



LETTERS

edited by Etta Kavanagh

When the Oil Supply Runs Out

THE ARTICLE "THE LOOMING OIL CRISIS COULD ARRIVE UNCOMFORTABLY SOON" (R. A. KERR, *News of the Week*, 20 Apr., p. 351) is far too equivocal in its discussion of such a vital topic, noting first that the most likely scenario is a resource-constrained peak by 2020, then that political factors must be taken into account in a discussion of peak oil production, and finally concluding that there is so much uncertainty that "predicting the peak may not be worthwhile."

Much, but not all, of the political uncertainty regarding production rates can be captured by partitioning conventional oil extraction into OPEC and non-OPEC components. This has been done by ExxonMobil and others (1–4); ExxonMobil has concluded that non-OPEC production will peak by 2010. On the basis of this forecast, ExxonMobil has publicly stated that it will build no new refineries, presumably because the crude supplies needed may not be available from OPEC producers. The high and rapidly fluctuating U.S. gasoline prices currently being experienced are due in large part to a shortage of domestic refinery capacity, so that we are in fact already feeling the effects of an imminent non-OPEC peak.

Recently, Ecuador rejoined OPEC, and Angola has also become a member. Over the next two or three years, it will become clear that crude oil is indeed a finite resource, and we will be forced to adapt to much higher petroleum prices as India and China continue to expand their automobile and airline fleets. Fortunately, there are many ways to cope with this new state of affairs, first and foremost by embracing energy efficiency and conservation not as virtues for the elite, but as urgent and universal national goals.

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Testosterone and Male Fertility in Red Deer

IN "MALE FERTILITY AND SEX RATIO AT BIRTH IN red deer" (*Reports*, 1 Dec. 2006, p. 1445), M. Gomendio *et al.* discovered that the proportion of males born to red deer was correlated with the degree of fertility of the fathers. These observations support the hypothesis that the strongly beneficial trait of male fertility favors the production of more sons that can then perpetuate this trait. This study provides

insight into possible extragenetic contributions to sex ratios among offspring that likely have implications in other mammalian species, including humans.

The proportion of male births has been steadily declining in some human populations from North America and Europe (1). The reason for this decline is unknown, but the phenomenon has been associated with exposure to chemical pollutants (2–5). Among the Aamjiwnaang First Nation community (Ontario, Canada), not only is the proportion of male live births decreasing, but the magni-

tude of this disproportion has increased over time (6). Investigators have suggested that this localized disruption in sex ratio is a consequence of the abundant chemical industry in the vicinity (6).

A decrease in the proportion of male offspring has been associated with reduced testosterone levels or decreased testosterone/gonadotropin ratios in fathers (7, 8). Gomendio *et al.* did not report testosterone levels among fathers in the studied red deer population. However, they associate fertility—the trait linked to altered sex ratio—with antler size. Testosterone is a major determinant of antler growth (9). Thus, it can be hypothesized that androgen status of fathers influences the proportion of males sired and that the decreasing proportion of male births documented in many human populations is due to declining testosterone levels among the fathers. A possible role for testosterone in regulating sex ratios of offspring has been debated for some time, but the issue remains unresolved. The study by Gomendio *et al.* provides new insight into a potential role for hormones in determining offspring sex in mammals, including humans.

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IN "MALE FERTILITY AND SEX RATIO AT BIRTH IN red deer" (*Reports*, 1 Dec. 2006, p. 1445), M. Gomendio *et al.* reported that in red deer, (i) male fertility is significantly and positively correlated with offspring sex ratio (OSR) (proportion of males), and (ii) the percentage of morphologically normal sperm correlates positively with OSR.



A decade of
animal cloning

990



Gravel piles
in space

993

These authors interpreted their results as supporting adaptive theory, but were uncertain of the identity of the proximate cause(s) of variation in OSR. They also noted that although much work has been done by adaptive theorists on OSRs of female mammals, little has been done by them on OSRs of male mammals. However, there are prodigious quantities of data relating the variation of men's OSRs to selected environmental factors. For instance, men's OSRs are affected by nine different adverse chemical exposures, five different pathological conditions, and four types of occupational exposure (1). In all 18 of these conditions, the OSRs correlated positively and significantly with men's testosterone concentrations. Indeed, there is strong evidence that the sexes of offspring of mammals (including humans) are partially controlled by the hormone levels of both parents around the time of conception (2, 3). This would suggest that high levels of testosterone around the time of conception are associated with the subsequent births of sons.

