Controversies surrounding evolutionary psychology

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Boy, this shit ticks me off. Anthropologist Jonathan Marks commenting on evolutionary psychology[1]

Galileo thought sunspots, recently discovered by him and others, might be clouds of some sort near the sun's surface. This clever idea was wrong, but it contained a deeper, radical truth: The physical laws governing the earth and the heavens are the same. Unifying seemingly incommensurable realms—heaven and earth, man and animal, space and time—within a single explanatory framework, as Galileo, Newton, Darwin, and Einstein did, often sparks revolutions that utterly transform science. The invention of the computer by Von Neumann, Turing, and others was such a revolution. By showing that a physical system could 'think', this invention unified mind and matter, demolishing Cartesian dualism and spawning the cognitive revolution that continues to roil the human behavioral sciences.

Evolutionary psychology (EP), following Darwin, envisions a much deeper unification of mind and body however, than that achieved by the cognitive revolution. Pervading modern computational theories of cognition is a largely unrecognized ontological dualism. Although the origins and nature of brain structures are widely assumed to be explicable by physical laws, they are implicitly assumed to have little, if any, relationship to the origins and nature of structures in the rest of the body. To provide just a few examples, the brain is variously viewed as hardware that runs culturally provided software, as one or more neural networks, as a Bayesian inference machine, as a semantic net, or as a hologram. Whether or not any of these models of the brain are correct, and many are certainly important and useful, none draw upon the model that has had well over three centuries of almost unparalleled scientific success: the Western scientific model of the body as a set of tightly integrated but distinct mechanisms that function to enable and facilitate the survival and reproduction of the individual organism.

If we learned of a mysterious new structure in the body, we might reasonably assume that it, like the heart, lungs, liver, kidneys, bones, muscles, blood cells, intestines, uterus, testicles, and ovaries performed one or more as yet unidentified functions intimately related to an individual's survival or reproduction. We would base this assumption not on evolutionary theory, but simply on the overwhelming empirical evidence that this is what all other tissues and organs do. When we then learned that this organ was responsible for a number of functions like vision, olfaction, and motor control that had clear utility for survival and reproduction, our assumption would seem reasonable indeed. When we further learned that this organ, though constituting only 2% of the body's mass, consumed 20% of its energy, and that substantial damage to this organ usually resulted in the immediate death of the organism, we would rightly conclude that the functions of this organ must be critical to the survival, and thus reproduction, of the individual. We would then seem to be on extremely solid ground if we proposed exploring the properties of this organ as a set of mechanisms designed to do just that. Indeed, given what we know about the organization of the rest of the human body, and given what we already know about some of the mysterious organ's functions, one should find this proposal almost banal.

EP, of course, has proposed exactly this for our mysterious organ, the brain. Far from being met with bored nods of agreement, however, EP has been met with often scathing criticisms. I will revisit five of the still smoldering controversies over EP and its sister discipline sociobiology: selfish genes, the environment of evolutionary adaptedness (EEA), nature vs. nurture, massive modularity, and EP's politically incorrect claims. I will show that almost all scientific criticisms of these five seemingly unrelated controversies derive, not from a mind-

[1] Presentation at the 99th Annual Meeting of the American Anthropological Association San Francisco 15 November 2000 (http://www.uncc.edu/jmarks/interests/AAA00discussionevpsych.pdf).

matter dualism, but from a genuine mind-*body* dualism, a dualism EP rejects. EP proposes that the brain was shaped by the same process and to the same end as the rest of the body.

Selfish Genes, Selfish People?

Origin of the metaphor

The controversies swirling around EP are often tightly bound up with Richard Dawkins' metaphor, the *selfish gene* (Dawkins 1976). If our genes are selfish, aren't we too, deep down, unalterably selfish? This metaphor is so powerful that it has often overshadowed what is was meant to represent: the modern synthesis of Darwin and Wallace's natural selection, Mendel's particulate inheritance, and Watson and Crick's DNA.

The seeds of the selfish gene metaphor are present in Darwin's pre-genetic formulation of natural selection. Ruffed grouse, North American game birds that live in wooded habitats, are frequently preyed upon by hawks, owls, foxes, and bobcats. Ruffed grouse with camouflage feathers that better conceal the grouse will be eaten less often, and so reproduce more than grouse lacking camouflage feathers. If this trait is heritable, after many generations all ruffed grouse will have the camouflage feathers. One could say that the camouflage feathers 'out competed' the original feathers. Because the 'success' of the camouflage feathers came at the 'expense' of the original feathers, one might call the camouflage feathers 'selfish'. Note that it is the feathers which are 'competing' and 'selfish', not the birds themselves. The result of 'competing' variants of feathers with different colorations is that ruffed grouse gradually evolve better protection from predators in their woodland habitat. The metaphor of 'selfish' heritable traits 'competing' with each other is simply a restatement of the theory of natural selection.

We now know that gene variations (termed *alleles*) account for the heritable variation of traits like feather coloration. What for Darwin and Wallace was the differential reproduction of organisms possessing different, heritable traits is for modern evolutionary biologists the differential reproduction of alleles for those traits. In a population of a fixed size, the increase in the frequency of an allele for superior feather coloration must correspond to a decrease in the frequencies of the alleles for inferior feather colorations. Dawkins, highlighting this iron-clad logic, termed these gene variants 'selfish'. Selfish genes are just a metaphor for the modern version of natural selection based on changes in the frequency of the genes that were unknown to Darwin.[2] The *selfish gene* metaphor has lead to a number of very important insights in biology.

Though Dawkins' books discuss it at length, what the metaphor itself fails to convey is Darwin's original, enormously important insight: natural selection produces well-engineered structures called *adaptations* that effectively and efficiently solve the numerous reproductive problems posed by the environment. Adaptations, not genes, are the unit of analysis in EP, an essential point that frequently confuses critics. When they do manage to focus on adaptations, critics disparage the concept: adaptations are difficult if not impossible to identify; they are vastly outnumbered by traits which are simply incidental byproducts of, e.g., a large brain (and therefore EP's search for adaptations is bound to fail); or, being a product of selfish genes, adaptations must, in some sense, be inherently selfish (and since humans are not unvaryingly selfish, EP is bankrupt). It is easy to show that none of these criticisms applies to the body and

[2] Most genes have an equal probability of transmission, but a few genes have enhanced their own transmission relative to the rest of the genome (e.g., transposable elements, B-chromosomes and meiotic drive genes). In contrast to the definition of the term 'selfish' here, which I think most closely reflects Dawkins, modern usage often restricts the term 'selfish' to these latter types of genes.

therefore, if body-brain dualism is rejected, none applies the brain.

Natural engineering

The careful study of [Paley's] works...was the only part of the Academical Course which, as I then felt and as I still believe, was of the least use to me in the education of my mind. Charles Darwin, Autobiography.

In order to claim that there is a psychological adaptation for, e.g., cheater-detection (Cosmides 1984), many critics believe that one must find a cheater-detection gene (Berwick 1998; Orr 2003). Absent evidence for such a gene, these critics scoff at the idea that such an adaptation might have been identified. Evolutionary psychologists rarely seek genetic data, however, a fact that critics often see as EP's fatal flaw. To see why the critics are confused, we turn first to the Christian philosopher William Paley. Paley's *Natural Theology*, written at the dawn of the 19th century, clearly identified one of the major scientific problems that Darwin and Wallace eventually solved: the manifestation in nature of *design*. Although Paley did not conceive of the problem as a scientific problem but instead as a theological problem, his clear and incisive arguments, synthesizing a long tradition in natural theology, nonetheless form the very foundations of EP.

Paley first emphasized that, in contrast to the non-living world, living things are characterized by mechanisms designed to accomplish specific purposes:

> CONTEMPLATING *an animal body* in its collective capacity, we cannot forget to notice, what a number of instruments are brought together, and often within how small a compass. It is a cluster of contrivances. In a canary bird, for instance, and in the single ounce of matter which composes his body (but which seems to be all employed), we have instruments for eating, for digesting, for nourishment, for breathing, for generation, for running, for flying, for seeing, for hearing, for smelling; each appropriate,—each entirely different from all the rest. (Paley 1809, p. 185)

Paley then emphasized that organismic mechanisms are only comprehensible in relation to the environments in which they must function. Organisms are engineered for their particular environments:

> In the eel, which has to work its head through sand and gravel, the roughest and harshest substances, there is placed before the eye, and at some distance from it, a transparent, horny, convex case or covering, which, without obstructing the sight, defends the organ. To such an animal, could any thing be more wanted, or more useful?
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> [T]he bodies of animals hold, in their constitution and properties, a close and important relation to natures altogether external to their own; to inanimate substances, and to the specific qualities of these, e. g. *they hold a strict relation to the* ELEMENTS *by which they are surrounded.*
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> Can it be doubted, whether the *wings of birds* bear a relation to air, and the *fins of fish* to water? (Ibid, p. 291)

Adaptations, the functional components of organisms, are identified not by identifying their underlying genes, but by identifying evidence of their design: the exquisite match between organism structure and environmental challenge so eloquently described by Paley. For Paley, the designer of the canary bird and every other intricate branch of the tree of life, was God. For Darwin and modern science, it was natural selection.

