

Letters to the Editor

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How Did the Horned Lizard Get Its Horns?

IN THEIR BREVIA "HOW THE HORNED LIZARD got its horns," K. V. Young *et al.* present an important example of natural selection in the wild, suggesting that loggerhead shrike predation drove the evolution of elongated horns in the flat-tailed horned lizard (2 Apr., p. 65). Although the authors acknowledge that selective forces other than shrike predation may also be involved, they make no mention of the possibility that one of these potential forces could have been the first instigator of the directional selection for horn elongation. Under this hypothetical scenario, the horns would have then only subsequently served to reduce shrike predation. Other likely cases of preadaptation [or exaptation (1)] have been described in vertebrates (2–5), some of which involve important transitions in evolutionary history. Perhaps the role of preadaptation in evolution is of great importance and is deserving of more widespread appreciation. Given the possibility of a preadaptation scenario in the evolution of crown horns in horned lizards, I find it ironic that Young *et al.* commented on the weakness of “just-so stories” (6) and also chose a title that reads remarkably like the titles of Kipling’s stories. Until presented with evidence suggesting that the horns were mere nubs until the onset of shrike predation, I will remain convinced that “How the horned lizard got its horns” is a poor choice for what is presumably meant to be an informative title.

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References

1. S. J. Gould, S. Vrba, *Paleobiology* **8**, 4 (1982).
2. K. P. Dial, *Science* **299**, 402 (2003).
3. S. J. Gould, *The Panda’s Thumb* (Norton, New York, 1980).
4. D. J. Futuyma, *Evolutionary Biology* (Sinauer, Sunderland, MA, ed. 3, 1998).
5. N. H. Shubin *et al.*, *Science* **304**, 90 (2004).
6. R. Kipling, *Just So Stories* (Doubleday, New York, 1902).

IN THEIR BREVIA "HOW THE HORNED LIZARD got its horns" (2 Apr., p. 65), K. V. Young *et al.* claim to have direct evidence of the defensive function of the long bony horns

that fringe the lateral and posterior margins of the head of the flat-tailed horned lizard (*Phrynosoma mcalli*). They show elegantly and convincingly that loggerhead shrikes (*Lanius ludovicianus*) prey on lizards with relatively short horns (corrected for body size) and that this source of mortality produces directional selection favoring longer horns. Unfortunately, the authors incorrectly conclude that “defense against shrike predation is one factor driving the radical elongation of horns in some species of horned lizards.” This conclusion is incorrect because they did not show that the lizards use their horns to defend themselves against shrikes, nor did they show that longer horns are better for defense. Suppose that lizards with longer horns also are more vigilant, escape faster, spend less time in the open, are more cryptic, or have other traits that reduce the chance they are seen, caught, killed, and eaten by shrikes. Any of these correlated traits could also explain the observed pattern of predation and selection. Observations of how shrikes attack lizards and how lizards defend themselves, and measurements of predation rates on lizards with experimentally shortened and lengthened horns are needed to test the validity of the intuitively attractive suggestion that the horns of horned lizards are defensive. At present, this explanation for the adaptive function for horns remains a “just-so story.”

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IN THEIR BREVIA "HOW THE HORNED LIZARD got its horns" (2 Apr., p. 65), K. V. Young *et al.* explain the causal processes of how the flat-tailed horned lizards (*Phrynosoma mcalli*) developed parietal horns as a defense against the impaling capabilities of the loggerhead shrike (*Lanius ludovicianus*). However, the actual selection factor that the horns help to defend the lizards from—how shrikes kill their vertebrate prey—was not discussed. Shrikes prey differentially on invertebrates and vertebrates. A shrike (*Lanius* spp.) kills its vertebrate prey (1, 2), including species that may weigh as much as an adult shrike (30 to 75 g depending on the species of shrike), with a bite directed at the portion of the prey’s neck immediately posterior to the skull. The bite disarticulates the vertebral column. When the prey is dead, a shrike will fly to a convenient perch where

the prey is either impaled on a sharp point or dragged and lodged into a fork of a branch (3). This allows a shrike to pull the prey apart with its bill into portions that can be swallowed.



Flat-tailed horned lizard in defensive posture.

Natural selection can only occur if individuals survive a given experience and are able to transmit that information to conspecifics or their progeny (4). Given my long experience in the field with shrikes, the attack period is the only possible event when a horned lizard could experience and escape the attacks of the shrike to the nape. Further, it is also possible that attacks by inexperienced juvenile shrikes, allowing for a greater percentage of escapes (3), on the horned lizards gave rise to the selection for elongated horns. It also does not make evolutionary sense for a trait to be incorporated into a prey species, as a result of a predator’s behavior, that results in all cases in its death (i.e., the impaling stage). Hence, although I accept the authors’ conclusion that “defense against shrike predation is one factor driving the radical elongation of horns,” I suggest that the parietal horns developed as a defense against shrike attacks to the nape region and not against their being impaled after they are dead. Thus, the posterior-directed (and perhaps even the lateral-directed) cranial horns of a *Phrynosoma* lizard are a potential danger to a shrike, aimed as they are at a shrike’s eye when it goes in for a lethal bite at the lizard’s neck.

