Holcomb, H. R. (1996a). Just-so stories and inference to the best explanation in evolutionary psychology. *Minds and Machines, 6,* 525–540.

Holcomb, H. R. (1996b). Moving beyond just-so stories: Evolutionary psychology as protoscience. *Skeptic, 4,* 60–66.

Holcomb, H. R. (1998). Testing evolutionary hypotheses. In C. Crawford & D. L. Krebs (Eds.), *Handbook of evolutionary psychology: Ideas, issues, and applications* (pp. 303–334). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Kourany, J. (1998). The validation of scientific knowledge. In J. Kourany (Ed.), *Scientific knowledge: Basic issues in the philosophy of science* (pp. 153–163). New York: Wadsworth.

Kuhn, T. (1970). Reflections on my critics. In I. Lakatos & A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 231–278). Cambridge, England: Cambridge University Press.

Lakatos, I. (1970a). Falsification and the methodology of scientific research programmes. In I. Lakatos & A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 91–196). Cambridge, England: Cambridge University Press.

Lakatos, I. (1970b). History of science and its rational reconstructions. In D. Rothbart (Ed.), *Science, reason, and reality: Issues in the philosophy of science* (pp. 59–76). New York: Harcourt Brace.

Laudan, L. (1998). Dissecting the holist picture of scientific change. In J. Kourany (Ed.), *Scientific knowledge: Basic issues in the philosophy of science* (pp. 327–338). New York: Wadsworth.

Popper, K. (1970). Normal science and its dangers. In I. Lakatos & A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 51–58). Cambridge, England: Cambridge University Press.

Silverman, I., & Eals, M. (1992). Sex differences in spatial abilities: Evolutionary theory and data. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 533–553). New York: Oxford University Press.

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 19–136). New York: Oxford University Press.

How to Keep Our Metatheories Adaptive: Beyond Cosmides, Tooby, and Lakatos

Geoffrey Miller
Centre for Economic Learning and Social Evolution
University College London, England

If Popper had never existed, would we need Lakatos to set us straight? Probably not. Good philosophy of science is useful mainly in inoculating scientists against bad philosophy of science, so we can get on with our business. Such preventative medicine is necessary only when pathological memes such as falsificationism are endemic in the academic population. Nevertheless, Popper did exist, and remains the only philosopher of science known to most scientists. Ketelaar and Ellis (this issue) do us the important service of providing an equally venerable philosopher we can invoke to protect our metatheories against the ghost of Sir Karl.

My quibbles with Ketelaar and Ellis are that (a) they overlook some important features of evolutionary psychology's metatheory, and some of these features are ripe for rethinking and extending; and (b) the Lakatosian framework seems inadequate to describe evolutionary psychology's scientific success, popular appeal, or institutional challenges. These quibbles do not undermine the power of Ketelaar and Ellis's anti-Popper antidote. Their target article usefully introduces the concept of metatheory to mainstream psychologists, many of whom have never encountered a useful metatheory before, so cannot distinguish between metatheory and ordinary hypothesis.

For a young science barely a decade old, evolutionary psychology has achieved a remarkably strong metatheoretical consensus. In part, this is because the metatheory was imported wholesale from contemporary adaptationism in evolutionary biology. As Ketelaar and Ellis point out, standard biological adaptationism includes many psychologically relevant ideas such as kin selection, reciprocity, and sexual selection. Yet evolutionary psychology's metatheory was also shaped very strongly by a series of ambitious, persuasive, and visionary articles by Cosmides and Tooby in the late 1980s and early 1990s that showed how adaptationism could be applied to the human mind (Cosmides & Tooby, 1987, 1994; Tooby & Cosmides, 1990a, 1990b, 1992). The Cosmides–Tooby vision of evolutionary psychology profoundly influenced the thinking of other leading researchers such as Buss (1995), Gigerenzer (Gigerenzer & Todd, 1999), Pinker (Pinker & Bloom, 1990), and Thornhill (1997). It was also adopted as the conceptual framework in the most influential popular accounts of evolutionary psychology (Buss, 1994; Ridley, 1993, 1996; Pinker, 1994, 1997; Wright, 1994).

