is significant developmental change (ontogenetic time span); a span covering a few generations (historical time span) or many (evolutionary time span). By explicitly marking the temporal dimension, major controversies or confusions – for example the nature-nurture debate – often disappear (McClintock, 1979).

We claim that any explanation of a phenomenon can be seen as located in a "space" on these four dimensions. Explanations are "points" whose location is given by four coordinates – its values along the four dimensions. The dimensions are rooted in the structure of the world and organize the various explanations proposed for a given phenomenon. As such, they are broad categories that provide a useful set of heuristics for doing science. By situating phenomena and their hypotheses along each of the four dimensions, scientists achieve a number of essential goals. (1) They make explicit crucial assumptions that guide their research. (2) They thus make it clear how their question may differ fundamentally from questions guiding others' work. (Such work may appear, at first, to be on precisely the same topic, but once located on the dimensions, is seen to be asking different, albeit related, questions.) (3) Works in apparent conflict or apparently unrelated can thus become potentially complementary, strengthening a case, providing new means for cross-checking conclusions, or providing new integration of apparently diverse phenomena. (4) By explicitly laying out the explanatory space for a given phenomenon, scientists may discover uncharted territory within that space – questions that haven't been asked and need to be. The analytic scheme can thus be useful, not only in interpreting science, but also in guiding exploration.

Not all of the four dimensions are continuous, as an analogy with physical space might suggest. Time span and level of analysis have discrete values or ranges of values along a continuum, but cause and perspective differ in having just two or three alternatives identified along each dimension. So the four dimensional grid may have gaps, yet it still offers a framework within which phenomena can be situated and compared. Moreover, current science has filled some of the areas in this four-dimensional

space more densely than others. Asking whether these gaps are inherent properties of the world or lacunae in our science can define the cutting edge of a field. For example, we know much about the effects of lower level mechanisms on higher level phenomena (e.g., the neural mechanisms of behavior). Much less is known, however, about downward causation – the effects of higher level mechanisms on lower level phenomena (e.g., social beliefs as mechanisms for change in neuroendocrine and immune function).

We first explore each one of the four dimensions in detail, illustrating how attention to that dimension can enrich our understanding of a phenomenon. We then consider two classic controversies at the intersection of the social and biological sciences – (1) the nature-nurture debate as it has been applied to language-learning, and (2) the mind-body controversy as it has been applied to notions of biology and culture – and we show how our analytic framework helps to clarify each controversy. We end with a warning call. The national trend to split psychology departments along level and perspective (into biological/cognitive enterprises taking a third-person perspective and social/emotional enterprises taking a first-person perspective) makes it difficult, if not impossible, to address the multidimensional controversies and thus jeopardizes psychology's pivotal position to solve problems at the interface of the biological and social sciences.

Level of Organization: Defining the Phenomenon

Are there criteria to guide our choice of the level on which to analyze a phenomenon? We all have intuitive conceptions of level and can agree that, for example, quark, atom, molecule, cell, tissue, organ, organism, social group, society and species represent units at increasingly higher levels of organization. Whole sciences and theories come tied to these levels. But consensus on an adequate general characterization of levels of organization is harder to come by. The objects at higher levels of organization are made up of lower level objects in a seemingly hierarchical structure. But we do not necessarily go up a level every time we put two parts together. How many levels are there and why are they located "where" they are?

Intuitively, a level is an assemblage of objects, processes, and phenomena that we use for giving a wide class of explanations. But how do we pick out these objects, and this class of explanations?

"What is a thought?" Is a person "nothing but" a collection of biological systems? A single theory won't suffice: There can be many different theories at one level and, in any case, we would want to avoid the specter of a vicious form of theory competition. Wimsatt (Wimsatt, 1974, 1976, 1994) proposes a strategy to answer these questions, which has its origins in Campbell (Campbell, 1958).

Campbell (Campbell, 1958) asked: "What makes an aggregate of persons a social entity?" The answer to this question solves the problem of determining when a description of a set of individuals should be moved up from the individual level to the group level. Campbell outlined several criteria that have been used to identify and isolate a physical object from its surroundings, and suggested that these same criteria can be used to identify units on any level but, in particular, on the social level: (1) similarity (the extent to which the "pieces" of an object resemble one another); (2) proximity (the extent to which the pieces of an object are near one another in space); (3) common fate (the extent to which the pieces of an object experience the same fate in an interaction). Greater resemblance, proximity, and commonality of fate are all associated with a well-defined object.

These criteria evolved into the famous "multi-trait multi-method" matrix of Campbell and Fiske (Campbell, 1958; Campbell and Fiske, 1959), in which covariation of a number of diverse indices, each measured by a different method, reliably (not certainly) gets us past the biases of different methods and the accidents of different associations to pick out objects or variables that are trustworthy, non-artifactual, and real. Likewise, Simon (Simon, 1996) identified a different, but overlapping, set of criteria for a stable unit. The central important aspect of both of these analyses is that each of the probes must use a technique or measure that is independent of each of the other measures. If independent probes converge on the same unit, we have good evidence for the stability of that unit; it is an object, an entity. George von Békésy ((von Békésy, 1967) quoted in (Teitelbaum, 1967)), the 1961 Nobel prize winner in medicine and physiology, quipped that he never published a finding until he had used five independent methods to identify an entity and, even then, he expected its scientific life span to be only 50 years because new scientific methods would inevitably become available.

Robust Entities. "Robust" is the adjective Wimsatt (Wimsatt, 1981) uses to refer to these entities, properties, processes and theorems that are detectable by converging operational probes (Culp,

1995; Feynman, 1965; Hacking, 1983; Levins, 1966). In a sense, robustness is built into our notion of what constitutes an object – we are more convinced that an object exists if we arrive at the same boundaries for that object using a variety of senses (e.g. sight, touch, and sound). We can see the surfaces of a speaker's podium. We are further convinced it is not an illusion when the speaker rests notes on it and slaps it to get our attention. Indeed, a hologram is an illusion precisely because light alone defines its borders, not touch, sound or temperature. Thus, robustness is the agreement of properties and boundaries as detected by several techniques.

When robust objects are likely to interact with each other, and not with objects that are either significantly larger or smaller, this assemblage of highly interactive objects constitutes a level of organization. In effect, the objects have a good deal of "common fate." As a result, most causal explanations involving objects at a level will involve other objects at that same level.   This situation yields a kind of dynamic autonomy for objects at a given level. It does not require total insulation from higher or lower level objects and processes, but it does make it optimal to construct theories in terms of objects and their interactions at that level. The concept of level of organization thus uses the concepts of both object and robustness to define a larger coherent whole, which is itself robust.

As Campbell (Campbell, 1958) suggests, robustness can be used to isolate units at the group level as well as at the object level. McClintock (McClintock, 1971; Stern and McClintock, 1998) showed the robustness of a set of social groupings by identifying two techniques (in this case from different levels!) that converged on the same groupings. A sociogram of friendships among women in a college dormitory resulted in social groupings similar to those identified through the synchrony of their menstrual cycles (women who were close friends began their menstrual cycles at approximately the same time, even if they did not live near one another).

At times, the level we choose to describe a phenomenon may not be ideal – in other words, one way in which we can go wrong is to attack a problem at a level of analysis that is too high or too low. Nowadays, strong reductionist methodologies make the latter error more common. Consider mating behavior in rats, which has typically been investigated at the level of the dyad despite the fact that the group level is much more revealing. Rats must have several intromissions during copulation in order to

trigger the males' ejaculation and the females' progestational state. The male and the female neuroendocrine systems are exquisitely sensitive to the timing of intromissions – there are optimal intervals for triggering both of these neuroendocrine events, and they are *not* the same for the two sexes. From the male perspective, a 3-minute interval is the most efficient for achieving ejaculation (Bermant, 1964; Bermant et al., 1969; Larsson, 1956); when intervals are either shorter or longer, more intromissions are needed for the male to reach his ejaculatory threshold. In contrast, from the female perspective, a 10 to 15 minute interval is optimal for inducing a progestational state (Edmonds et al., 1972). The problem, however, is that when intromissions are paced at these long intervals, the male may never ejaculate (Larsson, 1956).

At the neuroendocrine and behavioral levels of analysis, this system seems designed to ensure dyadic discontent. Indeed, when pairs of rats mate in a small enclosure, intromissions are paced at 1-minute intervals (McClintock and Anisko, 1982) (Beach, 1956; Dewsbury, 1967) – a temporal patterning that is not optimal for triggering either the male ejaculation or the female progestational state, and thus satisfies neither individual within the dyad. The dyadic rate is not even a compromise between the optimal intervals for the two sexes!