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References

1. T. J. Cade, E. C. Atkinson, *Birds N. Am.* **671** (2002).
2. R. Yosef, *Birds N. Am.* **231** (1996).
3. R. Yosef, *Vogelwarte* **42**, 25 (2003).
4. M. W. Strickberger, *Evolution* (Jones & Bartlett, Boston, 1990).

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LETTERS

Response

THE TITLE OF OUR PAPER WAS MEANT AS AN allusion to the *Just So Stories* of Kipling (1), which are often used as a shorthand criticism for unsubstantiated adaptive arguments. It is a bold statement, and we thought it so clearly over the top that it would not be taken as a literal explanatory title. The problem of identifying adaptations and their causes has (at least) two schools of thought, one that focuses on the source of the original character state change (as described by Fouts), and one that focuses on current value and selection (as described in our Brevia). Heritable traits that have current adaptive value, as is the case for the horns of flat-tailed horned lizards (*Phrynosoma mcalli*), will continue to change through natural selection, thereby leading to continued adaptation and explaining in part how horned lizards got elongated horns. The question of whether any horns on the head of horned lizards existed before shrike predation drove them to elongated states (i.e., were “preadapted”) is an interesting one, but one that is only answerable through comparative analyses with full phylogenetic information and ancestral environmental conditions (2). Although we have not performed such an analysis and could probably never reconstruct the ancestral predation conditions, it is worth noting that of the 13 species of horned lizards currently extant, *P. mcalli* has the longest relative horn lengths and belong to the most derived species group (3, 4), while some other species in the genus (e.g., *P. douglassi*) have virtually no parietal or squamosal horns (i.e., the nubs mentioned by Fouts).

Christy correctly points out the two primary shortcomings of any covariance analysis of selection: It is impossible to rule out every unknown unmeasured character that could drive the observed selection, and covariance analyses usually cannot assign a mechanism of selection because they are not manipulative studies (5). In the case of shrike predation selecting on horn length in lizards, however, we have measured a fitness component undeniably assignable to predation by a single predator. We also know that lizards routinely use their horns behaviorally in defense, jabbing them backward into anything that restrains them, often with enough force to draw blood from human fingers. It seems most parsimonious to conclude that the fitness advantages conferred by longer horns with respect to shrike predation accrue because of their defensive function, rather than to invoke some unknown correlated character that generates the observed covariance.

Yosef describes the predation behavior of shrikes attacking their prey and in doing so explains some of the critical natural

history driving the natural selection we observed. We regret that space limitations prevented us from fully describing the fascinating behavior of shrikes, and the comments of Yosef help to fill in some of these blanks and support the interpretations in our paper. The impaling behavior of shrikes provides a unique sampling of successful predation, but we never intended to imply that horn length served to prevent the impaling process per se.

The defensive behavior of flat-tailed horned lizards is consistent with the interpretation that longer horns deter attacks by shrikes. When attacked or grasped, flat-tailed horned lizards stab their spines into the offending object. In the case of human fingers, this behavior often results in bleeding and immediate release of the lizard. The predation behavior of shrikes, which typically attack near the neck, would place vulnerable areas of the predator’s face within range of the parietal and squamosal horns of flat-tailed horned lizards. Lizards with relatively longer horns would be expected to be more likely to be able to reach and inflict damage on a predator, thereby interrupting the predation sequence and escaping.

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References

1. R. Kipling, *Just So Stories* (Doubleday, New York, 1902), p. 249.
2. H. W. Greene, *Fieldiana Zool.* **31**, 1 (1986).
3. K. Zamudio, W. L. Hodges, *Mol. Phylogenet. Evol.* **31**, 961 (2004).
4. R. R. Montanucci, *Contrib. Sci. Nat. Hist. Mus. Los Angeles County* **390**, 1 (1987).
5. E. D. Brodie III, A. J. Moore, F. J. Janzen, *Trends Ecol. Evol.* **10**, 313 (1995).

The Importance of Educating Girls

IN HIS EDITORIAL “SUSTAINABLE DEVELOPMENT” (30 Apr., p. 649), J. Sachs eloquently describes scientists’ increasing concern about the difficulty of providing for a growing global population in sustainable ways.