The Cosmides–Tooby metatheory was a special form of adaptationism that stressed (a) functional efficiency criteria for identifying adaptations shaped by natural selection, (b) the context-sensitive psychological adaptation (rather than the "instinctive behavior") as the appropriate level of analysis for human nature, (c) a highly modular view of the mind as comprising hundreds of domain-specific psychological adaptations, (d) a computational metaphor for the mind imported from cognitive psychology, (e) the universality of evolved human nature rather than the heritability of individual differences, and (f) hominid small-group living in Pleistocene Africa as the most relevant ancestral environment for understanding most of human nature. These six emphases are consistent with evolutionary biology's adaptationism. However, the last five out of six are not currently shared by most researchers in animal behavior who would consider themselves adaptationists. Thus, they are the most distinctive aspects of evolutionary psychology's metatheory. Yet Ketelaar and Ellis do not discuss them, focusing instead on the more standard evolutionary concepts of kin selection, parental investment theory, and reciprocity theory that evolutionary psychology shares with the rest of biology.

Ten years after the Cosmides–Tooby metatheory was developed, it is worth asking which of its six core emphases remain adaptive guides to further research, and which could be viewed as historical accidents due to the field's peculiar intellectual phylogeny. I briefly assess the computational, modularity, efficiency, and universality emphases here.

The computational emphasis has been rhetorically important in making evolutionary psychology palatable to cognitive science, but very few evolutionary psychologists do any real computational modeling of psychological adaptations. Those who do attempt to identify specific algorithms for solving ecologically important problems, such as Gigerenzer's group in Berlin (Gigerenzer & Todd, 1999), often find their algorithms are generally useful across a wide range of content domains, contrary to the strong modularity view. For example, the "Take the Best" heuristic, originally developed to model how people judge which of two German cities is larger given probabilistic cues, appears useful for almost any pairwise choice or categorization task, regardless of content (Gigerenzer & Goldstein, 1996; Gigerenzer & Todd, 1999; Martignon, in press). So far, evolutionary psychology's evidence for domain specificity is almost all at the level of environmental cues, rather than at the level of computational mechanisms for integrating cues to guide behavior (Miller, 1997; Miller & Todd, 1998). This research strategy of identifying perceptual cues and assessing their ecological validity owes more to Brunswik's (1956) "probabilistic functionalism" than to cognitive science. Given the success of this neo-Brunswikian approach, perhaps evolutionary psychology no longer requires the pretense of computationalism. Biology's adaptationist metatheory is enough for evolutionary psychology; we may not need cognitive science's mind-as-computer metatheory.

Adaptations and Indicators

I have more serious concerns about the Cosmides–Tooby claims for modularity, efficiency, and universality, which are central parts of evolutionary psychology's current metatheory. One worry is that some of the strongest empirical research traditions in psychology appear to contradict these arguments. The existence of the *g* factor (the "general intelligence" factor) in psychometrics (Jensen, 1998) appears to contradict the strong modularity view of the mind. The moderate to high heritability of almost every reliably measurable human mental trait (Bailey, 1998; Plomin, DeFries, McClearn, & Rutter, 1997) appears to contract the universality claim. The high costs in time and energy of many human cultural behaviors (art, music, religion, gossip, conspicuous consumption), in the absence of any manifest survival value, appear to contract the efficiency claim. Most of these contradictions are more apparent than real, but evolutionary psychology needs to address them explicitly.