The paradox disappears, however, when the mating phenomenon is analyzed at the group level, the context in which mating behavior and its neuroendocrine mechanisms evolved. When rats mate in a group, copulation is timed in a pattern that matches the optimal patterns for both the male and the female (McClintock, 1984b; McClintock and Anisko, 1982). This harmonious state is made possible simply by changing partners after an intromission. At a given time, only one male is mating with all of the estrous females who take turns, each keeping her distance from the male after receiving an intromission and thus delaying her next intromission. After the first male achieves one or more ejaculations, a second male will have a turn mating with the group of females. In fact, the intervals achieved in group-mating approach the intervals that are optimal for triggering neuroendocrine events in each sex. Mating in rats is thus most usefully approached at the group level. Analysis at the level of the individual or the dyad misses crucial aspects of mating – aspects that serve to clarify the neuroendocrine system and make it explicable.

Reductionism. This example also underscores the fact that a more molecular level is not always better for describing and analyzing a phenomenon. Wimsatt (Wimsatt, 1994, 1999) warns us to guard against "nothing-but-ism" – the belief that higher levels of analysis are merely matters of convenience and that the best level of description, for all phenomena, is the lowest level (e.g., we are "nothing but" a bag of genes). Descartes (Descartes, 1649), if not Euclid, is the initiator of this view, at times dignified with the rubric "reductionism." Reductionism dictates that we begin with first principles, things of which we can be absolutely certain, and then, using logical principles, work our way up to explain higher-order phenomena (if only logical principles are used, then the derivations must be true).

The typical assumption is that the first principles are at the lowest level of analysis (for example, the laws governing genes, if not quarks, or whatever the current elementary particle is (Crick, 1966). Those units are held to be "in principle" sufficient to explain all higher level phenomena;Churchland, 1986 #16]. Others who recognize the enormity of the task of moving from quarks to higher levels of analysis may be pragmatic holists (e.g. (Simon, 1996), but still adhere to a belief in "in principle" reductionism. That is, in principle, human behavior can be reduced to the behavior of quarks, but to do so is computationally difficult and so psychological analyses are a pragmatic approximation.

In contrast, we take the view that many phenomena at the organismal and individual levels of analysis cannot and, in principle should not, be reduced to smaller units of analysis. Instead of using expedience, a better way of determining the appropriate level of analysis is to seek out multiple means to the same end. We begin with a series of levels, each defined by strong causal interactions of entities at that level. The goal of the enterprise is then to understand how entities and causes at one level can affect entities and causes at another level – moving either up or down across levels. The level on which a phenomenon is best described is determined, not by edict ("lower is better"), but by the phenomenon itself and the questions asked about it. The principles of necessity and sufficiency are the guiding lights.

We believe that certain phenomena, coordination of behavior and fertility by mating rats is a perfect example, cannot be adequately described at lower levels – the stable phenomenon resides at the level of the group. Indeed, it is not even visible at the individual level or even the dyadic level. An individual rat cannot mate alone; it obviously needs at least one other rat of the opposite sex. Moreover,

although rats can mate when experimenters put them together in pairs, their pair-mating does not fit with the evolved neuroendocrine mechanisms optimal for sustaining a pregnancy with a large litter. Large litters happen consistently only when rats mate in a group with several males and females, and the intricate social interactions of the group enable mating to optimally stimulate the mechanisms of fertilization and pregnancy.

The level at which a phenomenon is described also affects what one includes as "diagnostic" of that phenomenon. Before mating in rats was analyzed at the group level, the behavioral "solicitations" that the female rat makes toward the male during pair-mating had been identified (McClintock, 1978) but not accepted as essential to mating. However, once we realize that mating in rats is a group phenomenon, it becomes important to understand how rats "choreograph" the events – how they communicate to others within the group their readiness (or lack of readiness) to mate. In this context, the female solicitation and resultant pacing of mating not only makes sense, but turns out to be an essential characteristic of female sexual motivation and mating in the rat (Erskine and Hanrahan, 1997; McClintock, 1984b; Pfaus et al., 1999).

The inclusion, or exclusion, of characteristics within a description of a phenomenon at a given level of analysis is also important as it affects the types of explanations we are likely to entertain. For example, language in humans is traditionally described in terms of the sounds that come out of the mouth. One of the perplexing questions about language is how it came to be the province of the oral modality, particularly given that many evolutionary hypotheses posit an initial stage in which language was carried out in gesture (Armstrong et al., 1995; Corballis, 1992; Hewes, 1973; Wescott, 1974). Moreover, within deaf cultures where the oral modality is not accessible, full-fledged sign languages have evolved in the manual modality and function as do all linguistic systems (Klima and Bellugi, 1979); in other words, human language can and does exist in the manual modality without any use of speech at all. Why then has speech become dominant in hearing cultures that could easily exploit either modality?

The dominance of the oral modality in languages across the globe begins to make sense only when we enlarge our view of what comprises language in humans. In all cultures, speakers produce

hand movements – gestures – along with their talk (Feyereisen and de Lannoy, 1991; Goldin-Meadow, 2003a; McNeill, 1992). Although often ignored by students of language, these gestures turn out to form an integrated system with speech, synchronized in terms of both timing and meaning (McNeill, 1992). Each modality plays its own role in this system, with speech assuming the segmented and combinatorial representational format that is characteristic of human language, and gesture assuming a holistic and imagistic representational format that can "fill in" the gaps left by the categorical and analytic speech code. If, as cross-linguistic observations suggest, both a segmented and a holistic code are necessary for full human language, then speech's "take-over" of the segmented code makes sense. While either gesture or speech is qualified to assume a segmented code, only gesture is well suited to a holistic code. As a result, gesture takes over the functions it alone can serve well, leaving by default the remaining functions – what is traditionally called language – to speech (Goldin-Meadow and McNeill, 1999; Goldin-Meadow et al., 1996).

Thus, by including manual characteristics of the act of speaking that are typically considered "associated" but not essential features of language within the description of language itself, we open up new classes of explanations. The examples provided in this section make it clear that deciding the appropriate level on which to describe a phenomenon is an important step in the scientific process – one that affects, and is in turn affected by, decisions made on other dimensions. We turn next to the dimension of causal explanation.

Cause: The How's and the Why's of a Phenomenon.

In order to fully understand a phenomenon, it is necessary to understand not only the preceding events that cause it to happen (its mechanism) but also the subsequent events or consequences that cause it to happen again, creating the class of similar phenomena (its function). Aristotle (Aristotle, 1970 ca. 350 B.C./1958) used the terms "efficient cause" and "final cause," respectively, to distinguish these two types of causal explanations. In evolutionary biology, these are referred to as "proximate" and "ultimate" mechanisms.

As an example, coordination of estrous cycles within groups of female rats has both a functional and a mechanistic explanation. The phenomenon to be explained is that the majority of female rats

within a group is likely to be at the same phase of the estrous cycle on the same day (McClintock, 1978, 1981). Synchronization of fertility allows the coordination not only of mating but also fertility and infant care within the group and thus leads to increased survival of the group's young (in fact, two-thirds of litters born out of synchrony have no survivors (Mennella et al., 1990). This is a *functional* explanation for synchronization, an explanation that focuses on the effect of the phenomenon on reproductive success, a major component of evolutionary fitness. At the same time, temporal coordination of cycles occurs as the result of pheromones – one olfactory signal that advances the underlying rhythm of the cycle thereby shortening it (pheromones from pre-ovulatory females), and another olfactory signal that delays the rhythm of the cycle thereby lengthening it (pheromones from ovulating females; (McClintock, 1984a). This is a *mechanistic* explanation for precisely the same phenomenon, an explanation that focuses on the effects of other events on the phenomenon itself. Neither explanation is better than the other – both are important in understanding synchronization and coordination of fertility in a group of rats.

Mechanistic causes. The search for mechanisms is frequently driven by the assumption that phenomena are better explained at lower levels by processes operating on smaller units. (The human genome project has often been attacked, and justified, on just such an assumption). Indeed, there are excellent examples of mechanisms that operate at a lower level and exert influence upward. A female rat's hormonal state influences whether she will solicit a male rat to pace mating – estrogen and progesterone bind in specific parts of the brain (e.g. preoptic area, ventromedial hypothalamus and the midbrain reticular formation) and are sufficient to motivate feminine sexual behavior (Blaustein and Erskine, 2002).

But there are equally compelling effects in the opposite direction – effects of behavior on hormones, of higher level mechanisms that work downward. Rose, Gordon and Bernstein (Rose et al., 1972) showed that the company a male monkey keeps profoundly affects his testosterone level. Rose and colleagues first established the male monkey's testosterone levels when left alone. After the male was placed in a cage with a group of female monkeys, his testosterone levels began to rise, only to fall back to base-line when he was removed from their cage to his own. When placed in a cage with other

males, who were above him in the dominance hierarchy, his testosterone levels dipped well below his base-line levels. Even after he was removed from the male cage and placed in a cage alone, his testosterone levels remained well below baseline, demonstrating powerful and long-lasting effects of social experiences on hormonal levels.

