Pamela Lyon and Fred Keijzer

The Human Stain

Why Cognitivism Can't Tell Us What Cognition Is & What It Does

That the sciences concerned with cognition must move beyond cognitivism is not simply a good idea, it is a movement already well under way. Within a decade, perhaps sooner, few will disagree with the label 'first-generation cognitive science' used by Gallese and Lakoff (2005, p. 455) to describe the ultra-cognitivist period of this widely distributed, multidisciplinary enterprise. This suggests we already inhabit the second wave, whatever it is. By ultra-cognitivism we mean the thesis that the natural cognition of biological systems (the only kind we know so far) is meaningfully like what goes on inside a digital computer. That is, mental contents and processes are meaningfully thought of as symbolic (abstract, amodal) representations that combine according to formal syntactic rules, yielding language-like properties of thought such as productivity, compositionality and systematicity (Fodor, 1975). Because of these features ultra-cognitivism further proposed that cognitive processes —typically viewed as reasoning, in contrast to emotion and feeling —could themselves be considered abstractly, independent of their material context. Cognitivism can also refer generically, almost vacuously to an 'information processing' approach (cognitivism-lite), so we use the prefix 'ultra' to refer to the strong thesis that cognition is information processing of a particular type, which in its natural instantiation takes place in the brain of an agent, paradigmatically human.

Bechtel and colleagues (1998) locate the beginning of the end of first-generation cognitive science with an 'identity crisis' that began in the mid-1980s with the 'rediscovery' of neural networks, brain science, and the importance of the environment ('ecological validity' and 'situated action') to psychological processes (pp. 77–90). While the identity crisis has yet to fully play out, the parameters of the second generation are coming into focus (Winograd & Flores, 1986; Beer, 1990; Brooks, 1991; Varela *et al.*, 1991; Van Gelder, 1995; Clark, 1997; Keijzer, 2001). First and foremost, second-generation theoretical modelling can no longer operate purely in the abstract, divorced from how the brain works or the fact that cognition 'facilitates life in the real world' (Bechtel *et al.*, 1998, p. 91). Except perhaps in the narrowest circumstances, therefore, psychological explanations cannot bracket the rest of the body, mental features such as affect and feeling, and the fact that cognitive processes rely on phenomena outside the agent. Second-generation cognitive science thus is frequently referred to as 'embodied', 'embedded', 'situated', 'enactive', 'interactionist', and so on.

These developments are extremely positive, indeed, long overdue. However, we believe the post-cognitivist sciences of cognition will have to do much more than recognize the obvious: that natural cognition is a biological function which enables an organism to navigate an ecological niche the organism, in part, creates. A post-cognitivist science of cognition will have to do more, that is, if it truly aims to be a *natural* scientific enterprise, one capable of answering the three fundamental questions that Bechtel and colleagues (quite correctly) claim it must: *What is cognition? What does it do? How does it work?* So far, cognitivism has failed to provide sufficient traction on the first two issues (see, e.g., Neisser, 1976; Johnson and Erneling, 1997).

In this chapter we will argue there is a deeper issue that must be recognized if real progress is to be made toward understanding what we now think of as cognition, roughly: *the processes by which humans and other biological systems come to know the world*. Until this deeper issue is acknowledged and addressed, we suspect the best we can hope for is the continued accumulation of facts in disparate enterprises, despite an existing 'information overload that almost inhibits meaning' (Rose 1998, p. 87). The deeper issue revolves around the question of what sort of science the cognitive sciences, and psychology in particular, are supposed to be. Unlike any other science that has sought to understand a complex facet of the natural world, psychology and related disciplines have benchmarked their explanatory successes principally against a single organism: *Homo sapiens.*

This species-centrism, unique among the modern life-related sciences (Lyon 2006b), derives, naturally enough, from our understandable fascination with the (seemingly) peculiar human experience of being-in-the-world. However, it is also strongly supported by Anglo-European culture, in the context of which the so-called 'cognitive revolution' occurred. Judeo-Christian theology, which forms a major component of the cultural scaffolding, accords humans dominion over the rest of nature. This is the basis of the 'Great Chain of Being,' a concept that still haunts the Western imagination despite its comprehensive defeat by modern science. Many Asian cultures—for example, those influenced by Buddhism—have a much more egalitarian view of the distribution of cognition in nature. It is no accident that the first scientist to defend the once-heretical thesis that some nonhuman primates have 'culture,' an idea now the subject of much investigation, was Japanese (De Waal 2001). An equally titanic influence on the cognitive sciences' species-centrism is Cartesian psychology, which provided an 'enlightened' rationale for the theological picture by dividing the world into two stuffs, one exclusive to humans. Although dualism has long been a minority position among scientifically sophisticated moderns, the debt of cognitivism to Descartes—and the deleterious effects that intimate connection has wrought—is well known (for a recent critique in relation to neuroscience, see Bennett and Hacker 2003; to cognitive science generally, Wheeler 2005; but also Dupuy 2000; Gardner 1985).

Thus, while the great leaps of the 20th century in understanding human biology (e.g., genetics, development, physiology, pathologies) were made on the basis of experiments with simple model systems (e.g., bacteria, yeast, nematodes, fruit flies, frogs, zebrafish, mice, rats), cognitive psychology and related sciences largely focused on human intelligence—a highly complex and difficult to understand phenomenon—without much reliance on more simple animal model systems. In this chapter we will argue that, while not always overtly human-centred—although some comparative psychologists argue otherwise (e.g., Shettleworth, 1993; 1998)—cognitivism is, in fact, *anthropogenic*. It is so because it rests on the (usually implicit) assumption that the human case is the most fruitful, even necessary, starting point for extrapolating an ontology for the cognitive sciences, that is, for determining what the cognitive sciences are sciences *of* (Lyon, 2006a,b).

Biology often uses staining techniques in which a pigment is used to colour particular structures in a sample. The anthropogenic approach acts like a conceptual staining technique, which brings certain limited features of cognition into sharp relief. Using a 'human stain,' the sharp visibility of these artificially enhanced features makes them diagnostic or substantially indicative of cognition, to the exclusion of other processes that may be, and often are, more important. The pre-eminent use of a single technique is justified in a field of enquiry when it is the only or chief reliable method for investigation, but it can also mislead. The violet-coloured Gram stain revolutionized the field of bacteriology, for example, but also encouraged the postulation of a major taxonomic division that has not stood the test of time. The differential ability to retain the stain is the result of differences in cell-wall structure between Gram-positive and Gram-negative bacteria, differences once assumed to reflect a major natural division similar to that of animals and plants or, more recently, prokaryotes and eukaryotes. Just as sophisticated molecular biological techniques have blurred these other once-ironclad divisions, the Gram staining divide is now known to be highly permeable. It is no barrier to the exchange of genes (Ochman and Moran, 2001; Ragan, 2001), for example, or the marshalling of coordinated behaviour (Bassler and Losick, 2006). In other words, recent advances in microbiology suggest that bacteria are much more alike in general outline, and more different in detail, than the Gram stain shows.

Similarly, a major effect of cognitivism's 'human stain' has been the tendency to systematically underestimate the value of topics, such as 'basic behaviour' (Keijzer, 2001), which fall in the shadow of human cognition and/or consciousness. Whereas leading psychologists of the early decades of the 20th century assumed that the behaviour of even very simple creatures, such as amoeba and paramecia, were legitimate empirical avenues for understanding cognition (see in particular, Jennings, 1906; Washburn, 1936), scientists and philosophers in the revolutionary phase of ultra-cognitivism in the century's latter half largely rejected this work. Like little boys with their noses pressed against the window of a sweet shop, the cognitive revolutionaries waited for someone or something to break the window that separated them from the tantalizing goal they could intuit but not reach, while rejecting the option of searching for a door in the form of simple animal cases. The classic cognitivist's warrant for ignoring the behaviour of simple organisms in the quest to understand cognition, popularized by Dennett, is the putatively robotic provisioning behaviour of the well-known *Sphex* wasp. However, the *Sphex* example—originally published by Henri Fabre in 1879 —was in actuality a caricature of a behaviour that subsequent experiment revealed to be more complex and equivocal (Keijzer, 2001).

We believe the cognitivist tendency to neglect basic behaviour, which has proved surprisingly complex and resistant to easy explanation (Rosensweig *et al.*, 1996), has contributed to the cognitive sciences' failure to even *identify* their investigative target, much less explain it. After 150 years of scientific psychology and half a century of one of the most concentrated investigative efforts in human history, we still cannot agree what creatures exhibit cognition (Lyon, 2006b). Even non-human primates are not beyond doubt, as a former professor of animal behaviour states: 'If scientists, at least, finally cease to make the conscious or unconscious assumption that [non-human] animals have minds… [and] If the age-old mind-body problem comes to be considered as an exclusively human one, instead of indefinitely extended through the animal kingdom, then that problem too will have been brought nearer to a solution.' (Kennedy 1992:167-168). Comparing the state of his own discipline's theoretical armamentarium to that of the physical sciences, psychologist Christopher Green (2000, p. 5) concludes: 'To put it crudely…physics knows what it is talking about'—for example, electrons, quarks, pendula, falling bodies, turbulence in fluids, the behaviour of gases. '[T]o the extent these idealized entities correspond to real entities, physics works. Psychology does not, in this sense, know what it is talking about.'