It will be much easier to achieve decent, sustainable living standards if population growth slows more rapidly. Extensive research from diverse countries shows that while family planning and basic health care clearly play major (and reinforcing) roles, expanding education for women where female education levels are now relatively low is probably the single most effective way to encourage a shift to smaller, healthier, and better educated families (1,

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2). Education boosts women's earning capacity roughly as it does men's (3–5). Education also improves women's "bargaining position" in the family and society. As education and resulting higher earning capacity increase the opportunity cost of women's time, couples tend to have fewer children and to invest more in the health and education of each child. A World Bank study of 100 countries finds that when women gain four years of education, on average, fertility per woman drops by about one birth (6), and another study of 65 countries finds that doubling the proportion of women with a secondary education from 19 to 38% would reduce average fertility rates from 5.3 to 3.9 children (and improve child mortality too) (2).

Yet despite the benefits of female education, the UN estimates that 104 million school-age children—60 million of them girls—are not in school each year (7). The World Bank reports that in sub-Saharan Africa, more than half of girls do not complete a primary education (8). One reason is that even basic education carries considerable costs to parents—tuition may come to one-fourth of poor families' incomes. (Even when education is supposedly free, "extra fees" and indirect costs for schooling may burden poor families.) Yet the benefits of education accrue mainly to the girls when they grow up, to the families they have in their turn, and to their societies, not immediately to the parents who decide on schooling. The benefits may well seem distant and dicey to the parents, particularly in cultures where girls "marry out" and where poverty is widespread and the quality of available education is very poor.

Many countries—from Bangladesh, to China, to Mexico—have strong programs to improve education for girls and boys. But far more needs to happen to bring more girls into school, ensure that they stay beyond primary school, and provide them decent quality education. Although many if not most people support such efforts, it's a question of priority.

As Lawrence Summers emphasized when at the World Bank and the Treasury Department, once all its benefits are considered, female education may well be the highest return investment available to the developing world (9). The impact of female education on family size and well-being—and so also on population growth and the prospects for sustainable development—is enormous. Female education thus deserves far more priority in public policy both in particular countries and internationally. An international effort under UN aegis is under way to achieve "Basic Education for All" by year 2015. Whether this effort accomplishes its goal

depends on greater national and international political commitment, on increased financial support, on real education reforms, and thus on greater public understanding.

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References

1. B. Herz, G. B. Sperling, *What Works in Girls' Education: Evidence and Policies from the Developing World* (Council on Foreign Relations, New York, 2004).
2. K. Subbarao, L. Raney, *Econ. Dev. Cultural Change* **44** (no. 1), 105 (1995).
3. G. Psacharopoulos, H. A. Patrinos, "Returns to Investment in Education: A Further Update," World Bank Policy Research Working Paper 2881 (World Bank, Washington, DC, 2002).
4. T. P. Schultz, *World Dev.* **30** (no. 2), 207 (2002).
5. T. P. Schultz, in *Women's Education in Developing Countries: Barriers, Benefits, and Policy*, E. King, M.A. Hill, Eds. (Johns Hopkins Univ. Press, Baltimore, MD, 1993).
6. S. Klasen, "Does Gender Inequality Reduce Growth and Development? Evidence from Cross-Country Regressions," Policy Research Report on Gender and Development Working Paper No. 7 (World Bank, Washington, DC, 1999).
7. UNESCO, *Education for All Global Monitoring Report 2003/4* (UNESCO, Paris, 2003).
8. B. Bruns, A. Mingat, R. Rakotomalala. "Achieving Universal Primary Education by 2015: A Chance for Every Child" (World Bank, Washington, DC, 2003).
9. L. H. Summers, "Investing in All the People: Educating Women in Developing Countries," EDI Seminar paper No. 45 (World Bank, Washington, DC, 1994).

Future Global Warming Scenarios, Take 2

IN HIS LETTER "FUTURE GLOBAL WARMING scenarios" (16 Apr., p. 388), W. S. Broecker critiques our recent study for the Department of Defense on the national security implications of abrupt climate change (1). We admire Broecker and his work, which importantly informed the scientific underpinning of the study, and although we agree with the substance of his comments on the science of climate change, his critique does not accurately reflect the content of the report—or its intent.

First, we make no predictions. As our opening paragraph explicitly states: "The purpose of this report is to imagine the unthinkable—to push the boundaries of current research on climate change so we may better understand the potential implications on United States national security... We have created a climate change scenario that although not the most likely, is plausible, and would challenge United States national security in ways that should be considered immediately."

Broecker is correct in asserting that the most likely scenario is one of regional climate change (locations uncertain) many decades from now. But that would have little impact on today's strategic planning for national security. That is why we examined the plausibility of a low-likelihood,

LETTERS

near-term abrupt climate change scenario across all the major geographies.