There is no reason to expect the mechanisms that account for a phenomenon to reside completely at a lower level than the phenomenon itself. Indeed, the sex of one's offspring – a trait that seems to be fundamentally grounded at the genetic level – can be caused by events at a higher levels. In rats, the presence of an X or Y chromosome is, to some extent, under behavioral control. Female rats who solicit males before sundown and secure ejaculations quickly are more likely to have sons than female rats who solicit males and complete mating late in the evening (Hornig and McClintock, 1996). Thus, a full explanation of the proportion of males and females in a litter at its birth must refer not just to the presence of genes on the X and Y chromosomes, but also to their mother's sexual motivation and behavior prior to the conception of the litter. Indeed, since the discovery of genes, it is commonly accepted that any case of natural or sexual selection involves "downward causation," in which macroscopic interactions between organism and environment select the frequency of genes in a population.

Functional causes. Functions also operate at different levels and during different time spans. For example, the function of a solicitation in a female rat is, at the population level and on an evolutionary time span, to enable her to become pregnant in a complex social environment and enable her offspring to survive until they too reproduce, giving her grandchildren (McClintock, 1984b). However, at a lower level, and on smaller time span, the function of a female rat's solicitation is to precisely pace mating to acquire sperm, generate uterine contractions to transport the male's sperm to the egg, and trigger the prolactin surges and progesterone needed to thicken the uterine lining for implantation (Adler, 1969).

Not every biological phenomenon has a function (or at least it may not have a function on a particular time span). Gould and Lewontin's (Gould and Lewontin, 1979) classic example of the spandrels of the San Marco Basilica in Venice illustrates this point. Spandrels are the tapering triangular

spaces formed by the intersection of two rounded arches. Each spandrel contains a three sided design perfectly fitted into its tapering space – so perfectly that one might imagine that the spandrel had been created in order to provide a three-sided space for the paintings and designs symbolizing the trinity (a functional cause). However, it turns out that spandrels are the architectural by-products of mounting a dome on rounded arches (a mechanistic cause), and only secondarily have been elaborated for symbolic decoration. Thus, the function of spandrels (to display paintings symbolizing the trinity) played no role at all in their evolution, which is explained mechanistically in terms of architectural constraints. When such traits appear in evolved biological systems, such as the human chin (caused by differential growth rates of the maxillary and dentary fields) or ultrasound calls by rat pups (a byproduct of thermoregulation used for maternal care), they are termed "exapted " traits, to distinguish them from adaptive traits that are selected because of their direct effect on fitness (Gould and Vrba, 1982).

The relationship between functional and mechanistic causes. The final point we address in this section is the relationship between functions and mechanisms. Although the mechanism underlying a phenomenon can be the flip-side of its function, mechanism and function need not be reciprocally related. For example, in the evening, alligators go down into the Mississippi River. Because the alligator is cold-blooded and because the night air becomes quite cold, often much colder than the water, the evening trip into the river has an important function for the alligator – it serves to maintain its body temperature during the night, preventing torpor. Given this *function*, one might assume that the *mechanism* of the evening river trips would also involve the alligator's temperature regulation system in some way. But, in fact, the mechanism underlying the evening river trips involves sensitivity to light intensity – the waning afternoon light is the stimulus that entrains the alligator's daily entrance into the water. The independence of mechanism and function is particularly apparent in the laboratory when the light and temperature stimuli are artificially separated. If the temperature is dropped but the light does not dim, the alligator will remain out of water despite hypothermia. If, however, the light dims but the temperature remains warm, the alligator will nonetheless enter the water even though the trip is not needed to keep warm (Lang, 1976).

As an example in humans, we consider the causes underlying the spontaneous gestures that accompany a speaker's talk. One *function* that has been proposed for such gestures (which are found in speakers of all ages and all languages, (Goldin-Meadow, 2003a; McNeill, 1992)), is that they play a role in communication (Kendon, 1994). Indeed, several studies have shown that the gestures speakers produce along with their talk are comprehensible even to listeners who have not been trained to code gesture (Alibali et al., 1997; Goldin-Meadow et al., 1999; Goldin-Meadow et al., 1992; McNeill et al., 1994) and that gesture has an impact on the listener's response (Goldin-Meadow and Singer, 2003) . Gesture thus appears to serve an important communicative function for listeners.

But the *mechanism* by which we produce gestures need not involve communication and the listener. We might produce gestures as part of the process of thinking, and (like the Mississippi alligator) would continue to gesture whether or not a listener were around. Several pieces of evidence lend weight to this hypothesis. First, the gestures children produce when explaining how they solved a task are excellent predictors of each child's cognitive status, in particular, the child's readiness to profit from instruction on that task (Alibali and Goldin-Meadow, 1993; Church and Goldin-Meadow, 1986; Goldin-Meadow et al., 1993a; Perry et al., 1988). These findings suggest that gesture reflects the thinking process of the speaker (Goldin-Meadow et al., 1993b). Second, people do, in fact, produce gestures when a listener cannot possibly appreciate the act, as when they gesture on the telephone or with their backs turned to the listener (Rimé, 1982). That is, people gesture even when there is no apparent communicative function for those gestures. Third, the gestures that both children and adults produce when explaining how they solved a math problem appear to lighten cognitive load, facilitating the speaker's ability to remember a list of unrelated items (Goldin-Meadow et al., 2001; Wagner et al., 2003, in press) . Finally, and most compellingly, children who have been blind from birth and thus have never experienced the communicative value of gesture first-hand have been found not only to gesture, but to produce gestures that resemble those of the sighted child (Iverson and Goldin-Meadow, 1997). Indeed, blind children gesture even when conversing with other blind individuals (Iverson and Goldin-Meadow, 1998).

These findings suggest that, even though the function of gesture production is likely to involve communication, the process by which gesture is produced – its mechanism – may not. Gesture production may be the result of processes within the speaker alone, independent of the listener. Thus, the mechanism of a phenomenon need not be reciprocally related to its function, even within a single time span.

Perspective: Subjective or Objective Points of View

A phenomenon can be described in terms of contrasts either internal or external to the system. In psychology, a behavior or interaction can be described from the perspective of the actor or participants (a first-person account) or from the perspective of those who did not experience or participate in the phenomenon (a third-person account). The account from the two perspectives need not be the same. For example, suicide is typically considered an individual phenomenon, most usefully analyzed from the point of view of the person who wants to take his or her own life, the *subjective perspective*. It is notoriously difficult to predict who will and who will not commit suicide. In contrast, Durkheim (Durkheim, 1897/1951) discusses suicide as a social phenomenon and focuses not on the perspective of the person who commits suicide, but on the factors that surround the person and the event, the *objective perspective*. Moreover, he analyzes suicide from the objective perspective at the social level, showing that parsimonious patterns and predictors can indeed be identified from this perspective at a higher level analysis. Neither account is more valid than the other – they differ systematically in terms of the point of view from which the phenomenon is described and understood.

As a second example, many of the approaches to the study of intelligence differ in perspective. The Piagetian approach to intelligence attempts to slip inside the mind of the child and characterize knowledge from the child's point of view (a subjective perspective). Indeed, Piaget's goal is to construct a worldview in which the child's non-adult beliefs are coherent. In contrast, the Intelligence Quotient approach to intelligence attempts to characterize the knowledge of a child from the point of view of an adult observer (an objective perspective). It is remarkable how different the phenomenon of childhood intelligence looks when examined from these two different, yet equally valid, perspectives.

The "umwelt". The objective account is a public description, using the terms of the physical world. In contrast, the subjective account is a first-person description formulated in terms of the stimuli that the participant can sense and does experience. Perspectives differ because living organisms do not experience the physical world in the same way even if, from an objective point of view, the external stimuli are the same. Organisms select (by virtue of their nervous systems, not necessarily consciously) a subset of the information available in the world to create their own "umwelts" (von Uexküll, 1957).

Von Uexküll (von Uexküll, 1957) describes an animal's umwelt as its self-world or phenomenal world. He gives the tick as an example. Upon hatching, the tick is not yet fully developed, lacking a pair of legs and sex organs. After shedding its skin several times, it acquires the missing organs, mates, and starts its hunt for warm-blooded animals. The female tick climbs upward to a branch, clinging at such a height that she can drop upon any small mammal or be brushed off onto any larger mammals that may run under her. Having landed on an animal, she finds a hairless spot, burrows deep into its skin, and slowly pumps herself full of warm blood. Her next act is her last, as she then drops to earth, lays her eggs tucked in a crevice in the ground and dies a few days later.