Thousands of adaptations have been identified. Every bone, organ, tissue, cell-type, and protein is a specialized structure that evolved by natural selection and whose function has been, or will be, elucidated by analyzing the relationship between the trait's structure and its effects on the organism's survival and reproduction in a particular environment. Because almost all genes in the genome cooperate to build the organism they depend on for their mutual reproduction, scientists can, for the most part, avoid the currently intractable problem of the precise relationship between genes and complex adaptations and instead focus on the eminently tractable problem of the reproductive functions of the body, including the brain. They can confidently address the functions of hearts, lungs, blood, and uteruses using evidence of design without knowing anything about the genes that code for these organs. Similarly, we can address the functions of the brain without knowing anything about the genes that underlie these functions. Who can doubt that vision, hearing, smell, and pain—phenomena that rely critically on the brain—served crucial functions that facilitated the reproduction of the organism over evolutionary time?

If Darwin had known about genes, he would have been able to (among other things) modify the definition of adaptation to include functions that promoted the reproduction not only of the organism, but also of relatives of the organism (since they are likely to share some of the organism's genes). This modification allows evolutionary researchers to analyze an extremely large set of adaptations without ever having to refer to specific genes.

Despite the tremendous success of the functional, mechanistic approach in anatomy,[3] it is sobering to recognize that almost all progress has been made with no explicit recourse to (and virtual ignorance of) evolutionary theory. The simple presumption that body structures serve survival or reproduction has provided the foundation for the stunning advances in understanding body functions over the past several centuries. Evolutionary theory would seem to be superfluous for understanding body—and therefore brain—functions. We shall soon see why it isn't.

Spandrels

Gould and Lewontin (1979) observed that because many organism 'traits' are not adaptations but simply incidental byproducts of other structures, byproducts they termed *spandrels*,[4] organism traits might erroneously be identified as adaptations. If spandrels and adaptations were difficult or impossible to distinguish, this would undermine claims that true adaptations have been found. Gould and Lewontin were apparently unaware that George Williams (1966) had already both discussed this problem in depth and provided its solution: adaptations will exhibit evidence of design.

Williams' criterion is critical. Without it, it is possible to assign *every* cell in the body to a spandrel. Consider this hypothetical scenario. A CAT scan produces a detailed 2D image of a cross-section of the body, like slicing open an orange and photographing the freshly revealed surface. By taking a large number of 2D scans of the body, one can build up a 3D view of the body's internal anatomy. Imagine that a team of scientists who know nothing of anatomy gets hold of a large number of CAT scans of an entire human body, revealing all its tissues in detailed cross-sectional images. Each scientist begins analyzing one of the 2D images, not realizing that the individual scans can be composited into a single, 3D model. The scientists develop sophisticated statistical representations of the patterns in their images, scribbling down elegant equations of the images' shapes and curves. The equations are a rigorous, factual description of

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[3] Because the word 'physiology' too closely resembles the word 'psychology', I will use the term 'anatomy' and its derivatives to refer to all body tissues and structures excluding the nervous system.

[4] The term comes from architecture: it describes the triangular space that is necessarily created when a dome is supported by arches, a space that can then be put to other uses.

the entire body, but a description that is empty. The patterns of tissues revealed by the CAT scans are, if considered alone, spandrels of the true, functional organization that the team has failed to recognize. Ask the wrong questions, and virtually all normal body tissues will be seen as spandrels. Ask the right questions, and most normal body tissues will be recognized as playing a vital, functional role in the survival and reproduction of the organism.

Gould warned of the “dangers and fallacies” (Gould 1997, p. 10750) of over-attributing adaptive functions to traits that might not be adaptations, but the real danger is to fail to consider functional hypotheses. Tonsils often become infected and therefore are (or were) frequently removed by surgery. Which scientific response do you prefer?: (1) Mock any suggestion that tonsils might serve an important function by loudly insisting that not all traits have adaptive functions; or (2) generate and test as many functional hypotheses as you can think of to make sure that by removing the tonsils no lasting harm is done to the patient?[5]

It seems strange that anyone could possibly fear what is in fact routine science with an outstanding record—proposing and testing functional hypotheses for organism structure. EP must recognize, however, that by rudely breaking into the cathedral of the mind, and spray-painting ‘sex’, ‘violence’, and ‘competition’ across what for many are the mind’s beloved spandrels, it is bound to stir up some controversy. Further, many spandrels are enormously important in their own right.[6]

By failing to recognize the evolved functional organization of the brain, however, psychology and the rest of the human behavioral sciences, like our team of misguided scientists, are condemned to study nothing but spandrels.

Do selfish genes create selfish people?

EP proposes that our thoughts, feelings, and behavior are the product of psychological adaptations. EP critics fear that if psychological adaptations are a product of selfish genes, then we must all be essentially selfish. Yet *every* adaptation in the body evolved by natural selection, that is, by selfish genes which ‘out-competed’ (replaced) alternative alleles at some point in the past. The genes coding for your hair gradually replaced less effective versions of those genes in the past, and are therefore ‘selfish’. Despite this, no one is worried that selfish genes have produced selfish hair. Critics only worry when a process widely accepted to have produced the body’s specialized structure is claimed to also have produced the brain’s specialized structure. But describing most psychological adaptations as selfish is as nonsensical as it is for hair. The genes for vision, memory, and muscle control are all ‘selfish', yet none of these psychological adaptations is usefully termed ‘selfish’.

There is a narrow but important set of psychological adaptations whose properties do correspond to our folk notion of selfishness. When critical resources like food or mates are limited, genes that code for fighting abilities can increase in frequency. Psychological adaptations for aggression correspond to folk notions of selfishness, but these adaptations evolved by the same process as every other adaptation. The underlying genes are no more ‘selfish’ than are the genes underlying any other adaptation. Ironically, anatomical adaptations, not psychological adaptations, provide the clearest evidence for the evolution of aggression. Large canines, antlers, and increased muscle and body mass all have evolved to injure

[5] Tonsils do serve an important immune function (e.g., van Kempen et al. 2000), but their removal has not been demonstrated to cause significant immune deficiency (e.g, Kaygusuz et al. 2003).

[6] Women’s capacity for orgasm, for example, could be a byproduct of a male adaptation for orgasm, just as male nipples are a byproduct of a female adaptation for nipples (Symons 1979).

competitors. Because these weapons would be worthless if there were not corresponding psychological adaptations enabling their effective use in combat, they constitute strong evidence that the same processes produce both anatomical and psychological adaptations, some of which are selfish in the folk sense, but most of which are not.

A final point: One of Dawkins' major arguments, and one of the major achievements of sociobiology, was that the modern version of natural selection predicts that the evolution of cooperation is likely to be widespread. Individuals in many species are likely to possess adaptations for both competition *and* cooperation, adaptations that are based on genes that are equally 'selfish'. Genes for cooperation 'out-competed' alternative alleles. Although many challenges remain (Hammerstein 2003), the evidence strongly bears out this prediction (e.g., Dugatkin 1997). And despite the claims of some, cooperative adaptations based on selfish genes are not, deep down, selfish any more than your hair is, deep down, selfish.

If my genes made me do it, am I still responsible?

Critics worry that the very idea that adaptations could produce bad behaviors will undermine law and order. But, if you tell the judge that your genes made you do it, she can tell you that her genes are making her throw you in jail. The sword cuts both ways. EP posits that each of us has an innate cognitive ability to uphold the law (e.g., Boyd and Richerson 2001) as well as break it. This is hardly a radical idea. Laws are designed to prevent people from doing things that they might construe as being in their interest but which would impose costs on everyone else. Yet smart people worry about EP's possible moral consequences. Despite his clever arguments to the contrary, Galileo's scientific evidence favoring the Copernican model of the solar system *was* a threat to the Church. If EP is correct, then despite its adherents' clever arguments to the contrary, it too might constitute a genuine threat to the contemporary moral order. EP cannot simply dismiss the critics' fears. More on this later.

Are there enough genes to build psychological adaptations?

Evolutionary psychology is dead but doesn't seem to know it yet. Biologist Paul Ehrlich[7]

Some critics of evolutionary psychology claim that there simply aren't enough genes to code for a large number of innate cognitive adaptations (Ehrlich and Feldman 2003). Curiously, they don't suggest that there aren't enough genes to build the thousands of anatomical adaptations that have already been discovered, they haven't suggested the theory of natural selection is wrong, nor have they called for an immediate halt to the billions of dollars of research aimed at furthering the functional understanding of cells, tissues and organs, research that, if the critics were right, would be useless given that there aren't enough genes to build all those adaptations.