In particular, evolutionary psychologists standardly argue that natural selection should eliminate genetic variation underlying the functional efficiency of psychological adaptations, producing low heritability and low individual differences (Tooby & Cosmides, 1990a). Evolutionary psychologists also argue that selection should partition the mind into functionally specialized units, each optimized to solve particular adaptive problems (Cosmides & Tooby, 1994). These arguments make sense for adaptations shaped by survival selection, but the opposite arguments make more sense for adaptations that have been shaped by sexual selection as indicators of heritable fitness (Rowe & Houle, 1996). Sexually selected fitness indicators such as peacock's tails are expected to show high coefficients of genetic variation, often producing moderate to high heritabilities, and large individual differences (Pomiankowski & Moller, 1995). Such indicators are also subject to a game-theoretic constraint called the handicap principle (Miller, 1998b; Zahavi & Zahavi, 1997): To function as reliable indicators of fitness, they must incur high marginal fitness costs. These high costs can make indicators look very wasteful in every domain of efficiency other than signaling efficiency. Finally, indicators may be modular in phenotypic design, but must not be modular in underlying physiological mechanisms. If they were modular at both levels, they could not function as fitness indicators, because total modularity would undermine their reliability as signals. For example, if a peacock's tail used developmental and physiological processes quite distinct from the rest of the peacock's body, the tail could not function very well as an indicator of general bodily health.

It remains an open question what proportion of the human mind's adaptations have been shaped as sexually selected fitness indicators rather than naturally selected survival devices (Miller, 1998a, 1998b). The Cosmides–Tooby criteria for recognizing psychological adaptations would exclude most fitness indicators. For example, many evolutionary psychologists have argued that human music may not be a legitimate adaptation, because it shows such large individual differences in ability, such high heritability, such a high correlation with general intelligence, and such low apparent survival utility (e.g., Pinker, 1997). Likewise for art and humor. Yet these are precisely the features we would expect of sexually selected fitness indicators.

Evolutionary psychology's metatheory seems to have become too restrictive. The rhetorical emphasis on natural selection, engineering efficiency, and modular adaptation was useful in overcoming the standard social science model of the human mind as a domain-general computer that soaks up culture (Tooby & Cosmides, 1992). But we should learn from our successes: Sexual selection theory, not natural selection theory, has guided most of evolutionary psychology's best research. In the last 10 years, sexual selection theory has become less concerned with a narrow emphasis on sex differences and more concerned with the reliability of animal signals and the heritability of fitness. This can lead some evolutionary psychologists like Thornhill to the paradoxical position of defending the Cosmides–Tooby metatheory concerning naturally selected modular adaptations (Thornhill, 1997) while doing excellent research on sexually selected fitness indicators such as facial symmetry that violate the efficiency, modularity, and uniformity assumptions of their own metatheory (Thornhill, 1998). Biologists are developing new methods for identifying fitness indicators (e.g., Johnstone, 1995; Moller & Swaddle, 1997), but they do not resemble the Cosmides–Tooby criteria for identifying psychological adaptations. If our minds are largely advertisements for our fitness, we need to rethink our metatheory. We need to emphasize signaling theory, sexual selection theory, behavior genetics, and real evolutionary game theory (the kind that economists do) much more, and stop being so obsessed with altruism, kin selection, and reciprocity. This is the direction mainstream animal behavior research has gone in the last 10 years, and it would be unfortunate if evolutionary psychology were left behind.

Evolutionary psychology's claims to be the privileged metatheory for psychology rest on its claim to use the same concepts and methods as the rest of animal behavior research. For that claim to hold true, we have to update evolutionary psychology's metatheory as animal behavior researchers update theirs. At the moment, evolutionary psychologists use the new ideas concerning sexual selection and signaling in our day-to-day research, but we have not revised our metatheoretical manifestos to reflect that practice. Ketelaar and Ellis's points remain valid, but they are illustrated with examples drawn from a relatively old-fashioned viewpoint of 1970s sociobiology and cognitive psychology, when altruism was the central question in animal behavior, and when minds plausibly resembled computers.

Can Lakatos Account for Evolutionary Psychology's Strengths and Weaknesses?