This is a description of the tick's brief life from a non-participant's point of view, indeed, from a human point of view. But the tick does not see the world the way we do. It has fewer options to choose among, having an umwelt that is much smaller than the human umwelt. From a subjective perspective, the tick's ascent up the branch is achieved by the general photosensitivity of her skin. She has no sense of gravity, nor does she have any sense of different wave lengths or color – a light intensity gradient is all that she experiences and she moves towards light. Her drop on an unsuspecting warm-blooded animal is precipitated by her sense of smell. The butyric acid emanating from the skin glands of all mammals acts on the tick as a signal to hurl release her grasp, causing her to hurtle downwards. She has no sense of the animal behind the butyric acid. Indeed, if she were to land on a warm rock covered with butyric acid, she would enthusiastically attempt to burrow into it. Thus, the tick's umwelt is comprised of three all-important stimuli – light, butyric acid, and warmth. The tick's perspective is distinctively different from, and more restricted than, the perspective human non-participants have on her life events.

In contrast, there are organisms that have umwelt that are larger and thereby also different from the human worldview. For example, pigeons can migrate long distances and can do so even on cloudy days. These birds can sense magnetic north and guide their flight trajectories accordingly. This ability is likely mediated by cells containing magnetically sensitive molecules in the upper skin of the beak and neural projections to the brain structures that have yet to be found functional in humans (Hanzlik et al., 2000). Thus, the pigeon's umwelt includes physical stimuli that humans are of incapable of sensing. Note, however, that we humans can, and have, extended our first-person perspective by enlarging, through mechanical devices, the range of stimuli we can sense.

The subjective perspective and cause. The subjective perspective may be crucial to the definition of a phenomenon. For example, individuals identified as having multiple personality disorders have a different sense of self when "in" each personality. These different subjective perspectives within the same person have physical manifestations that can be measured and quantified. An optometrist, blind to the goal of the study, was asked to conduct several optometric evaluations on each of a series of individuals. Some of the participants in the study had multiple personality disorders and inhabited different personalities during repeated eye exams, while others did not and maintained a single personality throughout. The finding of interest is that the variance in visual acuity between evaluations was ten times greater for the individuals with multiple personality disorders than for the controls (Miller, 1989). Indeed, each personality appeared to have its own visual profile.

We may need to tap a woman's subjective experience in order to see an effect of hormones on behavior. A woman's sexual behavior, which is observable from a non-participant's point of view (an objective perspective), does not vary systematically with her menstrual cycle, presumably because her behavior is constrained by the availability of a partner (Bullivant et al., 2003, In Press). However, her sexual desire and sexual fantasies (her subjective experiences) do vary with her cycle – they peak just prior to ovulation. If we were to limit our observations to a non-participant perspective, we would conclude (incorrectly) that a woman's menstrual cycle has no effect on her sexual desire.

Thus, in addition to its relevance to defining a phenomenon, the subjective perspective can play an important role in the *causal process*. When an individual with a multiple personality disorder

willfully switches from one personality to another, the subjective perspective is likely to be involved in regulating the changes in body muscle tone that create the different profiles of visual acuity, even when the individual knows nothing about the anatomy of visual acuity. The subjective perspective is causal in non-human animals as well. Consider the male monkey in Rose, Gordon and Bernstein's (Rose et al., 1972) study described above. The monkey's low testosterone levels extended well beyond the period he spent with the group of male monkeys, perhaps because he experienced defeat during that period. Although the physical assault ended when he left the group, the monkey may have, in his subjective sense of self, carried the *experience* of defeat with him. It is this felt experience that is likely to have maintained his depressed hormone levels. Thus, the subjective perspective is not only important in *defining* a phenomenon but it may be *causally* involved in its creation as well. We turn now to our final dimension – time.

Time: Momentary, Ontogenetic, Historical, and Evolutionary Units of Time

Tinbergen (Tinbergen, 1968), in his Nobel Prize acceptance lecture, argued that the power of ethology arises from applying the methods of biology to the phenomenon of behavior. Doing so gives us four types of questions: (1) What makes a behavior happen at any given moment? How does its "machinery" work? (2) How does the behavior's machinery develop as the individual grows up? (3) How have the behavioral systems of each species evolved until they became what they are now? (4) In what ways does the behavior influence the survival or the success of the animal? The first three questions are concerned with mechanisms, each on a different time span. The fourth question has to do with the effects of behavior and is, in our framework, a functional question on the evolutionary time span. Tinbergen ((Tinbergen, 1968)) analyzed human aggression and risk for devastating wars in these terms and demonstrated that the mechanisms controlling aggression in momentary time are not the same as the developmental mechanisms involved in changes in aggression over either ontogenetic or evolutionary time spans. The answers to the three mechanistic questions are thus not the same. Tinbergen argued that a complete understanding of aggression must involve analysis at all three time spans. The need to call upon explanations at each time span derives from the fact that all operate concurrently, nested inside one another. For example, when a teenage boy shoots another, the precise

time that he pulls the trigger is determined by immediately preceding events (momentary time span). But he also has his own developmental history (ontogenetic time span), and the capacities of his body and mind have been created by selection pressures operating over the course of human evolution (evolutionary time span), all of which contribute to the trigger-pulling act.

Like level of organization, time span constitutes a continuum along which many divisions can be made. It is convenient in this paper to restrict ourselves to Tinbergen's three time spans – momentary, ontogenetic, and evolutionary – and many studies in the social sciences focus on one of these three periods. However, other time spans are possible. For example, the historical time span interposed between individual growth and evolutionary change is frequently used, particularly in fields studying cohort effects or cultural development. People born in Denmark after 1960 are more likely to develop allergies in adulthood than those born earlier presumaly because of (as yet unidentified) changes in life style and environment that began at that time (Linneberg et al., 2002).

How time spans relate to one another. Explanations within different time spans are clearly distinct types of explanations. Nevertheless, they are likely to bear some relationship to one another. For example, the reproductive systems of rodents, when examined in the *momentary time frame*, demonstrate that endocrine mechanisms are regulated both by the individual's behavior and by its social, physical, and biotic environment. More specifically, female solicitation serves to pace the timing of the male intromissions so that each sex can approach the interval that is optimal for its neuroendocrine system (McClintock, 1984b). The same phenomenon, when looked at in an *evolutionary time frame*, suggests that endocrine mechanisms are selected as a consequence of an organism's behavioral interaction with its internal and external environments. Specifically, the intervals between intromissions that are optimal for male and female rats were selected in the context of group-mating, the need for groups having been established on the basis of their utility in other domains, such as foraging and communal care of offspring (McClintock, 1984b; Mennella et al., 1990). This is a concrete example of how, over evolutionary time, the function of a behavior or trait can shape the neuroendocrine mechanisms that operate over momentary time (Mayr, 1974; Simon, 1996).

Sometimes certain time spans may play a role in creating a behavior, whereas others do not. Consider, for example, the internal contrasts that characterize languages and make it a system (e.g., the contrast between "-ing" and "-ed" in English, two forms that signal the difference between present and past tense when affixed to a verb). These contrasts are likely to be, at least in part, a product of the consensus that the users of a language reach over *historical* time. The natural process of language change occurs over just such a prolonged interval. However, it is possible that a single individual, attempting to invent symbols to communicate *de novo* over either *ontogenetic* or even *momentary* time, might also be able to generate a system of symbols that is characterized by internal contrasts.

To explore the role that time span plays in the generation of contrasts within a language system, Singleton (Singleton et al., 1993) compared communication in the manual modality created over three different time spans: (1) *historical* (a conventional language in the manual modality, American Sign Language, that has been passed down from generation to generation within a community of signers), (2) *ontogenetic* (gestures invented over a period of years by a deaf child who has not been exposed to sign language), and (3) *momentary* (gestures invented on the spot by nonsigning hearing individuals). They found that internal contrasts were not limited to the historical time span, but were evident in the ontogenetic time span as well. Thus, a deaf child who has not been exposed to a conventional sign language can develop gestures that form a coherent system, one that has different standards from American Sign Language but standards nonetheless such as…present vs. past tense? Or any good example (see also (Goldin-Meadow, 2003b)). However, no such internal contrasts were evident in the gestures generated in the momentary time span. The findings suggest that an historical time span is not necessary for human communication to form a system with internally contrasting standards of newterm – not clear, but that some stretch of time (perhaps a period on the ontogenetic time span) may well be essential.