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Response

WE REPORTED THAT MORE FERTILE RED DEER males, with a higher proportion of morphologically normal spermatozoa, produce a greater proportion of male offspring, who are likely to inherit enhanced fertility. Le Blanc and James suggest that testosterone may mediate the relationship between male fertility and offspring sex ratio (OSR) in this and other species, including humans. Le Blanc notes that, in our study population, male fertility is associated with antler size (1) and, on the basis of his premise that testosterone is a major determinant of antler growth, concludes that differences in OSR may be due to differences in testosterone levels between males. LeBlanc and James propose a role for testosterone by extrapolating from studies in humans where indirect evidence suggests that biases in OSR linked to environmental factors could be caused by changes in testosterone levels.



Although the idea has been around for some time, the hypothesis that testosterone influences OSR has not been properly tested. We do not have testosterone data from our OSR experiment, but we do have data on testosterone levels for a captive red deer population throughout the year ($N = 18$) and for a large sample of males from natural populations during the breeding season ($N = 77$), which we have used to test the relationships proposed.

Red deer are seasonal breeders and cast and regrow their antlers every year. In our captive population, testosterone levels remained low during antler growth, increased during antler mineralization, reached a peak just before the breeding season started, and decreased thereafter, similar to previous reports (2, 3). Thus, although testosterone may control the timing of key events in the antler cycle, the observation that testosterone levels are low during antler growth supports the current view that the presumed positive link between testosterone levels and antler size is mistaken (4, 5). In fact, the opposite may be true, at least in red deer, because males treated with anti-androgens grow larger antlers than controls, and testosterone reduces antler growth by influencing IGF-1 binding, the latter having an important role in antler growth (5).

Further evidence against the presumed link between testosterone levels and antler size comes from natural populations, where we found no relationship between males' testosterone levels during the breeding season and antler size. It should be noted that both variables are uncoupled in time, i.e., antlers grow in spring, when testosterone levels are minimal, and remain unchanged during the breeding season, when testosterone levels increase. Thus, the idea that testosterone levels during the breeding season are associated both with antler size and OSR would imply that males with higher testosterone levels during spring have increased antler growth rates, and that dif-

ferences between males in testosterone levels remain consistent during the breeding season when absolute values increase. Further studies are needed to test these possibilities.

The annual cycle in testosterone levels is mirrored by changes in testes size, and, in natural populations, males with higher testosterone levels have larger testes and produce more sperm. However, the potential links between testosterone and other aspects of semen quality remain to be demonstrated.

The close relationship between testosterone and sperm production justifies the use of sperm numbers as an indirect measure of testosterone levels for each male. This allows us to test the presumed relationship between testosterone and OSR for the males used in our OSR experiment. In our study sample, there was no relationship between numbers of spermatozoa and OSR. Thus, it seems unlikely that differences in testosterone levels between males during the breeding season explain the biases in OSR observed.

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Further Notes on Quasi-Crystal Tilings

WE APPRECIATE THAT *SCIENCE* HAS CLARIFIED its news article ("Quasi-crystal conundrum opens a tiling can of worms," News of the Week, J. Bohannon, 23 Feb., p. 1066; see Corrections and Clarifications on page 982 in this issue) regarding our paper "Decagonal and quasi-crystalline tilings in medieval Islamic architecture" (Reports, 23 Feb., p. 1106). We certainly recognized that our study builds on earlier work, as acknowledged in our references (3–6, 14, 18–19), and citations therein, although more can be said. Many authors from Hankin in 1925 [(14) in our Report] to Wade

CORRECTIONS AND CLARIFICATIONS

News of the Week: “Quasi-crystal conundrum opens a tiling can of worms” by J. Bohannon (23 Feb., p. 1066). The article presented opinions of Dov Levine of the Israel Institute of Technology and Joshua Socolar of Duke University in a way that has led to misperceptions. The article discussed a paper by Peter Lu and Paul Steinhardt (*Science*, 23 Feb., p. 1106) on the use of tiling designs by medieval Islamic architects that form the basis of nonrepeating patterns called quasi-crystals. It went on to report that Levine and Socolar “doubt that the architects truly understood quasi-crystals.” That comment—the only outside comment in the article on the paper’s conclusions—is consistent with what was concluded in the Lu-Steinhardt paper itself; it does not, and was not meant to, contradict the central claim that the architects used a method capable of creating a perfect quasi-crystal tiling. The article also included a quote from Emil Makovicky of the University of Copenhagen that his earlier publication on Islamic tiling patterns was cited by Lu and Steinhardt “...in a way that [the ideas] look like their own.” Immediately following, Levine and Socolar were quoted regarding Makovicky’s contributions to the field. The context of their quotes implied that they agreed with Makovicky’s characterization, but neither of them did so.

Special Section: Sustainability and Energy: Perspectives: “Biomass recalcitrance: engineering plants and enzymes for bio-fuels production” by M. E. Himmel *et al.* (9 Feb., p. 804): The legend describing panels B and C of Fig. 1 was reversed in the online version of the paper. Panel B shows the atomic force micrograph, and panel C shows the scanning electron micrograph. The legend was correct in print. The correct text was posted online on 13 February.