The second major problem with the Lakatosian framework is that it overlooks many scientific, personal, media, social, and institutional effects that have influenced evolutionary psychology's strengths and weaknesses. The Lakatosian vision of one metatheory per science underestimates the importance for scientists of achieving consilience between different research fields (Wilson, 1999). Evolutionary psychology has powerful appeal not just because it has a good isolated metatheory, but because it uses largely the same metatheory as biology, and because it touches on almost every aspect of human behavior, society, and culture. Thus, it promises a seamless integration between the biological sciences, the social sciences, and the humanities. This dedication to consilience is what leads evolutionary psychologists to defend and promote our metatheory with such passion. From our point of view, evolutionary adaptationism as a metatheory for understanding animal behavior has already been validated by a century of research in biology, and does not need to prove itself anew in our particular species of primate.

The Lakatosian framework advocated by Ketelaar and Ellis also underestimates the importance of personal satisfaction and media appeal in the success of evolutionary psychology. Many areas of mainstream psychology are alienating to students and young scientists because they ignore human sexuality, friendships, families, status, conflict, politics, power, birth, death, age, animals, plants, morality, and aesthetics. Textbooks in cognitive, perceptual, and even social psychology do not usually address such topics, whereas evolutionary psychology embraces them. When behaviorism and cognitivism dominated psychology, PhD programs had to socialize psychologists to expect very little personal insight from their research. Evolutionary psychology does not demand that young scientists forget about human nature when they become psychologists. It even accepts personal experience, interpreted from a Darwinian viewpoint, as a valid basis for generating hypotheses (although not for testing them). This appeal to natural human interests also explains evolutionary psychology's success in attracting popular media attention. Until philosophy of science incorporates an explicit, detailed model of the human nature that underlies the behavior of scientists, it cannot explain why some metatheories seem alienating, whereas others seem naturally congruent with human interests.

This puts evolutionary psychology in a unique position. In the physical sciences, the power of metatheory is usually inversely proportional to its popular accessibility, because strong metatheories (such as superstring theory) tend to be highly mathematical, and most people cannot follow mathematics. Because psychology has long suffered from physics envy, psychologists tended to assume that a good psychological metatheory should also be highly mathematical. This led to a distrust of candidate metatheories that were nonmathematical and popularly accessible. Such distrust is misplaced in assessing evolutionary metatheories, which can be expressed verbally to the general public without sacrificing much content. Evolutionary psychology has perhaps the first metatheory that is both scientifically fruitful and popularly accessible. This explains why it was able to circumvent the usual institutional channels of scientific acceptance, attracting a groundswell of popular interest long before it became scientifically reputable within psychology departments. Lakatos might have been surprised that a metatheory could be accepted by the general public before it is accepted within its nominal science.

Yet evolutionary psychology's popularity has also brought problems in assessing the success of its metatheory. When there is a very high proportion of media coverage to research effort, research breakthroughs can appear to come more slowly than expected. Because journalists writing about evolutionary psychology greatly outnumber evolutionary psychologists (probably less than a thousand, worldwide), the journalists become frustrated with the relative scarcity of new findings, and convey that frustration to the public, creating the impression of a metatheory that has not lived up to its initial promise. Yet accurate assessment of a metatheory's fruitfulness must take into account the resources and personnel devoted to exploring the metatheory. When media hype creates the impression that a new metatheory has attracted many more active researchers than it really has, such media-based assessments of success tend to be biased against the new metatheory. The proper measure of a metatheory's success is research productivity rate per scientist, not research breakthrough rate per journalist. Lakatosian philosophy of science misses these effects because it overlooks the relations between science, the media, and the public.