<u>Time span and the nature-nurture debate</u>. Time span is the dimension most relevant to one of the raging debates in the social sciences – the nature-nurture controversy. Intuitively, the term "innate" refers to the role that factors internal to the organism play in establishing a phenomenon. However, what is considered internal to the organism, and therefore innate, can vary depending upon the time span

within which the phenomenon is considered (McClintock, 1979). In other words, the term "innate" has different meanings on different time spans and ought to be modified to reflect these differences if it is to be useful (e.g. momentary-innateness, ontogentic-innateness, evolutionary-innateness). On the *momentary time span*, a behavior is often considered innate if it appears to "run off" independent of features of the environment. For example, the Mandarin drake typically performs a preening movement across the large sail feather by its tail. The bird will run through the entire movement even if the feather is cut short and there is nothing to preen (Mayr, 1974). On the *ontogentic time span*, a behavior is often considered innate if it appears fully formed without opportunity for it to be shaped by the environment. For example, there are innumerable cases where individuals, right after birth or hatching or when completely isolated from all other members of the species perform a fully-formed adult behavior (e.g., food-taking movements, courtship displays, nest construction, migratory orientation, and even choice of food (Mayr, 1974)). Finally, on an *evolutionary time span*, a behavior is often considered innate if the phylogeny of a group that is constructed on the basis of behavioral traits is similar to the phylogeny of the same group constructed on the basis of morphological characteristics. For example, among different species of storks world-wide (Family ciconiidae), there is 70% concordance between a phylogenetic tree based on early courtship behaviors, such as male "display preening" and female "gaping," and one based on DNA-DNA hybridization distances. The tested assumption is that some behaviors are as tightly linked to genotype as are physical traits (de Queiroz and Wimberger, 1993; Mayr, 1974; Slikas, 1998).

The crucial point is that what may be considered innate on one time span need not be innate on another time span. For example, on a momentary time span, when people find it hard to hear a speaker, they often put on their glasses, presumably so that they can have the added benefit of the speaker's visual cues (mouth movements, facial expressions) along with the speaker's auditory cues. This behavior has stereotypic qualities not unlike the feather-preening of a Mandarin drake. People have anecdotally been observed to put their glasses on to hear better even when talking on the telephone and no visual cues are available from the speaker. The glasses-donner's behavior is triggered by a particular circumstance (inability to hear) but is stereotyped in form and serves no immediate function; it is, in this sense, innate

on the momentary time span. However, it is extremely unlikely that such a behavior would meet the criteria for innateness on either the ontogenetic or the evolutionary time span.

McClintock (1979) isolates two other meanings of the term "innate" on the basis of time span: "developmentally innate" refers to the absence of plasticity during an individual's development over ontogenetic time (ontogenetic-innateness), and "genetically innate" refers to the information encoded in the genome, the form that information must take in order for the behavior to evolve over evolutionary time (evolutionary-innateness). McClintock notes that not only are these two meanings of the term different, there is no easy predictive relationship between them. In other words, the same behavior can be appropriately labeled "innate" in one sense of the term, when it would be completely inaccurate to do so in the other. For example, a particular trait that is genetically transmitted with a high heritability in most environments and is therefore innate in the genetic sense may also be very sensitive to changes in the environment during the life span of a particular individual and would therefore *not* be innate at all in the developmental sense. Phenylketonuria (PKU), an inherited disease resulting in severe mental retardation, illustrates this orthogonal relationship. Infants with PKU have a mutation in the PAH gene for phenylalanine hydoxylase, located on the long arm of chromosome 12. Without this enzyme, phenylalanine cannot be converted to tyrosine, a crucial step in protein metabolism. The diet of infants naturally contains protein (e.g., milk) and so unmetabolized pheylalanine builds up, quickly reaching levels that are toxic for neural function and development, producing an irreversible mental retardation. It is possible, however, to prevent the mental retardation by simply restricting protein in the dietary environment of these infants, beginning at 3 weeks of age and continuing throughout adulthood. Thus, PKU is a completely heritable trait, for which the gene has been identified – it is innate in the genetic sense. However, it is not innate in the developmental sense simply because its occurrence can be controlled completely by modifying the individual's environment.

Wimsatt ((Wimsatt, 1986)) has argued that it is primarily the issue of time span that distinguishes European ethologists from American psychologists. European ethologists look for explanations of innateness in terms of evolutionary factors and natural selection, with its genetic base. American psychologists look for explanations in terms of developmental factors. In fact, American psychologists

often argue that is not even worth using the term "innate." In their view, the focus of the scientific enterprise ought to be developmental processes, with the goal being to describe how internal and external factors interact over ontogenetic time. Genes have no special status for the American psychologist, as they are only one point (albeit the starting point) along a developmental trajectory. They do not, by themselves, determine outcomes. For example, an individual who has the genetic defect underlying PKU need not end up with mental retardation. As another example, an individual who has both an X and a Y chromosome and is therefore categorized as a genetic male can, because of abnormalities at the hormone receptor level, end up looking completely female. In other words, a developmental story is needed even for a phenomenon such as sex which is seemingly dictated by genetic material. In the next section, we explore the developmental story for language-learning in relation to the nature-nurture debate.

The Nature-Nurture Controversy and Language-Learning

Language-learning is a phenomenon particularly ripe for the nature-nurture debate. It is a rich multidimensional problem illustrating how our four-dimensional heuristic can be used to reformulate a singular question – one which has triggered much unproductive debate and controversy – into an organized series of fundamental questions that have unambiguous answers. Language-learning is obviously influenced by the environment within which a child develops – when exposed to Swahili, the child learns Swahili, not Spanish or Mandarin. Yet language-learning is universal to humans. No human culture has yet been found that did not, upon discovery, have language. Indeed, when human language cannot be processed in its typical channels – the mouth and the ear – it emerges in completely different modalities – the hand and the eye. Communities of deaf individuals have developed sign languages that resemble spoken languages in all functional and structural respects (Bellugi and Studdert-Kennedy, 1980; Klima and Bellugi, 1979; Lane and Grosjean, 1980). Thus, language-learning is a product of both external and internal factors and, as a result, invites strong claims about the contributions of each.

In his recent book, Pinker (1994: 18) calls language an "instinct." By this he means that "people know how to talk in more or less the sense that spiders know how to spin webs....spiders spin spider

webs because they have spider brains, which give them the urge to spin and the competence to succeed"
– that is, instinct on an evolutionary time span. Pinker's use of the term "instinct" aligns him with
European ethologists, and he is indeed interested in the possibility that language has an evolved genetic
base. Pinker (1994: 324-5) believes that we now have suggestive evidence for grammar genes – not for
a single gene responsible for all the circuitry underlying grammar but for a set of genes whose effects
seem most specific to the development of the circuits underlying parts of grammar.

What do we know about how children acquire language over the ontogenetic time span from the
claim that language is genetically encoded? At some level, this claim is vacuous in that whatever we
humans are capable of developing is made possible by the genetic hand we are dealt. The goal must be
to isolate the particular set of genes responsible for language in humans – a goal from which we are
presently a long way off. Must we wait until the genes are identified before we can begin our
exploration of language-learning over the ontogenetic time span? Clearly not. So why then (assuming
we are not geneticists) do we care about the genetic base of a behavior? Perhaps we shouldn't. Of the
very large number of definitions and criteria that have, over the years and over the disciplines, been
applied to the term "innate," Wimsatt (1986) argues that the one that is *least* central to the notion's core
is having a genetic base. A more central definition – developmental resilience – operates on the
ontogenetic time span.

The resilience of language in humans: The ontogenetic time span. Predispositions to develop a
behavior are often phrased in terms of how easy it is or, how much environmental support is needed, to
develop that behavior (Seligman and Hager, 1972). To the extent that the range of environments that can
support language development is large and varied, language can be considered developmentally resilient
(Alcock, 1988; Goldin-Meadow, 1982). To the extent that the range is narrow, language appears
relatively fragile.

Let's consider first variability in the way adults speak to children within a culture and whether
this variability has an impact on language development. Adults in each culture tend to use a distinct
register of speech with their children, called "motherese" (Newport et al., 1977; Snow and Ferguson,
1977). There is, however, variability across adults in how much they talk to their children and in the

frequency with which certain constructions are used. Variability in the amount of talk a child hears has been shown to affect that child's rate of vocabulary growth (Huttenlocher et al., 1991); and variability in how often a particular construction is used in speech to a child has been shown to affect how quickly the child develops that construction (Furrow et al., 1979; Hoff-Ginsberg and Shatz, 1982; Huttenlocher et al., 2002; Newport et al., 1977). Interestingly, not all aspects of language appear to be as responsive to variations in input as others (Gleitman et al., 1984; Newport et al., 1977); we return to this important point below. Despite the effects of input on the pacing of language-learning, there is no evidence that the particular way in which an adult speaks to a child affects whether or not language is ultimately learned by that child – a child may develop language more or less quickly, but all intact children eventually develop language.

The resilience of language-learning in the face of variation *across cultures* is just as impressive. Cultures hold different beliefs about the role that parents need to play to ensure the child's acquisition of language (Ochs and Schieffelin, 1995). Not surprisingly then, children across the globe differ in how much, when, and what types of language they receive – not to mention the fact that, in each culture, the child is exposed to a model of a different language. Despite the broad range of inputs, children in all corners of the earth learn language and at approximately the same pace (although the details of acquisition may vary with the details of model and input (Slobin, 1985)).