Current estimates are that humans have 30,000-60,000 genes. If genes and adaptations corresponded in a one-to-one fashion, then, if it took an average of 100 genes to code for an adaptation, there could only be 300-600 adaptations, a number we have already long surpassed in our investigation of anatomy and physiology.

Adaptations, however, are not the simple product of genes. Rather, they are the product of gene *interactions*. Although the processes by which genetic information directs the development of cells, tissues, and organs are still largely unknown, it is well known that both genes and non-gene regions of DNA control the protein production of other genes, and that multiple proteins combine to produce an adaptation. These simple facts fundamentally alter the math. Imagine an

[7] Mark Shwartz, Stanford Report, April 4, 2001. *Genes don't control behavior, Ehrlich says, urging studies of cultural evolution.*

organism with four genes, A, B, C, and D. In the naïve view, where genes do not interact, this organism could have at most four adaptations, one coded for by each gene. But since genes do interact, this organism could have as many as fifteen adaptations—not only those produced by A, B, C, and D, but also those produced by all possible combinations of A, B, C, and D (AB, AC, AD, ABC, ABCD, BC, BD, etc.). For an organism with 'only' 30,000 genes, the number of possible gene combinations explodes. The total number of two-gene combinations, for example, is almost half a billion. To produce an adaptation, however, often many more than two genes interact. The total number of 25-gene combinations is around 10^{86} (in comparison, the universe probably contains around 10^{80} particles). An organism obviously need make use of only a minute fraction of such gene combinations to produce an incredibly rich, functionally organized phenotype with enormous numbers of adaptations.[8] Just as there are more than enough genes and gene combinations to produce thousands of anatomical and physiological adaptations, there are more than enough to produce hundreds or thousands of psychological adaptations.

The EEA

The pseudo-science of evolutionary psychology purports to explain human behaviors by reference to an ancestral environment…. Ian Tattersall (2001, p. 657)

The Environment of Evolutionary Adaptedness (EEA) refers to those aspects of the ancestral environment that were relevant to the evolution, development, and functioning of an organism's adaptations—roughly, the environment in which a species evolved and to which it is adapted. The term environment includes the organism, its physical environment, its social environment, and other species it interacts with. Because alleles were selected and went to fixation in the past, the EEA concept, first formulated by John Bowlby of attachment theory fame (Bowlby 1969) and incorporated into evolutionary psychology by Don Symons (1979), is an essential and logically necessary aspect of the theory of natural selection.

It is the EEA concept that gives EP its power. The content of EP is almost entirely to be found in the structure of the ancestral environment, the EEA. The EEA concept has nonetheless been a lightening rod for criticism. Many critics claim we can never know anything meaningful about it (e.g., Ahouse and Berwick 1998), others that we often don't need to know anything about it (e.g., Smith et al. 2000). What is it, do we need it, and can we know it?

Reproduction and the causal structure of the environment

In order for a new, heritable trait to have positive reproductive consequences, it must, well, *do* something. It must transform the organism or environment in a way that enhances the reproduction of the individuals possessing it. Reproduction is an enormously complex process in which the organism must successfully accomplish thousands of transformations of itself and its environment. Each aspect of the organism and environment which must be transformed can be transformed in countless ways, yet only a small subset of these transformations further the goal of reproduction, with most impeding or preventing it. Virtually all of the ways light striking the lens can be reflected and refracted, for example, will not focus the light on the retina. These transformations—these causal chains—must therefore be initiated by adaptations which have the special physical properties required to change things in just the right way. The shape of the lens is exactly that required to focus incident light onto the retina.

Both the things an organism must do to reproduce, as well as those things it could do to

[8] Some have claimed that gene interactions are themselves an impediment to the evolution of adaptations. Although this can be true over the short-term, it isn't over the long term (Hammerstein 1996).

enhance reproduction are called *selection pressures*, because they either have resulted, or could result, in selection for an adaptation. In order to increase in frequency, a new heritable trait must improve an organism's ability to effect a particular transformation of the environment, or it must provide an ability to effect a new transformation of the environment. In either case, it must initiate changes that propagate along causal chains, causal chains whose ultimate effects increase the number of offspring of individuals possessing the trait relative to those that do not.[9]

Crucially, these causal chains are not part of the trait itself. They constitute the essential environmental background, the EEA, of the trait. Many such causal chains propagate within the body of the organism, but many also detour far outside it. The feathers on the ruffed grouse, for example, change the spectral and intensity distributions of incident beams of light, reflecting the altered beams. These altered beams strike the retinas of predators, whose brains process the patterns of retinal activation. Depending on whether the light was reflected off uncamouflaged or camouflaged feathers, the neural computations in the predator brains will either recognize or fail to recognize the grouse, and this will either result in claws, beaks, and fangs penetrating the grouse, killing it, or the passing by of the predator, leaving the grouse unscathed.

The spread of camouflage feathers in the grouse population depends critically on the rich, pre-existing causal structure of the environment inhabited by the grouse: the colors and patterns of the forest habitat, the types of predators, the structure of their brains, and their hunting strategies. This pre-existing causal structure is referred to as the EEA of the camouflage feathers. Because aspects of the causal structure of the environment that are relevant to one adaptation won't necessarily be relevant to another, the EEA is adaptation-specific. The grouse feather EEA, for example, is different from the grouse lung EEA (as shorthand, the term EEA is also used to refer to all environmental features that were relevant to an organism's reproduction). Environments change, so the causal structure of the environment an adaptation finds itself in may not correspond to the causal structure the adaptation evolved in, and therefore the adaptation may not work as designed. If the forest changes colors, for example, the camouflage feathers may no longer camouflage the grouse (but its lungs will continue to work just fine).

For humans, some aspects of the modern environment do diverge quite radically from their EEA. Automobiles kill far more people today than do spiders or snakes, for example, but people are far more averse to spiders and snakes than they are to automobiles because in the EEA, spiders and snakes were a serious threat, whereas automobiles didn't exist. We therefore evolved an innate aversion to spiders and snakes, but not to automobiles (e.g., Öhman and Mineka 2001).

If a species' current environment diverges too rapidly and too far from its EEA, the species will go extinct. The human species is clearly not going extinct; hence the common belief that evolutionary psychology claims humans currently live in an entirely novel environment is incorrect. Most aspects of the modern environment closely resemble our EEA. Hearts, lungs, eyes, language, pain, locomotion, memory, the immune system, pregnancy, and the psychologies underlying mating, parenting, friendship, and status all work as advertised—excellent evidence that the modern environment does not radically diverge from the EEA.

What evolutionary theory adds to brain research

If the analogy between anatomical and psychological research were perfect, then, because evolutionary theory has been mostly superfluous to anatomical research, evolutionary theory would also be mostly superfluous to psychology. But, although the analogy is perfect in most

[9] An adaptation can evolve if it has a positive impact on reproduction *on average*. It need not have a positive impact all the time, nor in every situation, nor even every generation.

respects, when it comes to actually identifying psychological adaptations it begins to break down for technological reasons. The explosion of anatomical knowledge over the last several centuries has been based on detailed examinations, dissections, and chemical analyses of organs and tissues. Given current technology, this approach is very difficult and often impossible to apply to the human brain. Brain functions arise from structures that are generally much bigger than single neurons, but much smaller than the gross anatomical features of the brain. A cubic millimeter of human cortex, for example, contains a network of roughly 50,000 neurons and 200,000,000 neural (synaptic) connections (Cherniak 1990). The most sophisticated brain imaging techniques available can just barely detect whether this cubic millimeter of brain tissue is, on average, more or less active after a stimulus than before, but they are 'blind' to the connections and activities of the many neural circuits contained therein. If we could 'see' human neural circuits, then, as we have with the rest of our anatomy, we could 'dissect' and analyze brain functions by analyzing their structure. But, with current technology, we usually can't.[10]

In contrast to the near impossibility of examining neural circuits for most brain functions, psychologists, using a large repertoire of ingenious techniques, have amassed mountains of indirect evidence for complex brain structures. By exposing human and animal subjects to special stimuli and observing their behavioral responses, psychologists have proven that the brain is composed of large quantities of richly structured circuitry. These breakthrough findings are only now filtering out to other social sciences like economics. Yet it cannot be overemphasized that cognitive and social psychological methods, however sophisticated, yield extremely oblique evidence of this circuitry. Subjects' immensely complex brains are constantly processing vast information flows from their senses and rich memories of past events, and constantly analyzing future scenarios. Into this individually unique blizzard of cognitive activity, the psychologist injects a usually brief stimuli and records a behavioral response. Guided only by an abstract information processing model such as symbolic processing or connectionism, and mostly *ad hoc* assumptions about cognitive domains, she then makes inferences about universal cognitive structure. This is like trying to infer the presence and functions of hearts, lungs, or kidneys without being able to conduct dissections and with no *a priori* theory of what kinds of mechanism should exist and what their functions should be. The prospects for success are grim.