This is not a trivial 'merely semantic' issue. At the very least the lack of agreement about basic theoretical constructs exacerbates commensurability problems already intrinsic to a multidisciplinary knowledge enterprise. Terminological confusion in psychology has been lamented since William James. The fact that this is still the case more than a century later, especially after five decades of extraordinarily intensive research, suggests to us that the subject matter of psychology is not only very complex but that the predominant manner of approaching it is also deeply flawed.

The shift away from cognitivism toward dynamic, embodied and situated approaches, however necessary and progressive, has so far left untouched the fundamental issues of a cognitive ontology, including the demarcation of the cognitive domain (although there have been some moves in that direction, particularly recently

(Moreno *et al.*, 1997; Harnad, 2005; Lyon, 2006b; Van Duijn *et al.*, 2006). We will argue that a truly post-cognitivist psychology will be impossible until we come to grips with the anthropogenic basis of the existing paradigm. What is required, we claim, is more attention to the deep biological context within which natural cognition arises. In contrast to the anthropogenic approach, a *biogenic* approach assumes that because natural cognition is first and foremost a biological function, which contributes to the persistence and wellbeing of an organism embedded in an ecological niche with which it must continually contend, then biological principles are the best guide to what cognition is and what it does. Like other biological functions (e.g., respiration, nutrient acquisition, digestion, waste elimination) the general outline may be broadly similar relative to the economy of an organism; some basic mechanisms may even be shared. On the other hand, the mechanistic details of how the function works are likely to differ from organism to organism, the result of making a living in a particular niche.

This chapter is structured as follows. First, we will sketch the characteristics of the anthropogenic and biogenic approaches to cognition[1] and point to some historical exemplars. Next we will explain why we think cognitivism is anthropogenic and outline some of the problems that arise for the paradigm for the very reason that it is so. Finally, we will show how biogenic theorizing is empirically constrained to a greater extent than are anthropogenic approaches to cognition, which provides advantages for addressing fundamental issues of scientific ontology. Basic forms of sensorimotor process are shown to be a principled starting point for demarcating the domain of cognitive phenomena, and although sensorimotor-based theories do not necessarily imply a form of experience, it is possible to address even such difficult topics as consciousness from a thorough-going biogenic perspective (e.g., Goodson, 2003).

It is important to stress that the anthropogenic and biogenic approaches are not mutually exclusive. Ideally, they are complementary. After all, we do want to know how the human mind works. However, if the cognitive sciences really do need a fundamental ontology—and there is growing sentiment that they do (Toulmin, 1972; Staats, 1983; 1999; Sternberg and Grigorenko, 2001; De Waal, 2002; Hartley, 2006), even in unrelated disciplines (Silver, 1998)—then we claim that the anthropogenic approach, of which

---

[1] The distinction was introduced in Lyon (2004) and developed in Lyon (2006a,b).

cognitivism is a prime example, is not likely to get us there. A biogenic approach is a more promising, potentially far less problematic vehicle.

The Anthropogenic Approach To Cognition

The choice of starting point for an inquiry into any phenomenon has important consequences for the ensuing science. It shapes the criteria by which the investigative target is identified, compared, described and explained, and has important consequences for the kinds of problems encountered and the permissible conclusions to be drawn. Fundamental conceptual matters present challenges in any discipline. The degree of difficulty is greater still in a multidisciplinary enterprise with varying explanatory agenda. Presuppositions about the starting point in the multidisciplinary cognitive sciences can be made explicit as an answer to a question. Do we begin with human cognition and work our way 'down' to a more general concept of cognition (if that is possible)? Or do we start from the facts of biology, derive a general concept, and then work our way 'up' to the human case, which we take (no doubt correctly) to be the most complex and sophisticated instance of cognition on this planet?

The terms *anthropogenic* and *biogenic* denote the different choices the answer to this question entails. The tradition of cognitive explanation that takes the human case as its starting point is called anthropogenic based on the Greek words for human (*anthropos*) and birth or origin (*genesis*). *Bios* is the Greek word for life, hence *biogenic* describes the cognitive approach that begins with biology. These adjectives are new only to the cognitive sciences. 'Anthropogenic' has long been used in plant ecology to refer to plants introduced by humans, and increasingly refers to global climate change associated with human activity. 'Biogenic' is employed in geology to refer to the origins of certain rock strata. Limestone is biogenic, for example, because its origin is material that once formed part of living organisms.

The important thing to keep in mind is that the anthropogenic/biogenic distinction refers to a methodological bias, a strategic calculation, not an ontological preference or belief. Of course, an ontological preference or belief may lurk behind the choice of methodology, but need not. The suffix is the key; *genic* is intended to convey the notion of a beginning or starting point. Thus, an investigator adopting an anthropogenic approach to cognition starts with the human case in the belief that the features of human cognition are the most plausible and potentially fruitful (possibly the only) guide to understanding the phenomenon of cognition generally. By contrast, an investigator adopting a biogenic approach assumes that the principles of biological organization present the most productive route to a general understanding of the principles of cognition because natural cognition is a biological process. Whether a machine can be engineered to either mimic or instantiate these processes is beside the point.

Assuming that the human case is the best starting point for an inquiry into mind is the oldest approach in the western philosophical and scientific tradition, and remains the dominant approach today. This is hardly surprising. We humans initially identify the features of the 'mental' domain as phenomena requiring description or explanation in the same way we identify spatial qualities and other features of the 'physical' world—through our experience of them (Fehr, 1991). Just as all human cultures appear to have words for 'big' and 'small', 'near' and 'far', so too do they have words for 'think', 'know', 'want', 'feel', 'see' and 'hear' (Wierzbicka 1996)—although it is important to remember that 'cognition' and 'mind' are not universal terms.

An argument in favour of the anthropogenic approach might run something like this. If cognition is a phenomenon amenable to scientific study and explication, then we would best profit by focusing our attention on the instance about which we are certain and with which we are most familiar. The most plausible (arguably the only) current candidate for a paradigmatic exemplar of cognition is human cognition. This is not to suggest that in the final analysis human cognition will prove to be the only or even the most typical example of the phenomenon. Indeed, it may prove to be quite atypical, depending on how a general concept of cognition shapes up. It is, rather, merely to point out the obvious: that human cognition is the sole example of the phenomenon upon which everyone can agree at this stage of investigation. Human beings, uncontroversially, are cognitive beings, however cognition ultimately may be cashed out scientifically. Cognition may not be an exclusively human phenomenon, but it nevertheless stands to reason that the properties of the human mind, which we know to a first approximation based on our own experience, will provide the best guide to developing a diagnostic criterion for determining which sorts of systems are cognitive and which are not.

Cognition not only is identified in the first instance as a describable phenomenon via human experience—the experience of thinking, feeling, wanting, believing, knowing, hearing, seeing, etc.—but also is apprehended elsewhere in the natural world, when it is so apprehended, based largely upon the prevailing understanding of the human case. This was so in pre-scientific times (Earle, 1881; Aristotle, 2001) and remains so today. This is not to imply that an anthropogenic approach to cognition is intrinsically anthropocentric; it need not be. Explanatory targets and starting points are not always identical. A researcher taking an anthropogenic approach might argue, however, that the only way cognitive features such as perception and memory can be identified in other animal species in the first instance is by virtue of their apparent similarity to the human exemplification of perception and memory. We have words for 'perception' and 'memory' to make sense of our own experience; they were not invented to account for non-human behaviours. We necessarily generalize from the human case; we cannot help but do so, as the anthropomorphism deeply embedded in ordinary language attests (Kennedy, 1992).

Contemporary theories of cognition need not explicitly take account of evolution (Fodor, 2005), but generally speaking, they aim to be consistent, more or less, with evolutionary theory. This means that features of human cognition are likely to be instantiated, to a greater or lesser extent, in our nearest primate relatives and, perhaps, other animals. Thus, the study of animal cognition, and primate cognition in particular, are potentially germane to the study of human cognition from the anthropogenic perspective. However, often an anthropogenic approach seems to presuppose a substantial, if not radical, cognitive discontinuity between humans (and perhaps their closest relatives) and other animals, which is how categorical concerns about anthropomorphism arise (Keely, 2004). An anthropogenic approach also is more likely to suggest that whether an animal can be said to be cognitive or not depends upon the degree of similarity its behavioural capacities bear to those of human beings (Shettleworth, 1993). Of course, estimations of which human cognitive features are most crucial for an ascription of mentality (e.g., consciousness, language, imagining the absent, 'theory of mind') vary widely. 'Similarity', too, is construed with varying degrees of liberality according to different criteria. Thus a worker adopting an anthropogenic approach could remain agnostic as to where on the phylogenetic bush cognition emerges—or even if it emerges solely in a biological context. (She could be a panpsychist, for example, or a worker in artificial intelligence.) Whether such agnosticism is found in practice is another matter.

The anthropogenic approach to cognitive explanation does not begin with René Descartes, but he is probably the best pre-20th century exemplar. Descartes' approach to cognition is anthropogenic because of its starting point (the human mind); his method of investigation (analytical introspection); and his assertion that a radical typological discontinuity exists between human beings and the rest of the natural world (Descartes, 1641/1986). Descartes conceived of thinking, as against perception or memory, as a capacity exclusive to humans, and the capacity for thought as dependent upon a special kind of substance (*res cogitans*), shared by no other living being.