Extending the range of variation in input even further, we consider children who have no model for language whatsoever. Deaf children whose severe hearing losses prevent them from learning spoken language and whose hearing parents have not exposed them to a sign language do no have usable input from a conventional language. Yet these children communicate in language-like ways and use gesture to do so (Goldin-Meadow, 2003b). The children produce gestures according to a segmented and combinatorial format akin to the format that characterizes all natural languages (e.g., a child might point to a cookie and then jab her hand several times at her mouth to convey "cookie eat"). Moreover, the gesture sentences that the deaf children generate can be described in terms of very simple "rules." The rules predict which semantic elements are likely to be gestured and where in the gesture sentence those elements are likely to be produced (e.g., gestures for objects before gestures for actions) (Feldman et al.,

1978; Goldin-Meadow and Feldman, 1977; Goldin-Meadow and Mylander, 1984, 1990). In addition to structure at the sentence level, the children's gestures have structure at the word level (morphological structure, (Goldin-Meadow et al., 1995)) and noun, verb, and adjective grammatical categories (Goldin-Meadow et al., 1994). Moreover, the children use gestures to serve a variety of functions – to communicate with others about both the present and the non-present (Morford and Goldin-Meadow, 1997, to tell stories [Phillips, 2001 #232), to "talk" to themselves (Goldin-Meadow, 1993), and even to refer to their own and other's gestures (Singleton et al., 1993).

Interestingly, the structure found at the sentence and word levels in each of the deaf children's gesture systems could *not* be traced back to the spontaneous gestures that their hearing parents produced when talking to them (Goldin-Meadow et al., 1994; Goldin-Meadow and Mylander, 1983, 1984, 1998; Goldin-Meadow et al., 1995), nor could many of the communicative functions that the children's gestures served (Butcher et al., 1991; Morford and Goldin-Meadow, 1997). The systems thus appeared to be generated in large part by the children themselves. Even the lack of a model does not prevent the human child from communicating in a language-like way. In this sense, language can be considered innate on the ontogenetic time span

The fragility of human language in chimpanzees: The evolutionary time span. The deaf child's accomplishments stand in contrast to the small gains in linguistic ability made by chimpanzees who have been exposed from birth, and in large measure, to a model of a conventional communication system created by humans. Although researchers appear to have been successful in getting chimpanzees to respond to and produce aspects of human language (e.g., consistent word order, (Savage-Rumbaugh and Rumbaugh, 1993)), the chimps lack most of the linguistic properties that the deaf children are able to develop without a language model (let alone the linguistic properties that hearing and deaf children develop with a language model). For example, the chimps' communication does not have grammatical categories or structure at more than one level, nor do the chimps use whatever language they do have for the full range of linguistic functions – most of the chimps' productions are requests in the here-and-now, not comments on the present or the non-present or on talk itself. Even Kanzi, the Cole Porter of

language-learning chimps, used statements in only 4% of his linguistic productions (Greenfield and Savage-Rumbaugh, 1991).

Whatever gains chimps make in learning language, they appear to do so at great cost and with much effort. In contrast, language comes naturally to human children – even when lacking an adequate model for language. The point here is that the most primitive of human language systems (like the deaf children's gesture systems) is still much richer than the most complex chimpanzee system, despite massive attempts at enriching the environment of one and the unfortunate impoverishment of the environment of the other. In this sense, language-learning may be considered innate in humans on the evolutionary time span (as well as on the ontogenetic time span).

Resilience at the individual level in the face of internal as well as external variability. Language is a resilient property of humans. However, it is not infinitely resilient, even in humans. There are conditions that are not compatible with the development of human language; for example, circumstances in which children have been raised by animals with no human contact at all (Brown, 1958) or by humans who have treated children inhumanely, depriving them of physical, social, and linguistic stimulation (Skuse, 1988). Human contact seems to be essential for language development in children – and those humans, at a minimum, must be humane. Nevertheless, aside from these limiting cases, language development appears to be remarkably resilient across a wide range of *environmental* conditions.

Interestingly, language is also resilient in the face of *organic* variation. For example, the acquisition of grammar in the earliest stages proceeds in a relatively normal manner and at a normal rate even in the face of unilateral brain injury (Feldman, 1994). Children with Down's syndrome have numerous intrinsic deficiencies that complicate the process of language acquisition; nevertheless, most Down's syndrome children acquire some basic language reflecting the fundamental grammatical organization of the language to which they are exposed (Fowler et al., 1994; Rondal, 1988). Finally, and strikingly given the social impairments that are at the core of the syndrome, autistic children do not appear to be impaired in their grammatical development, either in syntax or in morphology (although they do often have deficits in the communicative, pragmatic, and functional aspects of their language, (Tager-Flusberg, 1994).

Thus, language development can proceed in humans over a wide range of environments and a wide range of organic states, suggesting that the process of language development is buffered against a large number of factors, both external and internal to the organism. No one factor seems to be ultimately responsible for the course and outcome of language development in humans, a not-so-surprising result given the complexity of human language.

Resilience at the individual level over the ontogenetic time span and mechanisms of development. To summarize thus far, there appears to be a form that human language naturally assumes, and that form can be reached through a wide variety of developmental paths. In other words, language development in humans is characterized by "equifinality" – a term coined by the embryologist Driesch (1908, as reported in (Gottlieb, 1995)) to describe a process by which a system reaches the same outcome despite widely differing input conditions. Indeed, what is striking about the deaf children described here is not that they are creating a language with little environmental support, but that they are able to make use of the minimal support they do have to fashion a communication system that looks in fundamental respects just like human language. The deaf children are surrounded by a perfectly adequate spoken language model but, because of their hearing losses, they are unable to take advantage of that model. The only input they have is the spontaneous gestures that their hearing parents produce as they speak. The parents' gestures are no different from the gestures that any hearing individual uses along with speech (Goldin-Meadow et al., 1996) and thus are global and synthetic in form, with structure quite different from the structure of natural language (Goldin-Meadow, 2003a; McNeill, 1992)) – and quite different from the structure of the gestures the deaf children produce. To use their parents' gestures as input, the children must take the gestures they see and transform them into a system with linguistic properties – a system that is linear and segmented, with inter-gesture structure akin to syntax, intra-gesture structure akin to morphology, and grammatical categories. The surprising outcome (which is an excellent example of equifinality) is that the children's gestures are structured so much like natural language given that their input – their parents' gesture – is not.

Are there any implications for *mechanisms* of development that we can draw once having identified language as a behavior characterized by equifinality? Two types of systems are possible:

(1) A system characterized by equifinality can rely on a *single* developmental mechanism that not only can make effective use of a wide range of inputs (both external and internal) but will not veer off track in response to that variability; that is, a mechanism that is not sensitive to large differences in input. The image that comes to mind here is a sausage machine that takes inputs of all sorts and, regardless of the type and quality of that input, creates the same (at least on one level) product.

(2) A system characterized by equifinality can rely on *multiple* developmental mechanisms, each activated by different conditions but constrained in some way to lead to the same endproduct (cf. (Miller et al., 1990)). The analogy here is to four distinct machines, each one designed to operate only when activated by a particular type of input (e.g., a chicken, pig, cow, or turkey). Despite the different processes that characterize the dismembering operations of each machine, the machines result in the same sausage product. At first glance, it may seem improbable that a variety of developmental mechanisms would be constrained to arrive at precisely the same outcome. However, it is relatively easy to imagine that the *function* served by the mechanisms – a function that all of the developmental trajectories would share, such as communicating via symbols with other humans – might have been sufficient to, over time, constrain each of the mechanisms to produce the same product.

Language-learning and level of organization: What is the "right" unit of analysis? We close our discussion of language-learning with a look at another of our dimensions, level of organization, and its effect on how we ask and answer questions about language. We have been discussing language as though it were a unitary phenomenon, as though it were completely obvious what the appropriate unit of analysis for language is. However, it is not clear that language is the unitary whole that we have assumed, particularly when it comes to issues of resilience and innateness.

Not surprisingly given the minimal input they have at their disposal, the deaf children do not produce in their gesture systems all of the properties found in natural human languages. Some properties are relatively fragile with respect to linguistic input, needing a more specified and particular set of environmental circumstances within which to develop than do the resilient properties of language. Thus, the absence of a conventional language model appears to affect some properties of language more than others. Even when linguistic input is present, it is more likely to affect the rate of acquisition of

certain properties of language than of others (Newport et al., 1977). Finally, when language is acquired "off-time" (i.e., relatively late in the ontogenetic time span), certain properties of language are more likely to be acquired than others (Curtiss, 1977; Newport, 1991). Thus, some properties of language appear to be relatively resilient, while others are relatively fragile. Moreover, there is some evidence that the *same* properties of language are resilient in all three circumstances of acquisition – acquisition without a conventional language model, acquisition with varying input from a language model, and acquisition late in development after puberty (Goldin-Meadow, 1978, 1982).