Evolutionary theory can help enormously with the problem of 'invisible' neural circuits and the inherent ambiguity of cognitive and social psychological evidence for them. Natural selection has mapped the structure of the environment onto the structure of organisms. Gravity, carbon fuel sources like fats and carbohydrates and their patchy distribution on the landscape, metabolic waste products, toxins, pathogens, and temperature fluctuations have all been mapped by natural selection onto the structure of the human organism in the form of our bones, muscles, tendons, blood, intestines, kidneys, liver, immune system, and sweat glands. EP proposes that, exactly like the structure of the rest of the human body, the structure of the human brain should closely reflect the structure of the human EEA. Sunlight, acoustic oscillations, volatile compounds, foraging, mates, dangerous animals, children, kin, social exchange, and group living have all been mapped by natural selection onto the structure of the human brain in the form of our visual, auditory, and olfaction abilities, our ability to navigate, our sense of taste and our preferences for foods, our sexual desires, our fears, our love of children, relatives, and friends, our aversion to incest, and our ability to detect cheaters and to form coalitions.

Because it is currently easier to study the structure of the environment than it is to map the

[10] It is much easier to study neural circuits in animals, of course, especially those, like lobsters, with especially simple nervous systems.

neural circuitry of humans, EP is proposing that cognitive and social psychology and neuroscience can be fruitfully augmented with a single idea: the brain is not composed of arbitrary functions, nor simply of functions that one would expect in any information processing machine, like memory, nor of generic learning functions, but rather of a number of functions that solved specific reproductive problems in the human EEA. The *a priori* hypotheses about brain functions that can be generated by investigating the human EEA greatly increase the odds that the indirect methods of cognitive and social psychology will genuinely identify such functions. It is much easier to find something if you have some idea what you are looking for. If you take away only one idea from evolutionary psychology, take this: Though often tricky to interpret, the structure of an organism's EEA can be a masterful guide to the structure of the organism, including its brain.

Is the EEA knowable?

No one would dispute that our lungs evolved in an oxygen atmosphere (the lung EEA) nor that our immune system evolved in response to pathogens (the immune system EEA). Yet when it comes to the selection pressures that shaped the brain, some are skeptical that the past is knowable (e.g., Ahouse and Berwick 1998). The past, however, was much like the present. Physics was the same. Chemistry was the same. Geography, at an abstract level, was much the same—there were rivers, lakes, hills, valleys, cliffs, and caves. Ecology, at an abstract level, was also much the same—there were plants, animals, pathogens, trees, forests, predators, prey, insects, birds, spiders, and snakes. Virtually all biological facts were the same. There were two sexes, parents, children, brothers, sisters, people of all ages, and close and distant relatives. It is a common misconception that the EEA refers to aspects of the past that differ from the present, when it actually refers the aspects of the past whether or not they correspond to aspects of the present. We know that in the EEA women got pregnant and men did not. This single fact is the basis for perhaps three-quarters or more of all EP research. The hefty array of human universals (Brown 1991), although not as assuredly true of the past as, say, gravity, is nonetheless another important source of hypotheses about the EEA. Adding to our already detailed scientific understanding of the past are the historians, archaeologists, and paleoanthropologists who make a living studying it.

Psychological adaptations are just like other adaptations

Despite the technological difficulty of studying neural circuitry, the equivalence of psychological adaptations and other adaptations is not mere analogy. The specialized physical/chemical configurations of adaptations give them their functional properties: the distinctive ability to effect particular environmental transformations, precipitating causal cascades that, in the EEA of the adaptation, increased reproduction. In this regard, the neural circuits constituting psychological adaptations are no different than other adaptations. Like hearts and lungs, the specialized physical/chemical configuration of a neural circuit provides a distinctive ability to effect a particular environmental transformation—usually of other neural circuits or muscles—precipitating causal cascades that, in the EEA of the adaptation, increased reproduction.

Conversely, anatomical adaptations like hearts and lungs can be thought of as information processing adaptations. Any physical system can be characterized by what is known as a state vector—the values of a large, and potentially vast, number of system parameters.[11] Adaptations are systems that change other systems. These changes can be characterized by changes in the state vector. Adaptations ‘operate’ on input, the initial state vector of the target system, producing ‘output’, the transformed state vector of the target system, exactly what information processing adaptations do. In principle, the information processing model could be applied to all adaptations. There are differences in degree , however, that usefully distinguish information processing adaptations from other adaptations:

1. Information processing adaptations have high information content—the system can assume a large number of distinct and detectable states. Hearts, for example, can assume only a limited number of different states (e.g., beating at different rates), whereas the retina can assume an astronomically large number of different states (e.g., all the possible combinations of activation levels of the 125 million rods and 6. 5 million cones in each eye).
2. State transformations in information processing adaptations require little energy. Heart muscle requires a significant amount of energy to contract compared to the activation of a cone in the retina.
3. State transformations in information processing adaptations can occur very rapidly. The frequency of contractions of heart muscle is low compared to the potential frequency of state changes in cones of the retina.

Animals possess many high bandwidth sensors like eyes, ears, taste, and smell, each of which can assume a vast number of possible states in response to environmental conditions (the human hand, for example, has 17,000 sensor cells per square inch). To enable reproduction-facilitating actions by the animal, this vast quantity of information must undergo further processing by psychological adaptations.

Nature vs. nurture

Most, if not all, controversies surrounding EP can be traced to the nature-nurture debate. The nature-nurture debate, in turn, is intimately entwined with, and perhaps identical to, body-brain dualism: Our bodies are the product of nature, and our minds, many believe, are solely the product of nurture. Rejecting brain-body dualism should therefore resolve the nature-nurture debate, and it does. In fact, it provides two resolutions. In the scientific study of the body, the primacy of ‘nature’—a set of inherited, pan-human functional properties—is undisputed. If brain and body organization are deeply similar, then ‘nature’ should also form the foundations of brain science. The importance of ‘nurture’—learning—is, however, indisputably important to understanding the brain. The deep equivalence of brain/body organization then implies that ‘nurture’ should form the foundations of anatomy! Surprisingly, these two perspectives are equivalent, as I will explain in a moment. First, though, I will show that two other common solutions to the nature-nurture debate must be rejected.

Gene-environment interactions

One common attempt to resolve the nature-nurture debate is to invoke interactions of genes and environment—we are equally the product of both. This attempt fails.

[11] For example, the state vector of a volume of gas consists of the position and momentum vectors of all gas particles.

Gene-environment interactions are invoked in two distinctly different contexts. The first is the development of our incredibly complex, universal phenotypes. Both genes and environment are intimately involved in virtually every step of ontogeny. This is true, but vacuous. How could genes play any role in the development of phenotypes if they did not interact with the environment (everything that isn't a gene)? Once a (non-regulatory) gene is transcribed, it's all environment from there on out. This supposed resolution to the nature-nurture debate, commonly invoked by evolutionary scholars, has no scientific content whatsoever.

The vital question of ontogeny is how genomes manage to produce nearly identical, intricately structured phenotypes. A partial answer is that, within species (and often even across closely related species), the vast majority of genes are identical in every individual. Equally importantly, the environment (everything that isn't a gene) is almost exactly the same for each individual as well. The properties of the myriad chemical compounds necessary for organism development, and the principles by which they react, are identical for all individuals. The proteins produced by the identical genes, which then regulate the production of other proteins, are essentially identical for all individuals. Factors which vary, like temperature, can be dynamically maintained within a narrow range. The highly stable nature of the genome, as well as the stability of the environment in which it organizes development (but see Raser and O'Shea 2004) explains why, when compared to the potential variability they could, in principle, express, all humans are basically identical—we resemble each other far more than we do toads, trees, or termites.[12]

The second context in which gene-environment interactions are invoked is the study of individual *differences*. Although it might seem that the study of phenotype differences is closely related to the study of phenotypes, it isn't. By definition, studying phenotype differences ignores all of the immensely complex structure those phenotypes have in common. The claim that residual differences in phenotypes could be caused by residual differences in genotypes, residual differences in environments, and/or interactions between the two is not vacuous, yet has little relevance to EP. Even though they play a hugely important role, unvarying aspects of the genome and the environment are ignored when investigating phenotypic differences. But it is the unvarying, universal portion of the genome (the vast majority of genes), as well as both unvarying and varying aspects of the environment, that EP is primarily interested in.

Conflating the vacuous claim that our universal phenotypes are the joint product of both genes and environment, with the nonvacuous but completely unrelated claim that residual differences in those phenotypes can be attributable to residual genetic differences, residual environmental differences, or their interaction, may erroneously lead to the conclusion that environmental variability is deeply implicated in the development of adaptations coded for by universal genes. Such a conclusion is very unlikely to be true. If Murphy's law has any force, most environmental perturbations of developmental processes will disrupt the normal development of the target adaptation. I would therefore expect that the body is designed to ensure that developing systems only 'see' the environmental variation they are supposed to see; much, if not most, of the time, this will involve *shielding* developing systems from variation, not exposing them to it. One doesn't want the development of hearts or visual systems to be sensitive to most environmental variability. One instead wants them to reliably develop despite any variability that exists.