TECHNICAL COMMENT ABSTRACTS

COMMENT ON “A Centrosome-Independent Role for γ -TuRC Proteins in the Spindle Assembly Checkpoint”

Stephen S. Taylor, Kevin G. Hardwick, Kenneth E. Sawin, Sue Biggins, Simonetta Piatti, Alexey Khodjakov, Conly L. Rieder, Edward D. Salmon, Andrea Musacchio

Müller *et al.* (Reports, 27 October 2006, p. 654) showed that inhibition of the γ -tubulin ring complex (γ -TuRC) activates the spindle assembly checkpoint (SAC), which led them to suggest that γ -TuRC proteins play molecular roles in SAC activation. Because γ -TuRC inhibition leads to pleiotropic spindle defects, which are well known to activate kinetochore-derived checkpoint signaling, we believe that this conclusion is premature.

Full text at www.sciencemag.org/cgi/content/full/316/5827/982b

COMMENT ON “A Centrosome-Independent Role for γ -TuRC Proteins in the Spindle Assembly Checkpoint”

Beth A. A. Weaver and Don W. Cleveland

Müller *et al.* (Reports, 27 October 2006, p. 654) proposed a role for microtubule nucleation in mitotic checkpoint signaling. However, their observations of spindle defects and mitotic delay after depletion of γ -tubulin ring complex (γ -TuRC) components are fully consistent with activation of the established pathway of checkpoint signaling in response to incomplete or unstable interactions between kinetochores of mitotic chromosomes and spindle microtubule.

Full text at www.sciencemag.org/cgi/content/full/316/5827/982c

RESPONSE TO COMMENTS ON “A Centrosome-Independent Role for γ -TuRC Proteins in the Spindle Assembly Checkpoint”

Hannah Müller, Marie-Laure Fogeron, Verena Lehmann, Hans Lehrach, Bodo M. H. Lange

Weaver and Cleveland and Taylor *et al.* contend that our data on the involvement of γ -tubulin ring complex (γ -TuRC) in the spindle assembly checkpoint (SAC) can be fully explained by kinetochore-derived checkpoint signaling. We maintain that (i) the interactions of γ -TuRC with Cdc20 and BubR1 and (ii) the activation of SAC by γ -TuRC depletion, in addition to the abrogation of kinetochore microtubule interactions, argue for a more complex mechanism of SAC signaling.

Full text at www.sciencemag.org/cgi/content/full/316/5827/982d

(1), Critchlow (2), and Kaplan (3) have related Islamic geometric patterns to configurations of polygons, including some with the same outlines as the decorated girih tiles introduced in our paper. Bonner [(19) in our Report] has applied these ideas to self-similar geometric patterns with five-fold and other symmetries. Makovicky [(18) in our Report], and previously Zaslavsky *et al.* (4) and Chorbachi [(31) in our Report], suggested relations between certain historic Islamic tilings and Penrose tilings based on studies of small isolated motifs or fragments embedded within manifestly periodic patterns.

We gladly acknowledge all these contributions, which complement our own. However, we wish to emphasize a few distinctions here. First, our approach was founded on the historical record, particularly the Topkapi scroll first understood and published by Gulru Necipoglu (Harvard University), who guided us. Insisting on exact reconstructions of historical monuments resulted in some differences from previous work; for example, our analysis of the Gunbad-i Kabud tomb tower (Figs. 2 and S6), based directly on archival photographs, differs systematically from the transcription used in reference (18) and reveals plainly the intentional periodicity and regular deviations from a

true Penrose tiling. Second, our explanation of these patterns clearly differs from earlier ideas: We propose that historical designers constructed a wide range of patterns by tessellating with the same five units (“girih tiles”) described in our paper, not merely polygons but shapes with specific interior line decorations that form the pattern when the tiles are joined together. Constructing patterns by laying these girih tiles edge to edge this way is simpler than other proposed methods; we have observed young children successfully applying it in the classroom. Moreover, other methods generate many patterns that do not appear historically; by contrast, we presented a series of patterns from historically significant buildings, scrolls, and Qurans throughout the medieval Islamic world that can all be constructed from the same five girih tiles (including their decorations). Third, our analysis of the Darb-i Imam shrine revealed two other novel elements—the explicit subdivision of these girih tiles into smaller girih tiles of the same shape, and a large fragment based on decagonal symmetry that is not embedded in a periodic matrix, properties sufficient to transform the Darb-i Imam shrine pattern into an infinite quasi-crystalline tiling. Our conclusions were guarded, concurring with the remarks by Socolar and Levine in the accompanying news article, suggesting that evidence beyond a single large fragment is needed to prove that the designers understood this possibility. We hope our small contribution, combined with the earlier works, will lead to further explorations of these impressive works of art and mathematics.

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Letters to the Editor

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