The Biogenic Approach To Cognition

By contract, an investigator adopting a biogenic approach to cognition assumes that the properties and principles of biological organization present the most productive route to a general understanding of the properties and principles of what we now think of as cognition: the processes by which humans and presumably other biological systems come to know the world. The rationale behind this assumption is simple. Cognition as we know it—however we may conceive it in the future, and wherever else it may be found beyond the human domain—serves a biological function. Human beings are cognitive, and human beings are biological organisms. Cognition, however that ultimately may be characterized, exists because it makes a substantial contribution to the survival, wellbeing and reproduction of the human animal. For this reason, human cognition is still highly relevant to an investigator adopting a biogenic approach. After all, an adequate theory must account for the features of human cognition, and investigation of human cognitive capacities has generated a large amount of valuable data.

For the biogenic approach, however, human cognition is not the benchmark. While humans are obviously important to the study of cognition as a biological function—human traits typically are what we are most interested in—*Homo sapiens* is a privileged source of data only relative to human cognition. There is no assumption that human cognition is the 'most developed' or 'perfected' form of the biological function, however extraordinary and complex it may be. As modern biology moves ever further away from its essentialist roots in the *Scala naturae*, scientific justification for 'typological thinking' — the idea that a particular species or race is a 'generalized representative' of an entire order or class of phenomena — also diminishes (Hodos and Campbell, 1969/1996, p. 257). Thus even among closely related phyla, there are differences that reflect unique adaptive histories as well as shared features.

The second major difference between the biogenic and anthropogenic approaches is that evolutionary continuity, the idea that complex forms of life and organic process have evolved from simpler forms, is a *presupposition* of the biogenic approach, not an enforced necessity to accord with the current state of scientific theory. The principle of evolutionary continuity and the related principle of evolutionary convergence bear upon a biogenic approach to cognition in two ways. First, adaptations contributing to an organism's survival, wellbeing and reproduction tend to be conserved (positively selected) over evolutionary time. Molecular biology provides ample demonstration that this is overwhelmingly the case. Second, the repertoire of functional responses to identical or similar existential challenges tend to be rather more limited than mathematical possibility suggests (see, for example, Weinreich *et al*., 2006), not least because new biological solutions to changing environmental conditions tend to be built on processes whose usefulness is already demonstrated. Because all animate systems must acquire energy from the environment, transform it into usable forms, discharge waste and reproduce they all also share certain generic functions, such as ingestion, digestion, circulation, respiration, elimination and replication. The heart of a leech and a human are neither homologous (descended from a common ancestor) nor do they bear much structural resemblance, but both organs pump blood to circulate oxygen and other nutrients and to remove wastes.

Finally, as the preceding discussion suggests, a biogenic approach must take seriously the material conditions within which cognition arises in a way an anthropogenic approach need not. Whereas an anthropogenic inquiry may proceed in utter disregard of the material instantiation of cognition, as we will see in the next section, a biogenic approach simply cannot. In biology, the elucidation of any type of function entails elucidation of a material mechanism.

In sum, a researcher who takes a biogenic approach assumes that the nature of cognition is best understood in the general context of biological organization and functioning, not in the specific context of the human instantiations of these functions. Cognition may prove to be a complex, multifaceted global function, like respiration, without which no organism can survive, or it may be a complex but more circumscribed trait, like avian song learning, that provides an adaptive advantage only for those lineages that possess it. Whereas an anthropogenic approach can more easily assume that cognition might be an example of the latter rather than the former, a biogenic approach is more likely to treat it as the open empirical question it is in actual fact.

Aristotle may not be the most unambiguous exemplar of the biogenic approach, but he is unquestionably its historical progenitor. Aristotle voices what could be termed 'the biogenic lament' in the opening chapter of *De Anima*, his treatise on *psuche*.[2] '[U]p to the present time,' he writes, 'those who have discussed and investigated [*psuche*] seem to have confined themselves to the human [case]' (Aristotle, 2001, p. 536). Aristotle is not concerned with delineating the conditions for applying mental and physical predicates. In fact, he draws no distinction whatsoever between the mental and the physical (Frede, 1992); thus it has been argued that Aristotle 'properly speaking … does not have a philosophy of mind' (Nussbaum and Putnam, 1992, p. 28). Rather, Aristotle is concerned with answering the question *What is it?* and explaining how identity persists through change. His answer is form, or functional organization (Lennox, 2001). Functional organization, the pattern of interactive relations among the constituents of matter, is what differentiates one thing from another and maintains identity over time despite, in the case of animate things, continuous change. Functional organization, on this account, is importantly related to a thing's 'nature' or *telos* (purpose, goal), the ultimate realization toward which its development and maintenance tend (Charles, 1995, p. 56). For example, Aristotle (presciently) hypothesizes that the distinctive characteristics of human cognition, which he identifies as calculative reason and the ability to overcome desire, are largely determined by social living, which demands the capacity for weighing alternatives and behavioural restraint.

---

[2] This term, often rendered (wrongly, in terms of contemporary orthography) as *psyche*, has no English equivalent. Although frequently rendered by the medieval Scholastics as 'soul', it does not equate with that term. As the'form'of a living being *psuche* is mortal. Thus it accounts both for the characteristics of vitality and of mind. *Nous*, the 'active intellect' that enables philosophical reason is immortal (following Plato, and in puzzling contrast to the rest of Aristotle's philosophy), and thus is more akin to the Christian notion of 'soul'.

The advent of modern scientific psychology provides another example of the anthropogenic/biogenic distinction in the approaches of Wilhelm Wundt and William James. Wundt regarded immediate human experience as the special subject of psychology; he neither conducted nor sponsored animal experiments at a time when comparative psychology was becoming an active field (Watson, 1978). Wundt's psychological pursuits began with measuring the voluntary control of attention and moved to measuring sensations and feelings, which he believed to be the elements of consciousness (Wade, 1995). Wundt's experiments depended on his subjects' introspective reports—for example, of their awareness of changes in light intensity, colour brightness and hue, sound volume and so on—so his approach was necessarily anthropogenic. He took the human case as his starting point and paradigm, and from this experimental platform was able to derive a number of law-like generalizations about human psychology, many of which apply to nonhuman cognition (Blumenthal, 1980).

James (1890), by contrast, was more deeply influenced by the biological psychology of Herbert Spencer and Darwin's evolutionary theory. Although James draws liberally on human experience in developing his psychological ideas—his description of the mental effort required to arise from bed on a cold morning and his proposals regarding the 'stream of consciousness' are classics of introspection—he relies on biological principles to suggest what he takes to be the most general, defining features of mind. The 'mark and criterion of the presence of mentality' for James is not consciousness but, rather, 'the pursuance of future ends and the choice of means for their attainment' (James, 1890/1950, Vol. 1, p. 8). James derived his criterion from zoological observation. Reliance on biological principles to arrive at generalizations about the nature of mind places James squarely in the biogenic camp. His emphasis on goal orientation, or teleology, in psychological explanation also makes him Aristotle's heir.

Finally, it is important not to conflate the anthropogenic/biogenic distinction with another methodological distinction commonly drawn in the psychological literature between a 'psychological' approach and a 'biological' approach. The two sets of distinctions are not co-extensive. The psychological approach typically focuses on broad behavioural response patterns characterized as mental that are based on the wants and needs of a whole subject—usually, but not always, human and often in a social context—rather than the physiological details and biological principles underwriting the behavioural responses (Zachar, 2000). The biological approach, by contrast, targets the physiological details. A psychological approach to the emotions, for example, might be concerned with how the emotions fit into the cognitive economy of an individual or group of individuals; how they vary in differing contexts; how patterns of dysfunction manifest; and how patterns of affective response might have evolved (Stein *et al.*, 1990). A biological approach, on the other hand, would be concerned with brain structures, neuronal firing patterns, molecular dynamics and the genetic, developmental and other biological factors involved in the generation or modulation of affect. The psychological approach is often construed as 'top down,' meaning the phenomenon of interest is a complex global pattern of activity exhibited by an entire system. 'Bottom-up' approaches attempt to understand complex global properties in terms of their microstructural constituents. The biological approach is frequently identified as 'bottom-up', or reductionist, but this characterization is also erroneous. Biological mechanisms come in global as well as microstructural varieties, and in every sort in between.

Whether one takes the human case or the living state as the starting point for an empirical investigation of mind, both approaches are by definition 'psychological', in the above sense. After all, the phenomenon to be described and explained is cognition, which until the advent of *in vivo* brain imaging techniques was typically inferred from whole-organism patterns of behaviour. The source of controversy is just what sorts of behaviour indicate cognition. Both approaches are also necessarily 'biological', in the sense described above. Human beings, whatever else they may be, are animals. Moreover, contemporary scientific and philosophical opinion is univocal in asserting that human psychological capacities must be explained in the context of their biological underpinnings. Contra Deacon (1997), human biology is not 'almost incidental' to human cognitive capacities; it is the matrix from which they arise. Thus, an anthropogenic approach can be psychological *or* biological, that is, concerned with global behaviour patterns or with the physiological mechanisms that underpin them. Ditto for a biogenic approach. Likewise, a psychological approach need not be anthropogenic, nor a biological approach biogenic.