The exception, of course, is environmental variation that is necessary for the development

[12] In most species, there are gene and environment controlled 'switches' that direct phenotypes to develop into one of a few discrete types, like male and female. See Hagen and Hammerstein (in press) for more detail.

and performance of the adaptation. The cardiovascular systems of people who were raised at high altitudes, for example, operate more efficiently at those altitudes than those of people who migrate to higher altitudes as adults. In these cases, specific development mechanisms have almost certainly evolved to sample *relevant* environmental variation, and to then ‘tweak’ the target adaptation to enhance its performance under those conditions. In some cases, the ‘tweaking’ will be quite dramatic, such as acquiring a native language. In other cases, environmental cues might trigger significant shifts in developmental trajectories as part of an underlying evolved strategy—environmental sex determination in some species is a particularly dramatic example.

Plasticity

Another unsatisfying solution to the nature-nurture debate is the claim that the brain has an essential property—a secret sauce—called ‘plasticity’, which enables ‘nurture’ (e.g., Buller and Hardcastle 2000; Panksepp and Panksepp 2000). Plasticity is a vague term which basically means that the brain changes in response to the environment. The real question, however, is why and how the brain can change in such useful ways. The descriptor ‘plastic’ contributes little—if anything—to an understanding of either the why or the how of neural responses to environmental conditions. Even describing real plastics (i.e., various types of organic polymers) as ‘plastic’ reveals nothing about the nature of their ‘plasticity’. The plasticity of plastic is a consequence of very specific and hierarchical microscopic properties of the polymer chains, including the types of chemical bonds found on the polymer backbone, the length of the chains, and the number and nature of links between polymer chains. Similarly, the ‘plastic’ nature of the brain results from very specific and hierarchical properties of neurons and neural networks in the nervous system, and it is the latter which are of interest. At best, the term ‘plastic’ vaguely describes a property of the nervous system (that it can change in response to environmental change); it does not explain it. See Hagen and Hammerstein (in press) for an evolutionary strategic approach to gene-environment interactions and developmental flexibility.

Nurture is a product of nature

One genuine solution to the nature-nurture debate requires abandoning the idea that nature and nurture are equal partners. They are not. Nurture is a product of nature. Nurture, by which I mean learning in all it various forms, doesn’t happen by magic. It doesn’t occur simply by exposing an organism to the environment. It occurs when evolved learning adaptations are exposed to the environment. Dirt doesn’t learn. Rocks don’t learn. Learning is grounded in specialized adaptations that evolved just like all other adaptations (Tooby and Cosmides 1992).

Recognizing that evolved learning mechanisms are not special to the brain deepens our understanding of ‘nurture’. Our immune system, for example, is a superb learning mechanism, one that illustrates some the key insights that EP offers to the evolution of learning. Pathogens evolve rapidly, often within an individual organism. It would be impossible for organisms, via natural selection, to evolve defenses against a particular, rapidly changing pathogen. Natural selection, however, has discovered two things about pathogens that don’t change: (1) they are made of proteins, and (2) these proteins are different from the proteins comprising the host. Natural selection’s ‘discovery’ of these powerful *abstractions* allowed the evolution of a specialized mechanism to fight an enormous range of different pathogens by, to simplify greatly, learning to recognize and eliminate foreign proteins from the body. Despite the immune system’s ability to successfully combat a diverse array of pathogens, it is not a ‘general’ learning mechanism. It doesn’t learn what foods to eat or how to make different tools.

Evolved cognitive learning mechanisms can be expected to be similar to the immune system: highly specialized to acquire information about abstract domains that were relevant to reproduction in the EEA.

Nature is a product of nurture

EP comes down squarely in favor of the primacy of nature. It is possible, however, to view all our adaptations, including hearts, lungs, and livers, as the products of nurture. This surprising conclusion follows from the recognition that natural selection is a learning algorithm. Learning is the acquisition of useful information about the environment. Via the differential reproduction of alleles across generations, natural selection 'learns' what kinds of transformations increase reproduction in a particular environment, and stores this information in the genome. In a species, each allele that has gone to fixation by natural selection is a valuable piece of 'learned' information about the traits that are useful for that species' reproduction in its EEA. Thus, all of the body's adaptations are, in this sense, a product of 'learning. Because this 'learning' takes place across many generations, let's call it 'vertical learning'.

Like all learning algorithms, natural selection can only learn stable patterns or relationships. At one level, the environment is so variable that it seems impossible that natural selection could learn anything useful. Measles differs from strep, apples differ from oranges. Higher levels of abstraction, however, can be extraordinarily stable across generations. Measles and strep are both pathogens, a large and enduring class of dangerous organisms, all of which introduce foreign proteins into the body; apples and oranges are both edible fruits, a large and enduring class of plant products that are a rich source of carbohydrates. Natural selection can 'learn' to fight pathogens by evolving an immune system, and it can 'learn' to identify and metabolize carbohydrate-rich fruits by evolving a suite of sensory, cognitive, and digestive systems. Natural selection tends to produce adaptations that operate, not on the variable particulars of an environment, but on abstract domains like pathogens and fruit that are highly stable across generations.

If what natural selection often tends to learn are abstractions, then, of necessity, it must also produce mechanisms that 'fill in the details' by learning domain-specific patterns and relationships that are variable across generations (and thus cannot be directly 'learned' by natural selection), but stable within them. Let's call these mechanisms 'horizontal' learning mechanisms. Natural selection designed the immune system to detect and eliminate foreign proteins, but, in operation, the immune system must learn to detect and eliminate measles and strep. Similarly, natural selection designed our sensory systems to identify carbohydrate sources using reliable cues like color and taste, but these systems, in operation, must learn to identify particular carbohydrate sources, like apples and oranges.

These arguments suggest that learning (in the usual sense of the term) should be widespread in the body, and it is. Most body systems collect information about their environments and alter their properties in an adaptive fashion. Tanning is another example. These arguments also suggest that many organisms, including humans, will have a number of learning mechanisms specialized for particular reproductively relevant abstract domains. Learning to avoid poisonous animals is one thing, learning to locate nutritious foods another.

The nature-nurture distinction is real and important. It is the distinction between reproductively relevant environmental patterns that are stable across many generations versus those that are stable for much shorter periods. Relatively stable environmental patterns can cause the evolution of all types of adaptations—our nature. More variable environmental patterns can cause the evolution of a narrower class of adaptations: learning adaptations—specialized aspects of our nature that enable nurture.

Natural selection is a brilliant engineer. It is therefore tempting to speculate that, at least in a smart animal like humans, she could have produced a horizontal learning mechanism so powerful and effective that it obviated the need for other specialized cognitive adaptations. Could natural selection have endowed humans with a generalized über-learning mechanism that, perhaps by structuring itself during development, enables us to learn everything we need to know to survive and reproduce in most any environment we are likely to find ourselves in, as some have argued? (e.g., Buller and Hardcastle 2000; Karmiloff-Smith 1992)? Almost certainly not.

Reproduction is a complex business that is grounded in the complex causal structure of the environment. Natural selection 'learns' what to do in this environment by conducting enormous numbers of 'experiments'. Every individual in a population with genetic variation—one or more genetic mutations—is an 'experiment'. Those mutations that have positive reproductive consequences increase their frequency in the population gene pool. Each mutation going to fixation[13] represents learned information about some aspect of the reproductively relevant causal structure of the environment. This experimental process occurs generation after generation after generation, producing a substantial body of empirically verified information about reproduction.

Contrast natural selection with a hypothetical horizontal über-mechanism in a single organism that attempts to learn the reproductive consequences of different behaviors in one lifetime. Learning requires feedback, but learning how to reproduce requires feedback from far in the future. The goal of everything organisms do is to produce offspring that themselves successfully reproduce. Information about the degree to which an individual achieves this goal, however, will not be available for an entire generation—often after the individual is dead. And even if it could change something, what should it change? Every action it has taken over its lifetime could potentially impact the reproduction of its offspring (often just by producing them in the first place). Which actions moved it closer to the goal of creating reproductive offspring, and which farther? The individual has no way of knowing. Absent a tremendous amount of prefigured knowledge about what is needed to reproduce, reproduction is unlearnable. The reproductively relevant causal structure of the environment is just too complex relative to the number of reproductive events of an individual organism. What natural selection can learn about reproduction by experimenting with thousands or millions of individuals over hundreds and thousands of generations is, to an individual organism with but one lifetime, an impenetrable fog.

Massive modularity

This is the Unix[14] philosophy. Write programs that do one thing and do it well. Doug McIlroy.