The fact that some language properties are more robust than others makes language comparable to many other behaviors that have traditionally been considered innate. For example, the first nest of a young male African weaverbird is innate in the sense that it is constructed with knots and loops which are wonderfully intricate and adult-like. However, these perfectly constructed nest parts are joined in a form that only roughly resembles the adult nest (McClintock, 1979). Over time, these basic structures are replaced by the remarkably elaborate form of the adult nest. Language-learning in the human is like nest-building in the weaverbird in that the process is not all-or-none. Indeed, language-learning is more comparable to nest-building than to web-spinning simply because the young spiderling's web is as intricate in every detail as the adult spider's web the first time around. Any evaluation of the developmental innateness of nest-building in the African weaverbird, and of language-learning in humans, must first determine what the appropriate units of analysis for each phenomenon are. The answer to the innateness question is likely to differ depending on which unit is the focus of our attention.

The Mind-Body Problem: Biology and Culture

A passion for understanding the mind fuels psychology. Yet as psychologists focus in on specific aspects of the mind and behavior with the goal of designing controlled experiments with quantifiable results, they typically reject the concept of mind as too vague and amorphous for scientific inquiry. Indeed, until recently, the term "mind" was not even included in the index of many major introductory psychology texts [[Gleitman, 1981 #230](Kagan and Segal, 1988; Morris, 1982). Peterson (1997) has an entry, that says simply "See also Cognition" and lists two subheadings: "cognitive psychology and" and "in metaphorical terms. Lately, sections have been added to psychology textbooks

but only on the development of a theory of mind in young children and computers as a metaphor for mind in cognitive psychology (Gleitman et al., 2003; Gray, 2002).

Typically, psychology textbooks take an experimental approach to the problem of mind, restricting it primarily to cognition, including memory, learning, perception, and action. Likewise, the study of the body has become restricted to the brain and nervous system. As a result, cognitive and behavioral neuroscience – the union of these two approaches – has become the modern discipline for addressing the mind-body problem. When we step back, however, and view the mind-body problem from the broader perspective of our four dimensions of explanation, we can see that cognitive and behavioral neurosciences is only one, albeit essential, aspect of a much richer multidimensional problem. As such, cognitive neuroscience can provide only a partial solution.

The mind-body problem is not an issue of level but of perspective. In *Passions of the Soul*, Descartes (1649) distinguished between mind and body, establishing a dualism that enabled and stimulated scientific investigation of the complex mechanisms producing behavior and human action. In increasing detail, we have discovered how the nervous system allows an individual to perceive stimuli in the environment and produce specific appropriate actions in response. But by declaring that the mind and body are separate entities, Descartes created a major problem, if not a controversy.

How do body and mind interact? Indeed, do they interact at all? Perhaps the mind is simply an epiphenomenon, a by-product of the nervous system (Dawkins, 1976; Dennett, 1992, 2003; Huxley, 1874; Skinner, 1953). In this modern monism, the concept of mind is no longer necessary for understanding human behavior or psychology. Only actions and choices, quantifiable by an observer, are necessary and indeed admissible for scientific inquiry; if feelings, wishes, desires and beliefs serve a function, it is merely as constructs that serve as metaphors for human behavior.

This restricted focus does not recognize that the mind-body distinction not only involves a difference in levels of analysis (individual behavior vs. nervous system activity) but also a difference in perspective: the first-person experience of perceptions and actions vs. a third-person take on the very same event. We can observe and quantify how a person responds to stimuli in a given context, makes choices, and acts in a particular way. Simultaneously, that person is experiencing the very same events.

The mind, then, is a person's own first-person experience of their brain and body as they perceive and respond to a social and physical environment with a particular action. Both perspectives on the experience and action always co-occur.

It is not a matter of excluding one perspective or the other – both exist. Moreover, it is possible, and informative, to compare and contrast the two perspectives in order to determine which provides the more powerful and parsimonious explanation. Sometimes the first-person perspective may be the best predictor of behavior; sometimes it is the third-person perspective. The same point holds at other levels of analysis. Sometimes it is the first-person experience that has the tightest correlation with neural and hormonal events in the body; sometimes it is the third-person perspective. Sometimes aspects of culture, such as symbolic meaning, can only be described in terms of the experience of a member of that culture, first-person experience; sometimes the perspective of an outside observer is required, a third-person perspective in an ethnography (Headland et al., 1990)).

Pregnancy and labor: The importance of the first-person perspective at the individual level. There is no doubt that pregnancy and labor are major hormonal events of the body, and yet they can be altered by the mind – by a woman's beliefs – as much as, if not more than, by behavior or environment. Take, for example, pseudocyesis ("false pregnancy"), a condition in which women believe that they are pregnant when they are not and show many of the outward signs of pregnancy. Mary, Queen of Scots, is one of the notable historical examples. The woman's menstrual cycle ceases, her abdomen slowly begins to distend, and she begins to walk with a swaying lordotic gait typical of pregnancy.

The gait of a pregnant woman can be mimicked by a good actor; there is no need to invoke the unconscious mind to explain this aspect of pseudocyesis. The distended abdomen in pseudocyesis, however, results from the retention of gas in the GI tract, over which few people have voluntary control. Most striking, however, is the cessation of menses, which is controlled by a dynamic interaction between the brain, pituitary and ovary. Normally, menses begins when the corpus luteum of the ovary dies and progesterone drops (the hormone that maintains the uterine lining for 10 - 16 days after ovulation). During pregnancy, menses does not occur because a hormonal signal from the fetal placenta (Human Chorionic Gonadotrophin, HCG) stimulates the ovaries to maintain and increase progesterone

levels, enabling the further proliferation of the uterine lining requisite for full placentation and pregnancy. HCG maintains the corpus luteum and stops the menstrual cycle. Obviously, this complex interaction of neuroendocrine events is well beyond the knowledge of non-endocrinologists. Yet women with pseudocyesis maintain hormonal levels (gonadotrophins and prolactin) that are high enough to prevent onset of menses and mimic part of the hormonal profile of pregnancy.

The question is – does a woman's belief that she is pregnant change her neuroendocrine profile, or does she experience a hormonal imbalance for some other reason, an imbalance which she then interprets as pregnancy? A critical case study indicates that the woman's belief creates her hormonal condition and not the reverse (Yen et al., 1976). A young woman was brought to clinic by her mother because she was past her due date. Physical exam revealed that there was copious retention of gas and no fetus or enlarged uterus. Without being aware of the suspected diagnosis of pseudocyesis, the young woman was admitted to the hospital for detailed hormonal study. Her LH, FSH, and prolactin levels were indeed found to be elevated. During the evening, while blood sampling was still in progress, the woman had an unplanned conversation with a nurse who revealed the test results proving she was not pregnant. Upon hearing this news, the woman altered her beliefs about her state and accepted the fact that she was actually not pregnant. The next morning, her hormones dropped into the normal non-pregnant range and she passed the gas that had distended her stomach. The best predictor of this woman's physical state during her hospital stay was her belief system, not an endocrine abnormality.

Gender identity: The importance of the subjective perspective at the cultural level. Cultural and social context also plays an important role in shaping the interaction between mind and body in the process of sexual differentiation. One of the most striking genetic defects to affect sexual development is 5-alpha-reductase deficiency. Children born with mutations in the genes that make this enzyme appear at birth to be girls; they have a clitoris and labia rather than a phallus and scrotum. Nonetheless, they are genetically male, with a Y sex-chromosome, and have testes, which have yet to descend from the abdomen. Because 5-alpha-reductase is dysfunctional, the testes cannot produce DHT (dihydroxytestosterone), a key male hormone that normally works prenatally to masculinize the genital

tubercle into a phallus and fuse the labia into a scrotum, creating male external genitalia – the biological sign that is universally used to designate the sex of a newborn male.

As puberty begins, however, a striking transformation takes place. The testes increase testosterone production which now triggers growth of the clitoris into a serviceable phallus. The testes descend and the person is capable of fathering children. A girl turns into a man. Our culture can only label this turn of events as extremely pathological. Typically, such people are encouraged to remain female; they are castrated and given estrogen replacement therapy so that they can live as adult women, continuing to pursue their lives in the sex into which they were born and raised (Wilson, 2001).

Other cultures have very different interpretations of this remarkable biological event. In each culture, the genetic defect and biochemical events are the same. Yet individuals in different cultures manifest markedly different self conceptions and behaviors in terms of gender identity, sex role in society, and acceptance as normal adults. For example, there was at one time an isolated population in the Dominican Republic where the incidence of this phenotype was quite high due to multiple genetic mutations (Cai et al., 1996). In this culture, it was recognized and accepted that some girls become men at puberty. Thus, people with 5-alpha reductase deficiency were able to make the transition from female to male with public recognition and support, and were able to function as men and fathers during adulthood.