Why Cognitivism Is Anthropogenic

Cognitivism is anthropogenic by virtue of the conceptual framework adopted by the early cognitivists, their guiding metaphor (the computer), and the major tests and explanatory goals they set for themselves. This might strike some as counter-intuitive. Through its close association with philosophical functionalism, cognitivism is typically regarded as an ontologically neutral paradigm for investigating cognition that does not play favourites with respect to material circumstances, much less species (Shapiro, 2004). The Turing machine, the mathematical idealization upon which the von Neumann computer was based, at its simplest is a device to transform an input (some state of affairs represented in symbolic form) into an output by virtue of a specified procedure or set of instructions, typically referred to as a computational function or algorithm. In behaviouristic terms, the input can be conceived of as a stimulus condition, the output a behavioural response, and the computational function the intervening variables, including previous conditioning, that specify the correct behavioural response given the current state of the system and the type of stimulus involved. On the face of it, there is nothing intrinsically human about this picture. Indeed, its supposed wide applicability was very much part of its attraction.

It is worth recalling, therefore, that the Turing machine was conceived by its inventor explicitly as the mechanization of deliberative mathematical computation (Turing, 1936; Copeland, 1996). At the time Alan Turing proposed his hypothetical device, legions of men and women known as 'computers' were carrying out complex mathematical calculations according to task-specific protocols all over the world, in a wide variety of fields. Turing was convinced, and many agreed, the Turing machine captured the key features of the human intellectual procedure of calculation. Thus the Turing machine was an intrinsically anthropogenic construct. Even if a specific application of the Turing machine idea might have nothing explicitly to do with human capacities, cognitive or otherwise, its inspiration was a behaviour believed to be distinctively human.

The earliest uses to which the Turing machine concept was put also explicitly involved human capacities, for example, code-breaking during World War II. The McCulloch-Pitts model of the neuron, which was directly inspired by Turing's work, suggested that neurons could act as 'logic gates' capable of manipulating symbols according to Boolean functions. That the neurons in question were assumed to be in human brains follows from the fact that McCulloch, whose early research was influenced by logical atomism, originally conceived of the symbols being processed as elements of linguistic propositions. Early artificial reasoning machines were based on human symbol use and problem-solving capacities. Some (e.g., Logic Theorist, General Problem Solver) employed abstract rules and rules-of-thumb (heuristics) believed to reflect those used by humans when they solve logical problems, practical problems, or play logic-using games such as chess (Dreyfus 1972). Moreover, these and other AI programs were tested mainly using problems typically faced by humans, such as language learning or translation, ordering food in a restaurant, and understanding a story.

The Turing Test, long the grail of AI, was also construed in anthropogenic terms. A machine could be said to be 'intelligent' if in the course of an electronic conversation it could deceive a human being into believing (s)he were conversing with another human being and not a machine . The goal of classical AI—'to replicate human level intelligence in a machine' (Brooks, 1991, p. 139)—which powerfully shaped cognitive science in the early decades, thus was unambiguously anthropogenic and, indeed, anthropocentric. This meant that when the over-arching problem of intelligence was decomposed into specialized sub-problems (e.g., knowledge representation, natural language understanding, vision, truth maintenance) areas were typically defined in terms of, and system performance 'benchmarked against the sorts of tasks humans do within those areas' (ibid.). The human case thus was the starting point for understanding cognition and the inspiration for designing cognitive systems. Although some still defend their usefulness (e.g., French, 2000), sentiment seems to be growing that the Turing machine and Turing Test have proved to be something of a dead-end in AI, to say nothing of understanding natural cognition (Chomsky, 1997; Sloman, 2002; Eliasmith, 2002).

Another pillar of cognitivism was Claude Shannon's mathematical theory of communication (Shannon and Weaver, 1949), also known as information theory. Information theoretic terminology (e.g. encoding, decoding, input, output, signal transduction, noise) is ubiquitous in the life sciences, so the utility of information theory clearly transcends the human case. However, while Shannon's sender-message-channel-receiver model can be viewed in abstract terms of some generality there is no denying that Shannon's original theory was aimed at *human* communication and his theory fits in the anthropogenic mould. An engineer at Bell Laboratories, Shannon was concerned with measuring the efficiency of electronic signal transmission and quantifying information flows within human communications systems (e.g., telephony, radio, television). Shannon's concept of information famously is mute with respect to its biologically most salient feature: content, or meaning. Information theory has been applied to the study of cognition more broadly (e.g., Dretske, 1981; Godfrey-Smith, 1996), but the theory's presuppositions remain grounded in the human case.

Computational functionalism and the 'multiple realizability thesis' provided the philosophical justification for equating cognition and computation, mind and computer (Putnam, 1975). Computational functionalism holds that explanations of mental phenomena cannot be reduced to 'nothing-but' explanations of physical processes in a particular kind of system (e.g., a human brain). What matters is what a mental state does, what causal role it occupies in the system of which it is a part. A mental state is nothing over and above its causal role, which can be considered free of a particular material context, which theoretically could be many sorts of stuff. What makes computational functionalism anthropogenic is its tight linkage to AI and the common recourse to aspects of human experience (e.g., pain states, believing, desiring) or its science fiction equivalents (e.g., Martian pain, qualia-free zombies).

The psychology of language, especially Noam Chomsky's proposals, also contributed powerfully to the development of cognivitism by challenging the explanatory hegemony of Skinnerian behaviourism and suggesting causally efficacious internal mechanisms for language learning and use. Boldly for his time, Chomsky proposed that an innate mental ordering 'faculty' provides the syntactic structure in virtue of which children rapidly acquire language, despite the poverty of the stimuli with which they are presented. Fodor extended Chomsky's faculty approach to cognition more generally through his influential 'language of thought' hypothesis, which helped shape the agenda for classical cognitivism. Again, while aspects of the framework and its subsequent elaborations could be generalized to nonhuman species, the starting point (and indeed the focus) was human cognition.

The idea that the human mind has intrinsic power to structure experience and can know things prior to sensory experience is ancient, but its modern champion was Descartes, who as we have seen is the classical exemplar of the anthropogenic approach. Most significant for cognitivism is Descartes' view of what mentality crucially involves: *representation*, or the mind's capacity for making objects within itself both of things-in-the-world and of things-never-before-seen-in-the-world. Although he did not introduce the idea, mental representation was the 'core feature' of Cartesian psychology (Wheeler, 2005, p. 25) and became the core feature of 'the traditional cognitive science program' (Fodor, 1998, p. vii). Descartes claimed that perceptually guided intelligent action is a series of cycles in which some feature of the world is sensed, represented by the mind, the representation manipulated in some way, and action (including further representation) initiated (Wheeler, 2005). This putative cycle of sense-represent-plan-act was long the 'generic organizing principle' of classical AI (Putnam, 1975).

The nature of representational content and how it is acquired became the focus of much hypothesis and debate. Two aspects will serve to illustrate the anthropogenic bias of these explorations: the role of *inference*, long considered an exclusively human preserve, and the concern with *intentionality*. Inference, as used here, does not refer to deductive reasoning but, rather, to various forms of ampliative reasoning, inductive and abductive. Descartes suggested that an epistemic gap exists in human cognition between sensory perception, of which animals are capable, and the mental representation of a sensory object, which he believed only humans can do. An act of judgment 'essentially inferential in nature' was believed to fill the gap (Wheeler, 2005, p. 42). Helmholtz put psychophysical flesh on this idea with his hypothesis that human visual perception is a constructive process whereby the properties of objects are inferred on the basis of 'premises' supplied by the retinal image and unconscious 'assumptions' built into the structure of the perceptual apparatus (Rock 1983). The idea that mammalian behavioural outputs go beyond the information contained in stimulus inputs was the basis of the 'knowledge state' postulated to intervene between stimulus and response by 'cognitive' behaviourists like Tolman (Bindra, 1984).

Although their interpretations differed, philosophers in the Anglophone analytic and European phenomenological traditions were for years in unaccustomed agreement about the distinguishing characteristic of mentality: intentionality, or 'the mind's capacity to direct itself on things' (Crane, 1998). The term originated with the medieval Scholastic philosophers, was resurrected by Brentano in the late 19th century, and denotes 'concepts, notions or whatever it is before the mind in thought' (ibid.). 'Brentano's thesis' stimulated a huge and still expanding literature concerned (in the analytical tradition) with beliefs, desires and other so-called propositional attitudes. This licensed folk psychological 'intuitions' in cognitive theorizing in a way it never has been (or, arguably, could be) in any other science. The classic example is the 'intentional stance' (Dennett, 1987). Adopting an intentional stance means treating a system (any system) as a rational agent and figuring out what its beliefs and desires are likely to be. Thus we can often understand and predict what such a system will do without needing to know about its detailed physical makeup. Both the concept of intentionality and the intentional stance have been liberally applied to simple organisms and artefacts such as thermostats. Indeed, delineating 'genuine' from 'derived' or 'merely imputed' intentionality became something of a small cottage industry. Dennett (1994) himself suggests we 'don't ask' when it comes to determining where or when biological systems acquired 'genuine' intentionality. However, both concept and stance originate in an analysis of human mentality, and their only truly unproblematic applications are in the human domain.