The body is massively modular. It contains thousands of different parts, each with specialized functions. This means that the brain could be massively modular, but it doesn't mean that the brain *is* massively modular. It is, after all, only one organ among many. Our fingernails aren't massively modular, nor are our front teeth. It is clear, though, that living tissues are often, perhaps always, modularly organized. One can further conclude on empirical grounds alone that since natural selection designed the body, one thing natural selection does well is make modules. EP's provocative proposal that the brain consists of a large number of innate modules has come to be known as the massive modularity hypothesis (MMH).

To assess the MMH, we need to understand why our anatomy is modular. Our bodies, in a

[13] I.e., increasing its frequency to 100%. I am ignoring complications like frequency dependent selection.
[14] Unix is the powerful computer operating system that runs most of the Internet. It is also widely used by scientists, engineers, and financial institutions requiring high levels of reliability, flexibility, and speed.

deep sense, reflect the causal structure of the world. They are modular because, crudely speaking, the world is. As a species, we interact with an extraordinarily heterogeneous physical, biological, and social world. In order to successfully reproduce, we must change many aspects of that world in very specific ways, and those changes can only be reliably effected by specialized structures. Our incisors have a different function than do our molars. At least to a limited degree our brains, too, are clearly modular. Vision is different from olfaction is different from motor control. Many evolutionary psychologists believe, however, that the structure of the human EEA was so rich and heterogeneous that our brain contains at least hundreds, and perhaps thousands, of modules.

Jerry Fodor, widely credited with popularizing cognitive modularity (Fodor 1983), has, in a recent book (Fodor 2000), criticized both the MMH and EP. If one of modularity's strongest proponents doesn't like the MMH, there must be something really wrong with it. Fodor's MMH critique is based, in part, on (1) a narrow definition of modularity, a definition EP rejects, (2) a definition of 'cognition' which differs from EP's definition, and (3) a common misconception of domain specificity.

First, Fodor distinguishes between cognitive modularity with, and without, information encapsulation (Fodor 2000, p. 56-58). If, when performing the computations, modules only have access to information stored in the module itself, and cannot access information in other modules, the module is said to be informationally encapsulated. As a concept, information encapsulation is so unhelpful that one wonders whether its importation from computer science into cognitive science was botched. Why, except when processing speed or perhaps robustness is exceptionally important, should modules not have access to data in other modules? Most modules should communicate readily with numerous (though by no means all) other modules when performing their functions, including querying the databases of select modules.

The original computer science concept of encapsulation, in contrast, is powerful: encapsulated modules access and modify data in numerous other modules when performing their functions, but only do so via well-defined *interfaces*. This means, roughly, that modules communicate in standardized ways, and that access to a module's data and functionality is regulated by the module itself. As long as the interface between modules stays the same, programmers can tinker with modules' implementations without disrupting other modules. In computer science, it is a module's functionality that is encapsulated, not its data per se.[15]

Fodor wants to limit use of the term 'module' to informationally encapsulated modules, whereas EP takes all mechanisms, with or without information encapsulation, to be modules.[16] Fodor considers this more general sense of module, which he terms "functionally individuated cognitive mechanisms" (p. 58), to be a diluted and apparently uninteresting sense of module that almost everyone already accepts. Right off the bat, Fodor and EPs are talking past each other. Let me speculate on one source of the disjunction. Cognitive scientists like Fodor want to determine what kind of machine can think like the brain. The critical concepts come from

[15] The standardized way in which nerve cells communicate is a low-level example of encapsulation in the brain. Whether natural selection could have evolved this useful architecture at higher, neural network levels in the brain is an open question, but it would clearly allow individual modules to evolve without interfering with other modules.

[16] Buller and Hardcastle (2000) incorrectly claim that EP's multimodular model of the brain entails strict information encapsulation (and so any evidence against strict information encapsulation is evidence against EP). One incorrect argument they give is that since reproductively striving men with knowledge of sperm banks don't donate all their sperm to them, EP must be assuming strict information encapsulation. The mistake with the sperm bank example is, as EPs have explained countless times, that although there is a module for having sex, there is no (and can be no) module for reproductive striving (e.g., Symons 1987, 1989, 1990, 1992).

computer science: algorithms, connectionist networks, programming syntaxes, memory, object-oriented languages, and databases. Modularity is valued because it helps solve severe computational problems like combinatorial explosion. EP, on the other hand, wants to determine how the brain changes the environment to facilitate and enable the reproduction of the organism. For it, a radically different set of ecological concepts are critical: finding food and mates, besting competitors, avoiding predators and toxins, and helping kin. In addition to avoiding combinatorial explosion, EP values modularity because a specialized module can most effectively cause transformations of the environment that facilitate and enable reproduction.

The second basis of Fodor' critique is an attack on Cosmides and Tooby's (1994, p. 91) argument that the brain cannot consist only of domain-general mechanisms because "there is no domain-independent criterion of [cognitive] success or failure that is correlated with fitness." Fodor justifiably counters that "there is surely an obvious, indeed traditional, domain-general candidate for the 'success' of a cognitive system: that the beliefs that its operations arrive at should by and large be *true*" (p. 66, emphasis in the original). Unlike Fodor, however, Cosmides and Tooby aren't distinguishing between psychological mechanisms that learn about the world (cognition *sensu stricto*), and those that function to change it (what Fodor calls *conative* functions). For EP, the functions of the brain evolved because they could change the world to increase fitness over evolutionary time; learning about the world was but a means to that end.

Fodor then goes on the offensive, offering what he considers to be a two-part *a priori* argument against massive modularity. For it to collapse, I only need to refute one part. Fodor asks us to consider the following simple cognitive system (fig. 1). M1 is a cognitive module only for thinking about triangles, and M2 is a module only for thinking about squares. Because this system is based on Classical computation, "M1 and M2 both respond to formal, nonsemantic properties of their input representations" (p. 72), P1 and P2 respectively. P1 must be assigned to triangles, and P2 must be assigned to squares, and this function is performed by BOX1, which receives as input representations of both triangles and squares. Fodor then asks, "Is the procedure that effects this assignment [BOX1] itself domain specific?" *Contra* Fodor, it is.

$$\text{All representations} \rightarrow \text{BOX1} \rightarrow \text{P1 v P2} \begin{array}{l} \rightarrow \text{M1} \\ \rightarrow \text{M2} \end{array}$$

Figure 1: A simple, multimodular brain for thinking about triangles and squares (from Fodor 2000).

Fodor believes that because BOX1 doesn't think about just triangles or just squares, that it is somehow "less modular than either M1 or M2" and that "would undermine the thesis that the mind is *massively* modular" (p. 72, emphasis in original). No, it wouldn't. The 'domain' of BOX1 is: sorting out triangles and squares. Just because BOX1 is operating on more abstract entities than M1 or M2 doesn't mean it's not domain specific, nor that it isn't a module. Sorting out triangles from squares is a highly domain specific task that requires lots of innate information about triangles and squares. Without innate information about triangles and squares, BOX1 wouldn't know whether to sort on, e.g., the area of the representations, on the length of the perimeters, on those representations that had at least one right angle, or on the number of angles.

It is a very common error to believe that modules that operate on abstractions are somehow less domain specific or less modular than those that operate on more concrete representations. Computations on abstract domains require just as much specialized circuitry and innate knowledge as do computations on concrete domains. 'Object', for example, is a very abstract concept—it includes my Berlin Starbucks coffee mug, the sidewalk cobblestones, and the beautiful 400,000 year old Schöningen spears. A specialized psychology with innate knowledge of 'objects' is required, however, to identify instances of, and reason about, 'objects' (e.g., Spelke 2000). Abstract domains are just as domain-esque as concrete domains. The debate that EP is engaged in is not whether the brain is composed of a large number of modules that only operate on concrete domains vs. whether a lot of those modules operate on abstract domains. The debate, rather, is whether some sort of relatively homogeneous computational architecture with little-to-no innate knowledge about the world has any chance at all of successfully enabling its hosting organism to reproduce. A lot of people, implicitly or explicitly, seem to think that it can. EP is a clear voice claiming that it can't. What EP is offering to cognitive science is a rich, *a priori* theory of what, exactly, our "functionally individuated cognitive mechanisms" should be. For example, because humans have been making stone tools for around two million years, and picking berries from thorny vines for much longer, and because stone flakes and thorns both could, e.g., cause fitness reducing injuries, it is a solid prediction of EP, untested so far as I know, that humans should have an innate concept of 'sharp object'.

Turning to Fodor's critique of EP in general, it is clearly based on holding EP to standards that almost no scientific theory could meet. Irked by what he perceived to be the unduly chipper title of Steve Pinker's book on EP, *How the Mind Works*, a "jaundiced" Fodor wants to remind us that there are still Hard Problems. The foundation of EP is what Fodor calls the Classical Computational Theory of the Mind (CCTM): the idea that the brain is a computer. Despite being one of its strongest proponents, Fodor argues that the CCTM can't explain some of the brain's most interesting properties. For Fodor, these include its abductive, or 'global' cognitive processes; for others, these include the processes that produce consciousness.