Finally, the Lakatosian view has trouble predicting what happens when a powerful, institutionalized, but fragmented science lacking any metatheory meets a small group of scientists who offer a metatheory that threatens to unify the science. Lakatos offers a rather rosy image of scientists cherishing metatheories and appreciating their power to unify previous unconnected research areas. This overlooks the institutional boundaries that tend to keep research areas separate: separate journals, societies, funding agencies, university courses, textbooks, departments, degrees, academic job descriptions, and career tracks. New metatheories easily fall between such cracks, whatever their empirical success as research enterprises. Most of the physical sciences were fortunate enough not to expand institutionally until they had a workable metatheory in place. Psychology was unusual in growing institutionally long before it grew up metatheoretically, largely by promising results of immediate relevance to intelligence testing, social policy, education, crime, and mental illness. The most pressing philosophy of science question for evolutionary psychology is ethical rather than epistemological: Will mainstream psychologists with vested interests in rejecting a unifying metatheory behave with sufficient altruism and foresight to allow a psychological metatheory to flourish?

Note

Geoffrey Miller, Centre for Economic Learning and Social Evolution (ELSE), University College London, Gower Street, London WC1E 6BT, England. E-mail: geoffrey.miller@ucl.ac.uk

References

Bailey, J. M. (1998). Can behavior genetics contribute to evolutionary behavioral science? In C. Crawford & D. Krebs (Eds.), *Handbook of evolutionary psychology: Ideas, issues, and applications* (pp. 211–233). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Brunswik, E. (1956). *Perception and the representative design of psychological experiments* (2nd ed.). Berkeley: University of California Press.

Buss, D. M. (1994). *The evolution of desire: Human mating strategies.* New York: Basic Books.

Buss, D. M. (1995). Evolutionary psychology: A new paradigm for psychological science. *Psychological Inquiry, 6,* 1–30.

Cosmides, L., & Tooby, J. (1987). From evolution to behavior: Evolutionary psychology as the missing link. In J. Dupre (Ed.), *The latest on the best: Evolution and optimality* (pp. 277–306). Cambridge, MA: MIT Press.

Cosmides, L., & Tooby, J. (1994). Origins of domain specificity: The evolution of functional organization. In L. A. Hirschfeld & S. A. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 85–116). New York: Cambridge University Press.

Gigerenzer, G., & Goldstein, D. (1996). Reasoning the fast and frugal way: Models of bounded rationality. *Psychological Review, 103,* 650–669.

Gigerenzer, G., & Todd, P. (1999). *Simple heuristics that make us smart.* New York: Oxford University Press.

Jensen, A. (1998). *The g factor: The science of mental ability.* London: Praeger.

Johnstone, R. A. (1995). Sexual selection, honest advertisement, and the handicap principle: Reviewing the evidence. *Biological Reviews, 70,* 1–65.

Martignon, L. (in press). A Bayesian view of satisficing decision schemes. *International Journal of Artificial Intelligence.*

Miller, G. F. (1997). Mate choice: From sexual cues to cognitive adaptations. In G. Cardew (Ed.), *Characterizing human psychological adaptations* (Ciba Foundation Symposium 208, pp. 71–87). London: Wiley.

Miller, G. F. (1998a). How mate choice shaped human nature: A review of sexual selection and human evolution. In C. Crawford & D. Krebs (Eds.), *Handbook of evolutionary psychology: Ideas,* *issues, and applications* (pp. 87–129). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Miller, G. F. (1998b). Review of "The handicap principle" by Amotz Zahavi. *Evolution and Human Behavior, 19,* 343–347.

Miller, G. F., & Todd, P. M. (1998). Mate choice turns cognitive. *Trends in Cognitive Sciences, 2,* 190–198.

Moller, A. P., & Swaddle, J. P. (1997). *Developmental stability and evolution.* New York: Oxford University Press.

Pinker, S. (1994). *The language instinct.* London: Allen Lane.

Pinker, S. (1997). *How the mind works.* New York: Norton.

Pinker, S., & Bloom, P. (1990). Natural language and natural selection. *Behavioral and Brain Sciences, 13,* 707–784.

Plomin, R., DeFries, J., McClearn, G., & Rutter, M. (1997). *Behavioral genetics* (3rd ed.). San Francisco: Freeman.