Initially, the dominance of functionalism meant that recourse to brain science could be perfunctory or totally absent. When neurobiology began to figure in the design of computer architectures or theoretical speculations about the nature of mental content, however, reliance on the human or mammalian brain as the benchmark —'brain chauvinism'—was never far away (Vertosick, 2002). The bias dates back two centuries to Lamarck, who dictated that 'no mental function shall be ascribed to an organism for which the complexity of the nervous system of the organism is insufficient' (Bateson, 1979, pp. 93–94). Lamarck's criterion was not seriously challenged until the latter 20th century (Maturana, 1970).

In sum, the disciplines that contributed significantly to the emergence of cognitive science—e.g., AI, linguistics, psychology, philosophy, neuroscience, anthropology— to a large extent assumed a human starting point. Cybernetics, or mathematical control theory, whose homeostasis-like feedback principles were critical to the project of designing a mind, was neither biogenic nor unambiguously anthropogenic, but it also was not especially influential in the formulation of cognitivism's central tenets (Dupuy, 2000; Bindra, 1984). The anthropogenic nature of cognitivism can also be seen in its would-be rivals, all of which were much closer to a biogenic approach, for example, the 'ecological approach' to perception (Gibson, 1979); evolutionary epistemology (Campbell, 1974); and the autopoietic theory of cognition (Maturana, 1970). Biogenic hypotheses remained fringe concerns until cognivitism's 'identity crisis' began in the mid-1980s.

Problems Associated with the Human Stain

Cognitivism has been hampered by all kinds of problems from its inception, most of them well known and some of them already mentioned. Lack of traction on these problems has been related to the neglect of action and emotion (Freeman and Nuñez 1999), and the ways in which the elements of human cognition, such as concepts, function in everyday life (Rosch 1999; Auyang 2000). Two of the major conundrums for cognitivism—the 'frame problem' and the 'symbol-grounding problem'—continue to be the subject of (diminishing) research, although they emerged decades ago.[3] Trying to solve some of these problems has led increasing numbers of researchers to diverge from the ultra-cognitivist approach.

The failures of the serial, symbol-processing, syntax-centric approach of classic AI, for example, led to rediscovery of neural networks and parallel distributed processing, and thus to connectionism. The impasse that resulted from trying to simulate human problem-solving led roboticist Rodney Brooks, for one, to strike out in a new direction. Turning for inspiration to 'the way in which Earth-based biological evolution spent its time' constructing intelligence, Brooks concluded that the hard part of intelligent behaviour—the bit that took the most time—was developing 'the ability to move around in a dynamic environment, sensing the surroundings to a degree sufficient to achieve the necessary maintenance of life and reproduction' (Brooks, 1991, p. 141). Brooks' suggestion that intelligence is possible without representation became something of a manifesto for the embodied cognition movement and led to an assault on this cornerstone of cognitivism that continues unabated (Van Gelder, 1995; Cliff and Noble, 1997; Keijzer, 2001; Beer, 1990; Haselager *et al.*, 2003).

---

[3] The frame problem relates to how a cognizer updates the parameters of a problem-solving context as result of an action, when the parameters that can change are potentially immense and the predictability of which ones will change rather limited. The symbol-grounding problem arises from the silence of information theory regarding semantic content, which raises the question how elements subject to computation come to mean anything at all if cognition is essentially syntactic.

Cognitive robotics and the goal of creating artificial intelligence remain a lively research area, but computational functionalism — the license for equating biological and machine cognition — has taken serious knocks. Denounced by its founder as 'utopian' and 'science fiction' rather than a 'serious empirical hypothesis' (Putnam, 1997, p. 38), computational functionalism appears to be experiencing a large-scale defection (see, for example, Shapiro, 2004; Churchland, 2005). Nevertheless, the explanatory agenda of computational functionalism — to explain cognition in humans (and any other species for which the attribution is justified) in such a way that the explanation also covers intelligent artefacts — appears to be largely intact.

The concern to be both a specialized science and an engineering science meant that cognitivist cognitive science sought to be a *naturalized* but not wholly *natural* science. Motivated in large part by philosophical concerns with metaphysical dualism, the naturalism project initiated by Quine deferred to natural science even as it failed to appreciate its method (Chomsky, 2000; Hacker, 2006). As Chomsky points out, naturalized cognitive science sought to build machines to meet performance criteria rather than to explain the natural phenomena the machines were designed to mimic. Moreover, they were designed largely in ignorance of the latest empirical data relating to cognitive processes. No other natural science has ever proceeded on such an abstract basis (Chomsky, 1997). No surprise, then, that agreement about the chief explanatory goals of the general enterprise remains highly elusive.

The deep problem of the cognitive sciences is that *there is no 'problem'*. Innumerable highly specialized problems exist but few of broad generality on which researchers agree. Although the three key questions set out by Bechtel and colleagues make sense, they are not pursued in any systematic way. Because the fundamental issues remain untouched, data continue to be churned out at a staggering rate in many hundreds of journals but with little means of making sense of them — as De Waal (2002, p. 187) puts it, 'thousands of ideas that are barely interconnected' (but see also Silver 1998; Staats 1999; Sternberg and Grigorenko, 2001). The history of science strongly suggests that systematic inquiry progresses most effectively, as distinct from merely expanding, when there is a certain degree of consensus at the foundations.[4] While disciplinary confusion is not new in the sciences concerned with cognition and human behaviour (Toulmin, 1972; Staats, 1983), the illumination provided by cognitivism during the four decades of its dominance appears to have been, for the most part, illusory.

The difficulties bequeathed by Cartesian psychology, although by now cliché, are worth rehearsing if only because some arguably arise from taking an anthropogenic approach. Two examples will suffice. First is the problem of metaphysical dualism. Studies with children suggest that dualism is the naïve human ontology; by the age of three children draw a fairly strong ontological distinction between mental and physical things (Bloom, 2004). This suggests that an alternative metaphysics must be acquired, either by enculturation or ratiocination. Thus, while an anthropogenic approach to cognition might assume a form of materialism, dualism is the more 'intuitive' metaphysical stance. If metaphysical dualism is false, then it is an error to which an anthropogenic approach leads quite naturally. A biogenic approach, by contrast, does not lead easily to dualism.

Second is the 'homunculus problem,' the idea that cognition is effected by a 'little man in the head' who interprets and uses mental representations in the generation of behaviour. The homuncular inference arguably is the common result of Descartes' chief method, analytical introspection.[5] The naïve felt human experience of the introspecting 'I' is of a place (e.g., head, heart) or a quasi-person (i.e., a faint reflection of the introspecting subject) where percept, concept, affect, drive and whatever else combine to make a mental state, although neurobiological evidence strongly suggests no locus exists where 'it all comes together' (Austin, 2000). It is hard to imagine how the homunculus problem could arise without introspection. Descartes' account of animal perception, memory and bodily movement, which was based on physiological investigation, has no use for a homunculus (Sutton, 1998).

---

[4] It is sobering to note that in the same time span that psychology has considered itself a science—150 years—physics passed from the postulation of a heliocentric model of the solar system, which inspired Galileo to advance the mathematical model of physics, to the discovery of the three standard laws of motion, the law of universal gravitation and definition of the principal terms that would inform research for the next 300 years. All this was possible without benefit of mass publication, global electronic communication, computers, instruments of astonishing precision and large publicly and privately funded research teams.

[5] Certain deep states of meditation are known to yield a 'subject-less' or 'centre-less' experience (Austin, 2000).

In sum, while necessary for a complete understanding of cognition the anthropogenic approach appears ill-suited to the project of demarcating the cognitive domain, and cognitivism particularly so. The failure to do so despite centuries of anthropogenic theorizing and half a century of intensive research under the cognitivist paradigm supports this claim. Not only has cognitivism generated a number of problems that remain so-far intractable, it provided few empirical constraints to theorizing, another feature that differentiates the enterprise from other natural sciences. As we will see in the next section, the biogenic approach provides a substantial number of empirical constraints, which in our view is one of its great virtues for the ontological project.

Why a Biogenic Approach Is Suited to the Ontological Project

Lyon (2006b) sets out 17 empirical principles[6] that constrain biogenic theorizing about cognition. These principles both guide and set limits on hypotheses. As mentioned earlier, a biogenic approach presupposes that organisms are products of evolution by natural selection, and that complex biological functions, including cognition, have evolved from simpler forms of biological function. More important to biogenic theorizing about cognition, however, is the fact that organisms maintain themselves in a far from thermodynamic equilibrium by importing 'order' from their surroundings in the form of matter and energy, chemically transforming it to do work, and exporting 'disorder' in the form of waste products of various sorts. Living systems thus are forced to establish causal relations with features of their surroundings that lead to exchanges of matter and energy, which are essential to the organism's persistence, wellbeing and/or reproduction. Of necessity, then, organisms exhibit a wide variety of control and regulatory mechanisms, including multiple kinds of feedback mechanism, which maintain the system's fluctuating but steady state. Even in the simplest organisms (e.g., bacteria) control hierarchies regulate vital processes. Biological activities that have functions (e.g., homeostatic processes) operate within a range of values outside of which the organism's persistence or wellbeing is threatened. Essential functions thus are generally linked, directly or indirectly, strongly or weakly, to one another.

---

[6] Several additional principles were derived between publication of Lyon (2006a) and Lyon (2006b), the latter providing the most detailed treatment and the references for this summary.