Even if we grant Fodor everything here (c.f. Carruthers 2003), the CCTM underpins virtually all of cognitive science, not just EP. Fodor agrees that the CCTM is "by far the best theory of cognition that we've got" (p. 1), so he can hardly fault EP and nearly all other cognitive scientists for using it. The first three of five chapters of Fodor's book are a critique the CCTM, not EP in particular. (Chapter four discusses the MMH.) Chapter five attempts to refute three "bad argument[s] why evolutionary psychology is a priori inevitable." Requiring EP to prove itself a priori inevitable, however, is requiring far too much. EP is not a priori inevitable. Neither were relativity or quantum mechanics. All these theories must prove themselves empirically. Philosophers like Fodor worry if they are logically forced to accept EP. Well, no. Fodor, one of EP's inventors, can refuse to accept EP, just as Einstein, one of quantum mechanic's inventors, refused to accept quantum mechanics. For EP proponents, the unification of body and brain made possible by Darwin, von Neumann, and Turing is a beautiful idea. It will be a shame if it is wrong (evolutionary psychologists, of course, are encouraged about the evidence collected to date).

Political correctness

To propose that [rape] serves some evolutionary function is distasteful and unnecessary. Henry Gee, senior editor at Nature.[17]

In 1632, Galileo's *Dialogue concerning the Two Chief World Systems, Ptolemaic & Copernican* was published in Florence. *The Dialogue* effectively argued that Copernican theory was the factually superior theory of cosmology. Because the major moral/political power of the day, the Catholic Church, had grounded its authority in the Ptolemaic theory, Galileo's *Dialogue* was a threat. Galileo was summoned before the Inquisition in 1633, found to be vehemently suspect of heresy, forced to formally abjure, and condemned to life imprisonment.

[17] Nature, July 5, 2000.

Like the Church, a number of contemporary thinkers have also grounded their moral and political views in scientific assumptions about the world. In the current case, these are scientific assumptions about human nature, specifically that there isn't one (Pinker 2002). Theories calling these assumptions into question are, like Galileo's *Dialogue*, a threat. The problem, of course, is not with those who claim that there is a human nature, it is with those who have succumbed to the temptation to ground their politics in scientifically testable assumptions about humans. This is especially unwise because the science of human psychology is currently quite undeveloped. There are few solid facts and no proven theories about our behavior, thoughts, and feelings. *Any* set of assumptions will undoubtedly be challenged by future research. Yet the inevitable research that calls into question assumptions underlying popular moral and political views will, in effect, be heresy, and heresies are, as a rule, viciously attacked. As long as important political and moral views are grounded in scientific hypotheses, a true science of human cognition and behavior will be difficult, and perhaps impossible, to achieve.

Sociobiology sanitized?

Scientific understanding of the body paralleled advancements in physics, chemistry and technology. Until Darwin, however, no such foundations existed for understanding animal or human behavior. Even after Darwin, much animal behavior, particularly social behavior, remained mysterious. In the 1960's and 70's, biologists developed powerful new theories that could explain animal sociality as a product of natural selection (e.g., Hamilton 1964, Maynard-Smith and Price 1973; Trivers 1972). Because these theories represented a biological approach to animal sociality, they became known as *sociobiology*. These theories are to the study of animal behavior what optics is to the study of vision: a set of core, abstract principles about the social world that should be reflected in the structure of animal nervous systems, much as optical principles are reflected in the structure of the eye. This was more than a small breakthrough.

Although E. O. Wilson is usually credited as the inventor of sociobiology, he actually had little hand in its theoretical development. His main contribution was to christen the field by publishing an outstanding book-length survey, *Sociobiology*: *The New Synthesis* in 1975. Oh, and by briefly suggesting that the theories developed to explain the social behavior of non-human organisms might also explain the social behavior of humans, he also ignited a firestorm of controversy that smolders to this day.

If Wilson was right, the slate is not blank. The sun of the mind does not revolve around the earth of culture, but vice versa, a heresy that many believe threatens enlightenment values of equality (Pinker 2002). Predictably, sociobiology was attacked on extra-scientific grounds. A tiny clique of Harvard faculty cast it, and proponents like Wilson, as tools of the far right. But many prominent proponents of sociobiology were leftists. Wilson himself became an ardent champion of saving the rain forests and biodiversity (Wilson 1988), and key inventors of sociobiology like John Maynard Smith and Robert Trivers were also left or far left (Segerstrale 2000). The Harvard clique's stratagem prevailed nonetheless. In the war of words, sociobiology's critics, lead by the brilliant essayist Stephen J. Gould, won rapid and decisive victories. Applying sociobiology to humans quickly became taboo.[18] Attempting to capitalize on these victories, critics claim that EP is only slightly sanitized sociobiology. The closer they can tie EP with sociobiology, they hope, the faster they can sink it.

Despite their dazzling rhetorical successes, sociobiology's critics have been virtual no-shows

[18] This taboo is endorsed by many animal biologists, probably to avoid being stigmatized themselves.

on the battlefield of science. Many readers will be probably be surprised to learn that sociobiology is, as Alcock (2001) rightly claims, one of the scientific triumphs of the twentieth century. After the publication of Wilson's book, sociobiological research on non-human organisms exploded, generating a continuing flood of articles in top journals, including almost weekly appearances in Nature and Science, the world's premier scientific outlets. One of sociobiology's key theories, kin selection, has garnered overwhelming empirical support. Sociobiology is part of the core research and curriculum of virtually all biology departments, and is a foundation of the work of almost all field biologists, including figures like Jane Goodall. To avoid the stigma generated by the Harvard clique, sociobiology usually isn't called that anymore—the more general term 'behavioral ecology' is a common substitute.

The critics are right. EP *has* eagerly adopted sociobiology—its successes are impossible to ignore. EP is thus just as politically incorrect as sociobiology. Yet EP is not simply sociobiology redux. First, EP, the study of animal nervous systems from an evolutionary perspective, includes numerous aspects of cognition that have nothing intrinsically to do with sociality, such as vision, navigation, and foraging. Sociobiology, in contrast, is restricted to the biology of sociality. Second, although sociobiologists usually study social *behavior*, they also study organisms like plants (Andersson 1994), which have no nervous systems and are therefore outside the purview of EP. Third, EP pioneered a strong emphasis on the evolution of the neural mechanisms that generate behavior, whereas animal sociobiologists tended to emphasize the study of behavior itself. Fourth, EP emphasized that these neural mechanisms evolved in response to past selection pressures, whereas animal sociobiologists tended to investigate the fitness effects of behavior in current environments. Lately, however, animal biologists have also begun focusing on psychological mechanisms, and some of the original inventors of sociobiology were well aware of the important distinction between past and present environments (e.g., Maynard Smith 1978).

In the final analysis, social cognition and behavior do constitute an important subset of EP, and much EP research employs theories such as kin selection, reciprocal altruism, and sexual selection that form the core of sociobiology.

Is evolutionary psychology racist or sexist?

Perhaps the most important enlightenment value, one intimately bound up with the blank slate view of human nature, is that of human equality. If EP poses a severe threat to the blank slate, and it does (Pinker 2002), does it not also pose a severe threat to this rightly cherished value? Let me put off answering this question for a moment, and first explain what EP says, scientifically, about the equality of human capabilities. The answer is simple and by now easily guessed by the reader. Across the globe, human bodies are, in their functional organization, virtually identical. People in every population have hearts, lungs, and livers, and they all work the same way. A pan-human anatomy is a solid empirical fact. EP proposes that the same evolutionary processes that lead to a pan-human anatomy also lead to a pan-human psychology (Tooby and Cosmides 1990; see Wilson 1994 for a partial critique). Notwithstanding the above, it is possible for different populations to possess minor adaptive physical differences like skin color, so it is also theoretically possible for different populations to possess minor adaptive cognitive differences, though no such differences are known to exist. Just as anatomists have prioritized a focus on pan-human anatomy, EP has prioritized a focus on pan-human psychology.

Similarly, male and female bodies are identical in most ways, but profoundly different in some. Male and female hearts are essentially identical, but testicles are very different from ovaries. EP proposes that the same is true of the brain. Male and female cognitive abilities are likely to be identical in most respects, but to differ fundamentally in domains like mating where the sexes have recurrently faced different adaptive problems (Buss 2004).

If you consider these implications to be racist or sexist, then evolutionary psychology is racist or sexist. Nothing in evolutionary theory, however, privileges one group over another, or males over females. Are ovaries superior to testicles? The question is meaningless. Are male mate preferences superior to female mate preferences? The question is equally meaningless.

Is evolutionary psychology a form of genetic determinism?