Why should abrupt climate change matter to the Department of Defense? Because thinking the unthinkable is fundamental. In 2000, the senior writer of this report led one of the teams that explored "National Security in the 21st Century" with the Hart-Rudman Commission. The Commission's report, published in the summer of 2001, concluded that a major terrorist attack on U.S. soil was likely in the next quarter century and that we were ill prepared to either detect or stop it. At the time, this was considered a low-probability event; today, the government is under considerable fire for not seriously considering such scenarios.

Our climate change study was conducted and shared in that spirit. It was not an attempt to do climate science or influence climate policy. But its conclusions strongly suggest that it is in our national security interests to increase support for climate science so that we can gain better insight into the timing, nature, and likelihood of abrupt climate change.

PETER SCHWARTZ AND DOUG RANDALL

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Reference

1. P. Schwartz, D. Randall, "Abrupt climate change," report prepared by Global Business Network (GBN) for the Department of Defense, available at www.gbn.org/ArticleDisplayServlet.srv?aid=26231.

CORRECTIONS AND CLARIFICATIONS

Perspectives: Draft versions of the PDFs for three Perspectives (Busse, Stolow, and Levin) in the issue of 10 Sept. were inadvertently posted. The correct versions were posted on 13 Sept. at approximately 4 p.m. The HTML and print versions of these articles were correct. If you downloaded a PDF of one of these Perspectives prior to the above date, please return to Science Online to obtain the correct version.

TECHNICAL COMMENT ABSTRACTS

COMMENT ON "Role of NMDA Receptor Subtypes in Governing the Direction of Hippocampal Synaptic Plasticity"

Dmitri A. Rusakov, Annalisa Scimemi, Matthew C. Walker, Dimitri M. Kullmann

Liu *et al.* (Reports, 14 May 2004, p. 1021) reported that NMDA receptors containing NR2A and NR2B subunits are selectively coupled to long-term potentiation (LTP) and long-term depression (LTD), respectively. Because NR2B (but not NR2A) receptors occur outside synapses, and can be activated by glutamate spillover, this principle may underlie synaptic homeostasis.

Full text at www.sciencemag.org/cgi/content/full/305/5692/1912b

RESPONSE TO COMMENT ON "Role of NMDA Receptor Subtypes in Governing the Direction of Hippocampal Synaptic Plasticity"

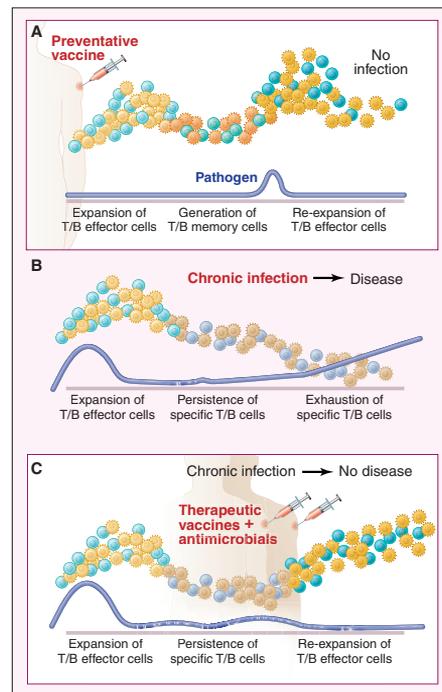
Tak Pan Wong, Lidong Liu, Morgan Sheng, Yu Tian Wang

Although we agree with Rusakov *et al.* that activation of extra-synaptic NR2B receptors by glutamate spillover may lead to heterosynaptic LTD, our data also support a role of synaptic NR2B receptors in homosynaptic LTD. The proposed role of extrasynaptic NMDA receptor-mediated LTD in synaptic homeostasis may thus be temporally limited.

Full text at www.sciencemag.org/cgi/content/full/305/5692/1912c

Random Samples: "Reason to exist" (13 Aug., p. 941). Susan Ganter, the new executive director of the Association for Women in Science (AWIS), is on leave from her position as associate professor of mathematical sciences at Clemson University and remains involved in educational and research activities. The item wrongly implied that she no longer has an affiliation with Clemson and that she would not be continuing her work in mathematics and education.

Special Issue on Immunotherapy: Viewpoint: "Therapeutic vaccines for chronic infections" by B. Autran *et al.* (9 July, p. 205). The purple lines in panels (B) and (C) of Fig. 1 were printed incorrectly. The correct figure appears here. Also, the authors would like to acknowledge support from the European Union.



Reports: "Antigen bias in T cell cross-priming" by M. C. Wolkers *et al.* (28 May, p. 1314). Two of the symbols in Fig. 3B were denoted incorrectly. The closed triangles represent RMA-S sE7-GFP-NP cells, and the closed circles represent RMA-S sNP-GFP-E7 cells.