Pomiankowski, A., & Moller, A. P. (1995). A resolution of the lek paradox. *Proceedings of the Royal Society of London B, 260,* 21–29.

Ridley, M. (1993). *The red queen: Sex and the evolution of human nature.* New York: Viking.

Ridley, M. (1996). *The origins of virtue.* London: Viking.

Rowe, L., & Houle, D. (1996). The lek paradox and the capture of genetic variance by condition dependent traits. *Proceedings of the Royal Society of London B, 263,* 1415–1421.

Thornhill, R. (1997). The concept of an evolved adaptation. In G. Cardew (Ed.), *Characterizing human psychological adaptations* (Ciba Foundation Symposium 208, pp. 4–13). London: Wiley.

Thornhill, R. (1998). Darwinian aesthetics. In C. Crawford & D. Krebs (Eds.), *Handbook of evolutionary psychology: Ideas, issues, and applications* (pp. 543–572). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Tooby, J., & Cosmides, L. (1990a). On the universality of human nature and the uniqueness of the individual: The role of genetics and adaptation. *Journal of Personality, 58,* 17–67.

Tooby, J., & Cosmides, L. (1990b). The past explains the present: Emotional adaptations and the structure of ancestral environments. *Ethology and Sociobiology, 11,* 375–424.

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 19–136). New York: Oxford University Press.

Wilson, E. O. (1999). *Consilience: The unity of knowledge.* New York: Random House.

Wright, R. (1994). *The moral animal: Evolutionary psychology and everyday life.* New York: Pantheon.

Zahavi, A., & Zahavi, A. (1997). *The handicap principle: A missing piece of Darwin's puzzle.* New York: Oxford University Press.

Epicycles and Explanations in Evolutionary Psychology

Robert C. Richardson
Department of Philosophy
University of Cincinnati

Evolutionary psychology incorporates the view that human cognitive and social abilities are the consequences of natural selection: Human inferential capacities, choices of mates, sexual preferences, and tendencies to aggression are adaptations no less than are analogous traits in social insects or our primate kin. There is no serious question that evolutionary explanations and selectionist explanations are testable.[1] Illustrations are easy to come by (cf. Endler, 1986). The sickle cell gene ranges widely through central Africa, India, and Central America. In heterozygote form, it provides some immunity to malaria and is sustained by balancing selection. The discovery of penicillin in 1928 imposed simple, extreme, directional selection. The result is antibiotic-resistant strains of bacteria. *Cepaea nemoralis* is a snail common in Europe. Thrushes are fond of the snails, and the broken shells left behind offer a record of selection that varies with habitat and season. The result is a shifting pattern of selection that results in a polymorphic population. All these are adaptations, shaped and maintained by natural selection. It is, likewise, an easy matter to find traits that are not the result of natural selection. To use an elegant example from Darwin (1859/1964), skull sutures are certainly useful to humans, because they facilitate passage through the birth canal. They have an important, and even essential, current use. Skull sutures are nonetheless not an adaptation for parturition, because birds and reptiles also have skull sutures, although they hatch rather than being live born. Sutures are the consequence of evolution, but not of natural selection.

What Ketelaar and Ellis (this issue) think of as the Lakatosian "hard core" of evolutionary theory is thus secure, insofar as it amounts to a commitment to natural and sexual selection as central to evolution. This by no means implies that all evolutionary explanations are testable, or that it is practically feasible to evaluate the claim that some particular trait is the product of natural selection. The critical question for evolutionary psychology is the practical one: Can we, in practice, validate the explanations offered for human psychology?

The study of adaptation within a robustly evolutionary framework involves inferring historical process from contemporary products. The focus is on historical sequence and causal antecedents, emphasizing prior conditions as determinants of contemporary patterns

[1] In its classic formulations, due to Popper, falsifiability is used as a demarcation criterion, distinguishing science from nonscience. Although at one point Popper did hold, notoriously, that evolutionary biology was on the nether side of his demarcation criterion, he was wrong (see Brandon, 1990, for discussion).