Moreover, organisms are autopoietic; they are continually being produced by a network of components, which are themselves being continually produced by networks of components. At the same time that this continual production cycle is under way, the organism as a whole is interacting with a surrounding medium (as are the organism's constituent components within their local milieu). Because the features of its surrounding medium are constantly changing at varying time scales, an organism must have one or more mechanisms for reducing or managing the impact of environmental variability on its functioning. To persist, grow, thrive or reproduce, an organism must continually adapt to regular or stochastic fluctuations in the surrounding medium by altering its internal structure and/or its interactive relation to features of that medium. This is adaptive behaviour.

A state of affairs that stimulates an organism to adaptive behaviour (i.e., alteration of its internal structure and/or its interactive relation to environmental features) conveys information for that organism. Adaptive behaviour thus is dependent upon information. However, an organism is not capable of interacting profitably with all of the features of its environment, only some of them; hence not every state of affairs is information for that organism. Differentiation among states of affairs involves the comparison of what is happening now relative to what was happening at some moment in the past; this requires memory. Based on its evolutionary and interactive history and current needs, an organism responds to different states of affairs according to an internal projection of value—attractive, aversive or neutral salience—relative to its own persistence or wellbeing.

Finally, organisms are operationally closed, as well as open to flows of matter and energy. The activities that produce and maintain an organism take place within a semi-permeable boundary, which is the basis of its autonomy. As operationally closed (bounded) entities, organisms differentiate states of affairs that are permissible or belong within the boundary (self) from other phenomena (non-self). Although past events affect their adaptive behaviour, organisms are intrinsically oriented toward what happens next.

There are several things to notice about these constraints. First is that the options for theorizing remain wide open. Not as open across the material spectrum as computational functionalism would allow, perhaps, but more open along the biological spectrum than cognitivism typically admits. There is no *a priori* reason why data relating to, say, the learning and memory of the fruit fly *Drosophila melanogaster* has no bearing on an understanding of the biological function of learning and memory in humans, for example. Neither does a biogenic approach require that such data be taken into account. Remember, the biogenic approach is a methodological starting point, not a detailed prescription for conducting cognitive science, nor a prediction of what the results will be. However, a biogenic approach licenses the use of simple model systems of the sort that have been responsible for so much progress in the rest of the life sciences, without demanding tortuous explanations of why they might be useful, as is typically the case with an anthropogenic approach.

The second thing to notice about a biogenic approach is that it provides a wider range of properties and/or criteria for delineating the cognitive domain, such as the capacity to differentiate among and differentially value states of affairs within a context. Whereas cognitivism focused on rational problem solving as against emotion and feeling—which reflected the traditional 'trilogy of the mind' (Hilgard, 1980)—the biogenic principles do not provide *prima facie* justification for carving psychological nature at these particular joints. Indeed, they suggest what empirical evidence more than amply demonstrates: that the classic trilogy of cognition, emotion and motivation are principally heuristic, and at the level of physiology are more or less fictional (Lazarus, 1990).

The third thing to notice is that a biogenic approach allows a fundamental starting point for articulating what a minimal form of cognition might look like, more about which in a moment. It might seem that aligning the investigation of cognition so closely with that of the conditions of biological existence would lead to a potentially unproductive blurring of vital and cognitive processes. Indeed there are some biogenic approaches that emphatically claim that all life is cognition (Maturana & Varela, 1980; Stewart, 1996), or vice versa. This blurring can be avoided, however. The fundament of autopoiesis lies with self-producing metabolic interactions within a semi-permeable boundary. In addition there are systematic interactions between the autopoietic organization itself and its environment. These interactions can take many forms, some of which go beyond the fundamental level of molecular and energy exchanges. One important form can be described as sensorimotor coordination or basic behaviour. Basic behaviour is the sort that humans have in common with all animals, apes and insects alike (Keijzer, 2001). Examples include moving about over natural surfaces, using sensory stimulation to initiate, guide and terminate action, and performing behavioural sequences. Basic behaviour derives from the use of movements locked in step with sensory feedback resulting from these movements. The resulting sensorimotor couplings can modify environmental conditions in ways that enhance, overall, an organism's metabolic and reproductive success. For example, basic behaviour brings organisms into proximity with nutritive substances, lets them ingest these, enables the avoidance of predators, finding and courting mates, and so on.

We want to stress that basic behaviour is not defined in terms of these functional regularities, a strong tendency within behaviourism (Keijzer, 2005). Similar functionality is produced by very different means in organisms with varying body forms. Basic behaviour builds on a specific body structure—involving specific movement and sensing capabilities—as well as a dynamical structure provided by the sensorimotor couplings in which the organism takes part. The specifics of these sensorimotor couplings have their own information-processing characteristics influencing whole-system behaviour (Lungarella & Sporns, 2006). The focus on detailed morphological and sensorimotor organization makes basic behaviour a congenial domain for the investigation of minimal forms of cognitive phenomena in a way that is markedly different from sophisticated contemporary versions of behaviourism (Keijzer, 2005).

The structural organization of basic behaviour can already be differentiated from that of more fundamental metabolic processes in bacteria. The signal transduction pathways that underlie chemotaxis, movement toward or away from a feature of the environment, can be clearly differentiated from molecular pathways that underlie nutrient metabolism, although the two functions (chemotaxis, nutrient metabolism) are clearly structurally linked and both are subject, under stress conditions, to global regulatory control (Van Duijn *et al.*, 2006). Thus sensorimotor coordination sub-serves metabolism and reproduction, but is itself a different kind of process, which is played out at the global scale of a whole organism.

The recourse to a bacterial example is not facetious. Although typically regarded in the cognitive scientific literature as automata, bacteria display behaviour that is far more flexible, complex and adaptive—not merely adapted—than commonly believed (Lyon, 2006b, submitted).[7] Bacteria have memory, select actions based on the integration of multiple environmental cues sampled over time, amplify faint chemical signals by several orders of magnitude, 'tune' signal-to-noise ratios of their sensory perceptions, gain new behavioural competences to cope with changing environmental conditions via the acquisition of foreign DNA (including sex), and communicate with one another to effect complex behaviour, enabling populations to function as multicellular individuals. Some of the mechanisms that underlie these capacities in bacteria are also used in mammals, including humans. For example, the two-component signal transduction mechanism of bacterial chemotaxis involves a sensor and a response regulator that relies on the addition and subsequent removal of chemical moieties (e.g., phosphorylation, methylation). This mechanism is the basis of signal transduction within (not between) neurons, for example, in relation to neurotransmitters and neuromodulators such as serotonin and dopamine. Bacterial sensory perception is also subject to habituation and amplification, which are basic to the operation of human perception.

Casting basic behaviour and sensorimotor coordination as minimal forms of cognition provides a principled starting point for answering question concerning what cognition is. Moreover, it is a starting point that is organizationally separable from fundamental metabolic processes that constitute the heart of living organization (Van Duijn *et al.*, 2006). Sensorimotor coordination sub-serves metabolism but is itself a different kind of process played out at a larger scale of whole organisms acting as a unity on its environment by physical displacements of this unity with respect to the environment. In other words, the key point is the switch from molecular interactions to whole organism motility. This issue is especially important as it dissociates cognition from any intrinsic connection with nervous systems. Sensorimotor coordination is essential, whether or not it involves a nervous system. The whole organism may be large with respect to metabolic processes, but as in the case of bacteria can still remain extremely small compared to us.

Sensorimotor coordination and basic behaviour also provide a principled starting point for explaining what features—behavioural, cognitive and experiential—the evolution of nervous systems add to this minimal set-up. Nevertheless, being a *nervous*

---

[7] See these two sources for a detailed treatment of and evidentiary support for these claims.

system is not necessarily what makes it special, but how it operates within a particular sensorimotor organization. Of course, the above is at present primarily the sketch of an option, but at the very least it gives an indication how a biogenic approach can turn into a very concrete project aimed at answering fundamental questions, such as what cognition is and what cognition does.

In sum, a biogenic approach provides a principled, specifically empirical rationale for taking sensorimotor coordination as a starting point for investigating the fundamental issues relating to cognition, but it also suggests that the historically necessary connection of cognition with a nervous system is less motivated than once it was, and thus may require justification in a way it previously did not.

Squinting against the Intentional Glare

Although the shape of second-generation cognitive science is coming into focus, we have argued that simply taking an embodied, embedded and situated approach will not be enough to eradicate the distorting residue of cognitivism's human stain. By acknowledging that the only cognitive mechanisms about which we are certain are those that have evolved in biological systems constantly engaged in body-world interactions, embodied cognition exhorts us to take prevailing biological knowledge and evolutionary theory seriously. But biology can be taken seriously in all sorts of ways. One need not *begin* with the principles of biology to ensure at a minimum that one's theory of mind does not *contravene* those principles. Whereas a biogenic approach to cognition is intrinsically embodied, an embodied approach need not be biogenic. Assuming that beliefs and desires are the *sine qua non* of cognition and then building a plausible biological case for how they function in the economy of an animal, and how they might have evolved, may be a thoroughly embodied approach, but it is not biogenic. Beliefs and desires derive their privileged status in cognitive science from folk psychology, and 'the folk' are necessarily human. It is quite another thing to derive a picture of what cognition is and what it does from the principles of biology and then see how beliefs and desires (such as we experience them) arise from that matrix.