Critics often accuse evolutionary psychologists of genetic determinism, and, in one sense, they are right. It is telling evidence of a pervasive dualism, though, that anatomists escape this abuse. Although the processes whereby genetic information directs the development of bodily functions are still largely unknown, there are compelling empirical and theoretical reasons to believe that there are genes for arms, legs, and lungs. Because all humans (with rare exceptions) have arms, legs, and lungs that are built the same way, we can surmise that we all share essentially the same genes for these limbs and organs. The universal architecture of the body is genetically specified in this sense. Since psychological adaptations like vision are no different from other adaptations in this regard, they, too, are genetically specified human universals.

This, however, is not what is usually meant by ‘genetically determined.’ Sometimes what is meant is that behavior is genetically determined. But genetically determined mechanisms does not imply genetically determined behavior. Just as a genetically determined universal skeletal architecture of bones and muscles can perform a huge variety of new and different movements, so too can a genetically determined universal psychological architecture that evolved to be exquisitely attuned to local environmental circumstances produce countless behavioral outcomes in different individuals with different experiences and in different situations. If the brain had only twenty independent mechanisms, each of which could be in only one of two states set by local environmental conditions, the brain would have 2^{20}, or about a million, different states and, potentially, a corresponding number of different behaviors. Because the EP model of the brain posits a very large number of innately specified mechanisms (perhaps hundreds or thousands), most of which are sensitive to environmental conditions, the brain could potentially be in any one of an astronomically large number of different states with different behavior outcomes, even if many of these modules were not independent of one another. EP’s model of a genetically determined, massively modular brain predicts far too much behavioral flexibility and diversity, not too little.

Is evolutionary psychology a form of Social Darwinism?

Nor does an interest in genetically determined psychological mechanisms imply an interest in defending status quo social structures. According to John Horgan (1995), evolutionary psychologists are the new social Darwinists—those who supposedly want to justify current social hierarchies with Darwinian theory. Ironically, it looks like the old social Darwinists never existed. Robert Bannister, seeking the social Darwinists of the history books, “came close to concluding that someone had made the whole thing up” (Bannister 1979; cf. Hofstadter 1955).

> A reconsideration [of social Darwinism] alone yields two conclusions, both important although neither groundbreaking. One is that Gilded Age defenders of free market mechanisms, individualism, and laissez faire (so-called “conservatives” but in reality liberals by mid-19th century standards) rarely laced their prose with appeals to Darwinism, and virtually never in the way described in conventional accounts. Rather, they were suspicious if not downright frightened by the implications of the new theory. Such was even the case with Herbert Spencer and his American disciples—the stereotypical textbook social Darwinists—whose world view remained essentially pre-Darwinian. The second conclusion is that New Liberals, socialists, and other advocates of positive government appealed

> openly and with far greater regularity to Darwinism to support their causes. These appeals typically contrasted “false” readings of Darwin (i.e. of the opposition) with a “correct” one (i.e. their own). Although important in their way, these two points are essentially preliminary.
>
> To ask how the epithet social Darwinism functioned, on the other hand, is to turn the conventional account rather literally on its head. Not only was there no school (or schools) of social Darwinists: the term was a label one pinned upon anyone with whom one especially disagreed….A social Darwinist, to oversimplify the case, was something nobody wanted to be. (Bannister 1988, preface, citations omitted)

Social Darwinism is obviously still being used as an epithet. Sociobiology (and thus EP) does have an explanation for the social hierarchies that are ubiquitous in both animal and human social groups (e.g., Schjelderup-Ebbe 1922; Wilson 1975), but an explanation is not a justification. Neither sociobiology nor EP makes any attempt to either justify the existence of social hierarchies, or any particular ranking of individuals.

Why do people hate evolutionary psychology?

Slavish support for reigning political and moral attitudes is a sure sign of scientific bankruptcy. It is reassuring, then, that EP has something to offend just about everyone. Surely you, the reader, if you are not already a jaded evolutionary psychologist, are offended by at least one of EP’s speculations that there might be innate, genetically based adaptations hardwired into our brains for rape, homicide, infanticide, war, aggression, exploitation, infidelity, and deception. I know I was. If, further, you would like to see these plagues wiped from the face of the earth, you might understandably be sympathetic to critics who advance something like the following syllogism, which appears to underlie most criticisms of EP:

> I [the critic] want political change, which requires changing people. Evolutionary psychologists argue that people have innate and unchangeable natures, so they must therefore be opposed to social or political change, and are merely attempting to scientifically justify the status quo.

If EP predicted that social or political change were impossible, then it would be wrong on its face. The tremendous amount of social and political change over the course of human history is irrefutable. This is no real mystery. Consider a hypothetical population of organisms whose ‘natures’ are completely genetically specified and unchangeable. Suppose, further, that these organisms have a number of identical preferences and desires, all unchangeable, but, because resources are limited, not all individuals can fulfill their desires. These creatures are therefore often in conflict with one another. Suppose, finally, that these organisms have the ability to negotiate. It is not hard to see that even if individuals’ natures are unchangeable, social outcomes are not. Because our hypothetical organisms are able to negotiate, they are (potentially) able to form social arrangements that are equitable, fairly dividing resources and punishing individuals who violate these agreements. When circumstances change, new agreements can be forged. Circumstances *will* change, so social change is inevitable despite the creatures’ unchangeable natures. In fact, it is their genetically determined, unchangeable cognitive ability to negotiate that guarantees social change! Because humans, too, can negotiate, and can also dramatically ‘tune’ their individual, innate, psychological architectures based on their past experiences and current circumstances, the possibilities for social change are multiplied thousandfolds.

Conclusion

To study metaphysics [psychology] *as they have been studied appears to me like struggling at astronomy without mechanics.—Experience shows the problem of the mind cannot be solved by* *attacking the citadel itself.—the mind is function of the body.—we must find some stabile foundation to argue from*. Darwin, Notebook N, p. 5, quoted in Ghiselin 1973.

The bricks outside the window of my office are riddled with bullet holes, scars of the fierce house-to-house street fighting between the Red Army and the *Volkssturm*, the rag-tag defenders of the capital, in the battle for Berlin. The rear of the building remains, almost 60 years later, a bombed out shell. The bullet holes and bomb damage are a stark reminder, if the nightly news somehow failed to be, that the world can quickly become a nightmare. Although the values and institutions that permit most of us in the West to enjoy unparalleled health, safety, and freedom were sculpted over the course of millennia, they can be almost instantly destroyed.

Galileo's unification of heaven and earth had immense scientific and social consequences, some foreseeable, most not. Galileo labored to reassure the church that his theories and ideas were no threat to the social order it had established, but, in fact, they were. Church authorities were right to be alarmed. EP, like Galileo, has labored to reassure the intelligentsia that its unification of body and brain poses no threat to the social order, an order now based, in part, on the dualism of a blank slate ideology. But, as its critics correctly perceive, it does. If EP's modern operationalization of Darwin is correct, it will be immensely powerful. Whether the social consequences will be, at most, a minor modification of liberal democracy, as many EPs believe, or something else, is impossible to predict. (Much of the world, it is worth remembering, does not live under liberal democracy.) As some critics fear, EP might be used to justify social hierarchies and roles (e.g., Rose and Rose 2000), but blank slate ideologies have done the same and worse (Pinker 2002). As some adherents hope (e.g., Singer 2000), EP might be used to reduce the world's misery. Most likely EP will be used for other things entirely.

Whether or not EP is correct, I hope this Handbook will convince you that it is not scientific window dressing for a political ideology, but rather a compelling scientific approach to human nature. This does not mean that EP is harmless. Critics, fearing EP to be a Trojan horse of the right, have raised countless objections to EP, objections that, as this chapter has shown, would border on the absurd were they raised against one of history's most successful scientific paradigms: the functional, mechanistic approach to organism anatomy. What the surprisingly myopic critics have failed to perceive is that the power of EP will be, not to prevent change, but to cause it.

Fully realized, EP would constitute a functional understanding of the neural circuits underlying our every thought, emotion, and action. With that understanding would come the power to mold our humanity to a disquieting degree. Perhaps it is naïve to believe that EP can keep up with the manipulative expertise of Hollywood and Madison Avenue, but serious critics of EP would do well to re-read their Huxley and Orwell. The dangers of EP lie as close to *Brave New World* and *1984* as they do to *Mein Kampf*.

More worrisome, EP challenges the foundations of crucial enlightenment values, values we undermine at our peril. Perhaps the mix of secular and religious values upon which the priceless institutions of democracy rest are like a tablecloth that can be quickly yanked out, leaving everything standing upon some solid, though as yet unknown base. But I wouldn't bet on it. We are at a cross-roads. A vibrant science of human thought and behavior must always be able to question its own premises, and is thus utterly unsuited to be that solid base. Yet if we discard the secular, quasi-scientific notion of the blank slate, or even subject it to genuine scientific scrutiny, we may threaten institutions far more valuable than a science of human nature. The vital question is not, as most critics seem to think, whether EP is correct, but whether any real science of the brain is prudent.

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