With time, however, this society has changed as it has had more contact with modern culture, both within the Dominican Republic itself and as the focus of much attention from United States medical teams. The term "guevedoces" was coined to label the individuals who changed sex (Spanish idiom for "eggs [balls] at twelve"), thus distinguishing these fathers from fathers who had, as children, been boys. The condition began to be viewed as pathological, and the individuals who had it became stigmatized as deviant. As a result, their risk for suicide and alcoholism rose sharply.

In the New Guinea highlands, this same genetic syndrome is also common. Moreover, among the Sambia in New Guinea (Herdt, 1990, 1997), it is not only recognized, but the people are designated "kwolu-aatmwol" (turning-man) and play a unique role in the culture. The Sambia are an extremely sex segregated culture, with men living, sleeping and eating separately

from the women and children. Around age eight, boys are taken from their mothers and undergo

a series of rituals lasting several years that are necessary to turn them into men. The fate of a

kwolu-aatmwol is therefore particularly problematic. However, while they are not viewed as

"normal" men, neither are they deviant. In fact, they serve a specialized, and high status, shaman

role in society because they have knowledge of both male and female perspectives. Herdt (1997)

has even argued that they constitute a third sex within this culture; that is, they are a category

unto themselves, not an amalgam of male and female.   Individuals with 5-alpha-reductase

deficiency in the United States, the Dominican Republic and New Guinea have the same body.

But individual and social behaviors, as well as self-concept, are dramatically different as a

function of the system of beliefs and cultural context in which the person lives.

Localizing the mind: Finding correlates of the first-person perspective at the physiological level.

Descartes localized the essence of the human mind in the pineal gland (Descartes, 1649). He proposed

that, from this organ, nestled deep between the hemispheres, the mind directs the bodily machinery,

producing actions both animalistic and human. We now know that the pineal gland does indeed serve as

an interface between the outside environment and the body, but its role appears to be restricted primarily

to transducing information about light and day length and integrating it with activity patterns and

reproduction, e.g., entraining seasonal cycles of reproduction and modulating circadian activity rhythms

(Prendergast et al., 2000; Stehle et al., 2003).

Is it possible to localize a first-person experience (such as a belief) that affects behavior and

distinguish it from the stimuli that a third-person observer would detect? This is a reformulation of

Descartes' original problem – it is asking how the mind is instantiated in the body. Hypnosis provides a

compelling arena within which to address this problem. Some individuals can easily enter an hypnotic

trance (Fromm, 1987; Spiegel and Spiegel, 1978) and, in this state, they can be induced to perceive color

when the physical stimulus reaching their eyes is only black and white. Skeptics have countered that the

verbal reports and behavior of these hypnotized individuals are a product of "play-acting" – that their

claims and behaviors are based on memories of seeing color, but their actual perceptions are, in fact, no

different from when they are not hypnotized (Kihlstrom, 1997). However, neuroimaging studies suggest

that these individuals are not simply acting and, indeed, that brain activity in the visual cortex is best predicted by first-person experience, i.e. by perception, not by the physical stimulus of the light being processed by the retina (Kosslyn et al., 2000). Subjects were asked to view two versions of a painting by Mondrian: (1) an accurate color reproduction of the original painting and (2) a gray scale reproduction of the same painting. Not surprisingly, positron emission tomography (PET) scans of the brain were different in the two conditions – there was more metabolic activity in the color perception areas of the left and right hemispheres when the subjects viewed the image presented in color than in gray scale. Importantly, however, there was also more brain activity in these same areas when the subjects were put into an hypnotic trance and asked to "see" the color image in response to the gray scale picture. This is not true for non-hypnotized subjects.

We now know that it is possible to associate some mental events with aspects of brain function. Other aspects of mind may not be as readily localizable. Still others may depend not only on the brain, but also on the state of other major integrating systems of the body (hormones, neuromuscular tone, immune function). But our main point is that localizing aspects of mind and first-person experience is clearly possible, thus enabling the identification of transduction pathways by which the mind can affect neural, hormonal, and immune function.

Uniqueness of the human mind and scientific inquiry. Descartes split the mind from the body in part to secure a place for the uniqueness of individuals and to distinguish humans from animals. The mind-body split was essential to maintain man's unique position in the universe and avoid the wrath of the Christian church. This dualism persisted as research progressed rapidly towards understanding the interaction of brain and observable behavior. Many scientists resist quantifying first-person experience because, they argue, we each have our own unique experience that precludes generalizations holding across humans in general. But simply having a different perspective does not, in and of itself, obviate generalizability. Consider as an informative analogy, the difference between your own eyes and those of others (Gunderson, 1970). You can look directly at a human eye and make judgments about color, pupil size, shape of the lens, and the projection of light on the retina. With this information you can predict how pupil diameter responds to sudden changes in light or autonomic nervous system activity. But you

cannot observe your own eyes in the same direct way that you can observe other peoples' eyes. You can look at your own eyes in a mirror or look at pictures or a video. But your method of measuring, and therefore knowing about your own eyes cannot be the same as those you use to measure other peoples' eyes. There is an inherent asymmetry in the point of observation.

Do you conclude, therefore, that your eyes are so unique that it is not possible to make scientifically testable hypotheses about your own eyes just because of this observational asymmetry or bias? Most would say no. And by the same reasoning, Gunderson (1970) argues, we can be as confident in our inferences about the minds of other people as we are of our own, as long as we have many forms of replicable measurement and can thereby achieve a robust definition of a particular state of mind.

A warning call

We end with a warning call to psychologists. The current trend across the nation is for psychology departments to split into two sections, with the biological and cognitive enterprises (frequently taking a third-person perspective) on one side and the social and emotional enterprises (often taking a first-person perspective) on the other.   The concern we have with a division of this sort should be obvious given our discussion of the relationship between mind and body, culture and biology. The mechanisms that underlie a psychological phenomenon and the functions that lead to its recurrence may not even be visible when the phenomenon is divorced from its social context – recall gender identity, beliefs about labor across cultures, and sexual motivation. Indeed, mating in the rat looks like a completely different phenomenon when analyzed at the group level in its appropriate social context than when analyzed at the dyadic level.

In terms of the mind-body problem, separating enterprises that take a third-person perspective from those taking a first-person perspective has the unfortunate effect of putting body in one department and mind in another. Similarly with respect to the nature-nurture debate, although developmental research is often represented in both halves of typical departmental splits, the foci of the inquiries that take place over the ontogenetic time span differ in these departments – with those who do research on cognitive or biological development in one half and those who explore social or cultural development in

another. When we split the social or biological context off from psychological phenomena, or ignore the first-person experience of an observable behavior, we run the risk of doing excellent work but on the wrong question, perhaps even a question that is not worth asking. In our view, psychology should capitalize on its unique position as a bridge between the biological and social sciences. By splitting into two sections, one focused on the first-person subjective perspective and the social level, and the other focused on the objective perspective and the individual and biological levels, psychology may lose its pivotal position among the sciences and lose its identity and utility.

In sum, a full explanation of a phenomenon will often require not one but a whole set of explanations at different levels of organization, time scales, perspectives, and causal modes. Many conceptual confusions and heated debates in the social sciences can be seen as a product of different choices of preferred loci within the different explanatory dimensions, either stemming from an explicit argument that one choice is preferable to another, or from a failure to notice that there are choices. There can be a best choice of loci on the explanatory dimensions to answer a given question for a given audience in a given context. However, what makes an explanation a "good" explanation is relative to the question asked, and the audience and context addressed, and is not an absolute matter. Complex multidimensional problems require multidimensional answers.

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[1] Some may feel more comfortable talking about explanations rather than causes because the term "cause" has come to be synonymous with immediately antecedent events or processes – in effect, mechanism, Aristotle's "efficient cause".

[2] In many contexts, functional causes indicate conscious reasons or intentions, but they need not do so. The primary qualification that a process, object or event needs to have to be considered a function is to increase the probability of its own recurrence or survival. Functional causes operate not only in evolutionary contexts with natural selection but also in ontogenetic (learning, intentional action) and historical (scientific, technological, and cultural evolution) contexts Campbell, D. T., 1969, Variation and selective retention in socio-cultural evolution: General Systems, v. 14, p. 69.; Boyd, R., and P. J. Richerson, 1983, The cultural transmission of acquired variation: effects on genetic fitness: Journal of Theoretical Biology, v. 100, p. 567-96.; Wimsatt, W. C., 1972, Teleology and the logical structure of function statements: Studies in History and Philosophy of Science, v. 3, p. 1-80.. This view of function as a cause is also implicit in Simon Simon, H. A., 1969, The Sciences of the Artificial: Cambridge, MIT Press.; Simon, H. A., 1996, Understanding the Natural and the Artificial Worlds, The Sciences of the Artifical, v. 3rd Edition: Cambridge, MIT University Press..

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