The divergent concerns that flow from the usually tacit, possibly unconscious choice about starting points make addressing basic issues of discipline-related ontology in the cognitive sciences especially troublesome, in our view. But addressed they must be, if there is any hope of drawing together the disparate empirical strands of inquiry in the myriad disciplines concerned with cognition. The business of addressing these basic issues is complicated, not helped, by keeping one eye on the human case, as cognitivism has, not least because it licenses appeals to personal, culturally conditioned 'intuitions' in ways that are unsupportable in other natural sciences. What the natural sciences have generally taught us is that our untutored intuitions are almost always false. The world is not flat, the sun does not revolve around the earth, solid objects are mostly space, and the diverse kingdoms of life are vastly more similar than ordinary observation would suggest. To provide a credible answer to the basic ontological questions—what is cognition and what does it do—the cognitive sciences will have to become fully natural, not simply naturalized, sciences. Their best hope, we believe, is taking far more seriously than they have to date the over-arching knowledge enterprise in which they are embedded, the science of life.

References

Aristotle (2001), 'De Anima', in ed. R. McKeon, *The Basic Works of Aristotle* (New York: Modern Library Classics/Random House).

Austin, J.H. (2000), *Zen and the Brain: Toward and Understanding of Meditation and Consciousness* (Cambridge, MA: MIT Press).

Auyang, S.Y. (2000), *Mind in Everyday Life and Cognitive Science* (Cambridge, MA: MIT Press).

Bassler, B. and Losick, R. (2006), 'Bacterially speaking', *Cell*, 125(2), pp. 237–246.

Bateson, G. (1979), *Mind and Nature: A Necessary Unity* (New York: E.P. Dutton).

Bechtel, W., Abrahamsen, A. and Graham, G. (1998), 'The life of cognitive science', in ed. W. Bechtel and G. Graham, *A Companion to Cognitive Science* (Malden, MA and Oxford: Blackwell Publishers Ltd.), pp. 1–104.

Beer, R.D. (1990), *Intelligence as Adaptive Behavior: An Experiments in Computational Neuroethology* (San Diego: Academic Press).

Bennett, M.R. and Hacker, P.M.S. (2003), *Philosophical Foundations of Neuroscience* (Oxford: Blackwell Publishing).

Bickhard, M.H. (2001), 'Why children don't have to solve the frame problems: cognitive representations are not encodings', *Developmental Review*, 21, pp. 224–262.

Bindra, D. (1984), 'Cognition: its orgin and future in psychology', in ed. J.R. Royce and L.P. Mos, *Annals of Theoretical Psychology, Vol. 1* (New York: Plenum Press), pp. 1–29.

Bloom, P. (2004), *Descartes' Baby: How the Science of Child Development Explains What Makes Us Human* (New York: Basic Books).

Blumenthal, A.L. (1980), 'Wilhelm Wundt and early American psychology: a clash of cultures', in ed. R.W. Rieber and K. Salzinger, *Psychology: Theoretical-Historical Perspectives* (New York: Academic Press), pp. 25–42.

Boden, M.A. (2006), *Mind as Machine: A History of Cognitive Science* (Oxford: Oxford University Press).

Brooks, R. (1991), 'Intelligence without representation', *Artificial Intelligence*, 47(1-3), pp. 139–159.

Campbell, D.T. (1974), 'Evolutionary epistemology', in ed. P.A. Schlipp, *The Philosophy of Karl Popper, Vol. 1* (La Salle, Ill.: Open Court), pp. 413-463.

Charles, D. (1995), 'Aristotle', in ed. T. Honderich, *The Oxford Companion to Philosophy* (Oxford: Oxford University Press), pp. 53–57.

Chomsky, N. (1997), 'Language and cognition', in ed. D.M. Johnson and C.E. Erneling, *The Future of the Cognitive Revolution* (Oxford: Oxford University Press), pp. 15–31.

Chomsky, N. (2000), 'Naturalism and dualism in the study of language and mind', in ed. N. Chomsky, *New Horizons in the Study of Language and Mind* (Cambridge and New York: Cambridge University Press).

Churchland, P.M. (2005), 'Functionalism at forty: a critical retrospective', *Journal of Philosophy*, CII,(1), pp. 33-50.

Clark, A. (1997), *Being There: Putting Brain, body and World Back Together Again* (Cambridge, MA: MIT Press).

Cliff, D. and Noble, J. (1997), 'Knowledge-based vision and simple visual machines', *Philosophical Transactions: Biological Sciences (Royal Society of London)*, 352, pp. 1165–1175.

Copeland, B.J. (1996), 'What is computation?', *Synthese*, 108(3), pp. 335–359.

Crane, T. (1998), 'Intentionality: history of the concept of intentionality', in ed. E. Craig, *Routledge Encyclopedia of Philosophy* (London: Routledge), retrieved 28 November 2005, from http://www.rep.routledge.com.virtual.anu.edu.au/article/V019SECT1.

De Waal, F.B.M. (2001), *The Ape and the Sushi Master: Cultural Reflections by a Primatologist* (London: Allen Lane).

De Waal, F.B.M. (2002), 'Evolutionary psychology: the wheat from the chaff', *Current Directions in Psychological Science*, 11(6), pp. 187–191.

Deacon, T.W. (1997), *The Symbolic Species: The Co-Evolution of Language and the Brain* (New York: W.W. Norton & Company).

Dennett, D.C. (1987), *The Intentional Stance* (Cambridge, MA: MIT Press).

Dennett, D.C. (1994), 'Daniel C. Dennett', in ed. S. Guttenplan, *A Companion to the Philosophy of Mind* (Oxford: Basil Blackwell Ltd).

Descartes, R. (1641/1986), *Meditations on First Philosophy* (Cambridge: Cambridge University Press).

Dretske, F. (1981), *Knowledge and the Flow of Information* (Cambridge, MA: MIT Press).

Dreyfus, H.L. (1972), *What Computers Can't Do: A Critique of Artificial Reason* (New York: Harper & Row).

Dupuy, J-P. (2000), *The Mechanization of the Mind: On the Origins of Cognitive Science* (Princeton, N.J.: Princeton University Press).

Earle, J. (1881), 'The history of the word "mind"', *Mind*, 6(23), pp. 301–320.

Eliasmith, C. (2002), 'The myth of the Turing machine: the failings of functionalism and related theses', *Journal of Experimental and Theoretical Artificial Intelligence*, 14, pp. 1–8.

Fehr, E.S. (1991), 'Mind and body: an apparent perceptual error', *Journal of Mind and Behavior*, 12(3), pp. 393–406.

Fodor, J.A. (1975), *The Language of Thought* (New York: Thomas Y. Crowell).

Fodor, J.A. (1998), *In Critical Condition: Polemical Essays on Cognitive Science and the Philosophy of Mind* (Cambridge, MA: MIT Press).

Fodor, J.A. (2000), *The Mind Doesn't Work That Way: The Scope and Limits of Computational Psychology* (Cambridge, MA: MIT Press).

Fodor, J.A. (2005), 'Reply to Steven Pinker: So how *does* the mind work?', *Mind and Language*, 20(1), pp. 25–32.

Frede, M. (1992), 'On Aristotle's conception of the soul', in ed. M.C. Nussbaum and A.O. Rorty, *Essays on Aristotle's* De Anima (Oxford: Clarendon Press), pp. 93–107.

Freeman, W.J. and Nuñez, R. (1999), 'Restoring to cognition the forgotten primacy of action, intention and emotion', in ed. W.J. Freeman and R. Nuñez, *Reclaiming Cognition: The Primacy of Action, Intention and Emotion* (Thorverton: Imprint Academic), pp. ix–xix.

French, R.M. (2000), 'The Turing Test: the first 50 years', *Trends in Cognitive Sciences*, 4(3), pp. 115–122.

Gallese, V. and Lakoff, G. (2005), 'The brain's concepts: the role of the sensory-motor system in conceptual knowledge', *Cognitive Neuropsychology*, 22(3/4), pp. 455–479.

Gardner, H. (1985), *The Mind's New Science: A History of the Cognitive Revolution* (New York: Basic Books).

Gibson, J.J. (1979), *The Ecological Approach to Visual Perception* (Dallas: Houghton Mifflin).

Godfrey-Smith, P. (1996), *Complexity and the Function of Mind in Nature* (Cambridge: Cambridge University Press).

Goodson, F.E. (2003), *The Evolution and Function of Cognition* (Mahwah, NJ: Lawrence Erlbaum Associates).

Green, D.C. (1996), 'Where did the word 'cognitive' come from anyway?', *Canadian Psychology*, 37, pp. 31–39.

Green, D.C. (2000), 'Is AI the right method for cognitive science?', *Psycholoquy*, **11**(061), pp. 1-7.

Hacker, P.M.S. (2006), 'Passing by the naturalistic turn on Quine's cul-de-sac', *Philosophy*, 81(2), pp. 231–253.

Harnad, S. (2005), 'To cognize is to categorize: Cognition is categorization', in ed. C. Cohen and C. LeFebvre, *Handbook of Categorization in Cognitive Science* (Amsterdam: Elsevier Science).

Hartley, T.A. (2004), 'Does cognitive neuropsychology have a future?', *Cognitive Neuropsychology*, 21(1), pp. 3–16.

Haselager, P., de Groot, A. and van Rappard, H. (2003), 'Representationalism vs. anti-representationalism: a debate for the sake of appearance', *Philosophical Psychology*, 16(1), pp. 5–23.

Hilgard, E.R. (1980), 'The trilogy of mind: cognition, affection, and conation', *Journal of the History of the Behavioral Sciences*, 16, pp. 107–116.

Hodos, W. and Campbell, C.B.G. (1969/1996), '*Scala Naturae*: why there is not theory in comparative psychology', in ed. L.D. Houck and L.C. Drickamer, *Foundations of Animal Behavior: Classic Papers with Commentaries* (Chicago: University of Chicago Press), pp. 246–259.

James, W. (1890/1950), *The Principles of Psychology, Vol. 1* (New York: Dover Publications Inc.).

Jennings, H.S. (1906/1962), *Behavior of the Lower Organisms* (Bloomington: Indiana University Press).

Johnson, D.M. and Erneling, C.E. (1997), *The Future of the Cognitive Revolution* (New York and Oxford: Oxford University Press).

Keely, B.L. (2004), 'Anthropomorphism, primatomorphism, mammalomorphism: Understanding cross-species comparisons', *Biology and Philosophy*, 19(4), pp. 489–520.

Keijzer, F.A. (2001), *Representation and Behavior* (Cambridge, MA: MIT Press).

Keijzer, F.A. (2005), 'Theoretical behaviorism meets embodied cognition: Two theoretical analyses of behavior', *Philosophical psychology*, 18(1), pp. 123–143.

Kennedy, J.S. (1992), *The New Anthropomorphism* (Cambridge: Cambridge University Press).

Lazarus, R.S. (1990), 'Constructs of the mind in adaptation', in eds. N. Stein, B. Leventhal and T. Trabasso, *Psychological and Biological Approaches to Emotion* (Hillsdale, N.J.: Lawrence Erlbaum Publishers), pp. 3–19.

Lennox, J.G. (2001), *Aristotle's Philosophy of Biology: Studies in the Origins of Life Science* (Cambridge: Cambridge University Press).

Lungarella, M. and Sporns, O. (2006). 'Mapping information flow in sensorimotor networks', *PloS Computational Biology*, 2(10), pp. 1301–1312.

Lyon, P. (2004), 'Autopoiesis and *knowing*: Maturana's biogenic explanation of cognition', *Cybernetics and Human Knowing*, 11(4), pp. 21–46.

Lyon, P. (2006a), 'The biogenic approach to cognition', *Cognitive Processing*, 7(1), pp. 11–29.

Lyon, P. (2006b), *The Agent in the Organism: Toward a Biogenic Theory of Cognition*, PhD thesis (Canberra: Australian National University).

Lyon, P. (submitted), 'The cognitive cell: bacterial behaviour revisited', *Biology & Philosophy*.

Maturana, H.R. (1970), 'The biology of cognition', in ed. H.R. Maturana and F.J. Varela, *Autopoiesis and Cognition: The Realization of the Living* (Dordrecht: D. Reidel Publishing Company).

Maturana, H.R. and Varela, F.J. (1980), *Autopoiesis and Cognition: The Realization of the Living* (Dordrecht: D. Reidel Publishing Company).

Moreno, A., Umerez, J. and Ibañez, J. (1997), 'Cognition and life: the autonomy of cognition', *Brain and Cognition*, 34(1), pp. 107–129.

Neisser, U. (1976), *Cognition and Reality: Principles and Implications of Cognitive Psychology* (San Francisco: W.H. Freeman and Company).

Nussbaum, M.C. and Putnam, H. (1992), 'Changing Aristotle's mind', in ed. M.C. Nussbaum and A.O. Rorty, *Essays on Aristotle's* De Anima (Oxford: Clarendon Press), pp. 27–56.

Ochman, H. and Moran, N.A. (2001), 'Genes lost and genes found; evolution of bacterial pathogenesis and symbiosis', *Science*, 292, pp. 1096–1098.

Putnam, H. (1975), *Mind, Language, and Reality: Philosophical Papers, Vol. 2* (Cambridge: Cambridge University Press).

Putnam, H. (1997), 'Functionalism: cognitive science or science fiction?', in ed. D.M. Johnson and C.E. Erneling, *The Future of the Cognitive Revolution* (Oxford: Oxford University Press), pp. 32-44.

Ragan, M.A. (2001), 'Detection of lateral gene transfer among microbial genomes', *Current Opinion in Genetics and Development*, 11(6), pp. 620–626.

Rock, I. (1983), *The Logic of Perception* (Cambridge, MA: MIT Press).

Rosch, E. (1999), 'Reclaiming concepts, in ed. W.J. Freeman and R. Nuñez, *Reclaiming Cognition: The Primacy of Action, Intention and Emotion* (Thorverton: Imprint Academic), pp. 61–78.

Rose, S. (1998), 'The rise of neurogenetic determinism', in ed. J. Cornwell, *Consciousness and Human Identity* (Oxford: Oxford University Press), pp. 86–100.

Rosenzweig, M.R., Leiman, A.L. and Breedlove, S.M. (1996), *Biological Psychology* (Sunderland, MA: Sinauer Associates Inc.).

Shannon, C.E. and Weaver, W. (1949), *The Mathematical Theory of Communication* (Urbana: University of Illinois Press).

Shapiro, L.A. (2004), *The Mind Incarnate* (Cambridge, MA: MIT Press).

Shettleworth, S.J. (1993), 'Where is the comparison in comparative cognition —alternative research programs', *Psychological Science*, 4(3), pp. 179–184.

Shettleworth, S.J. (1998), *Cognition, Evolution and Behavior* (New York and Oxford: Oxford University Press).

Silver, B.L. (1998), *The Ascent of Science* (New York and Oxford: Oxford University Press).

Sloman, A. (2002), 'The irrelevance of Turing machines to artificial intelligence', in ed. M. Scheutz, *Computationalism: New Directions* (Cambridge, MA: MIT Press).

Sorley, W.R. (1926), 'Fifty years of *Mind*', *Mind*, 35(140), pp. 409–418.

Staats, A. (1983), *Psychology's Crisis of Disunity: Philosophy and Method for a Unified Science* (New York: Praeger Press).

Staats, A. (1999), 'Unifying psychology requires new infrastructure, theory, method, and a research agenda', *Review of General Psychology*, 3(1), pp. 3–13.

Stein, N., Leventhal, B. and Trabasso, T. (1990), *Psychological and Biological Approaches to Emotion* (Hillsdale, N.J.: Lawrence Erlbaum Publishers).

Sternberg, R.J. and Grigorenko, E.L. (2001), 'Unified psychology', *American Psychologist*, 56(12), pp. 1069–1079.

Stewart, J. (1996), 'Cognition=life: implications for higher-level cognition', *Behavioural Processes*, 35(1–3), pp. 311–326.

Sutton, J. (1998), *Philosophy and Memory Traces: Descartes to Connectionism* (Cambridge: Cambridge University Press).

Toulmin, S. (1972), *Human Understanding, Vol. 1, General Introduction and Part I, The Collective Use and Evolution of Concepts* (Oxford: Clarendon Press).

Toulmin, S. (1998), *Cognition, Evolution and Behavior* (New York and Oxford: Oxford University Press).

Turing, A.M. (1950), 'Computing machinery and intelligence', *Mind*, 59(236), pp. 433–460.

Turing, A.M. (1936), 'On computable numbers, with an application to the *Entscheidungsproblem*', *Proceedings of the London Mathematical Society*, 42(2), pp. 230–265

Van Duijn, M., Keijzer, F.A.. & Franken, D. (2006), Principles of minimal cognition: Casting cognition as sensorimotor coordination. *Adaptive Behavior*, 14(2), pp. 157–170.

Van Gelder, T. (1995), 'What might cognition be, if not computation?', *Journal of Philosophy*, XCI(7), pp. 345–381.

Varela, F.J., Thompson, E. and Rosch, E. (1991), *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press).

Vertosick, F.T. (2002), *The Genius Within: Discovering the Intelligence of Every Living Thing* (New York: Harcourt, Inc.).

Wade, N. (1995), *Psychologists in Word and Image* (Cambridge, MA: MIT Press).

Washburn, M.F. (1936), *The Animal Mind: A Text-Book of Comparative Psychology* (New York: MacMillan Company).

Watson, R.I. (1978), *The Great Psychologists* (Philadelphia: J.B. Lippincott).

Weinreich, D.M., Delaney, N.F., DePristo, M.A. and Hartl, D.L. (2006), 'Darwinian evolution can follow only very few mutational paths to fitter proteins', *Science*, 312, pp. 111–114.

Wellman, H.M. (1990), *The Child's Theory of Mind* (Cambridge, MA: MIT Press).

Wheeler, M. (2005), *Reconstructing the Cognitive World: The Next Step* (Cambridge, MA: MIT Press).

Wierzbicka, A. (1996), *Semantics: Primes and Universals* (Oxford: Oxford University Press).

Winograd, T. and Flores, F. (1986), *Understanding Computers and Cognition: A New Foundation for Design* (Norwood, NJ: 1Ablex Publishing Corporation).

Zachar, P. (2000), *Psychological Concepts and Biological Psychiatry: A Philosophical Analysis* (Philadelphia: John Benjamins Publishing).