

Condensed-phase nanotubes

SIR — Carbon nanotubes¹ are conventionally prepared by gas-phase deposition in arc reactors, or by thermal decomposition of hydrocarbons². We have found that the synthesis of nanotubes from a condensed phase is also possible. Specifically, we have prepared multi-walled nanotubes by passing an electric current between carbon

electrodes in molten lithium chloride.

A simple carbon crucible, made by drilling a cylindrical hole (2.5 cm × 3 cm) in the centre of one face of a 5 × 5 × 5-cm cube of high-purity carbon, was filled with around 1 g of lithium chloride and heated to its melting point (600 °C) in air. A 3-mm-diameter high-purity carbon rod was immersed in the melt (to a depth of about 1.5 cm) in order to form the cathode of an electrolysis cell; the crucible acts as the anode. Around 30 A was maintained through the melt for 1 min. The immersed surface of the cathode rod was eroded during electrolysis, small pits appeared and particulate material (10–30 mg) was found dispersed throughout the melt. After cooling, the solid melt was added to water in order to dissolve the lithium chloride and react with the residual lithium metal. The mixture was set aside for 4 h, then toluene was added to the aqueous suspension and the whole was agitated for several minutes.

After allowing the mixture to settle, it was found that all the solid material seemed to have passed into the toluene layer. The aqueous and organic layers were separated by careful decanting. After sonication, droplets were removed from the toluene fraction and deposited on a carbon grid for transmission electron microscopy (TEM). A microscopic solid remained after removing the toluene by evaporation.

Low-resolution TEM studies reveal the particulate material to consist of multi-walled nanotubes and spheroidal carbon particles of 30–50 nm diameter; the latter tend to cluster. These are onion-like polyhedral particles, similar to those observed by Iijima³ and Ugarte⁴. Some of the nanotubes (2–10 nm in diameter) are very long (>500 nm) and show evidence of encapsulated material (lithium chloride, oxide or possibly lithium metal). The nano-

tubes consist of 5–20 concentric layers and, unlike those produced by the vapour arc/plasma technique^{1,2}, are not always straight, but tend to form loops. The tubes collapse on prolonged irradiation (around 15 min) in the electron beam, forming irregular distorted tube-like structures. We believe that the formation of nanotubes during electrolysis may have important implications for continuous methods of nanotube production, as well as, for example, facilitating encapsulation of material within the nanotubes.

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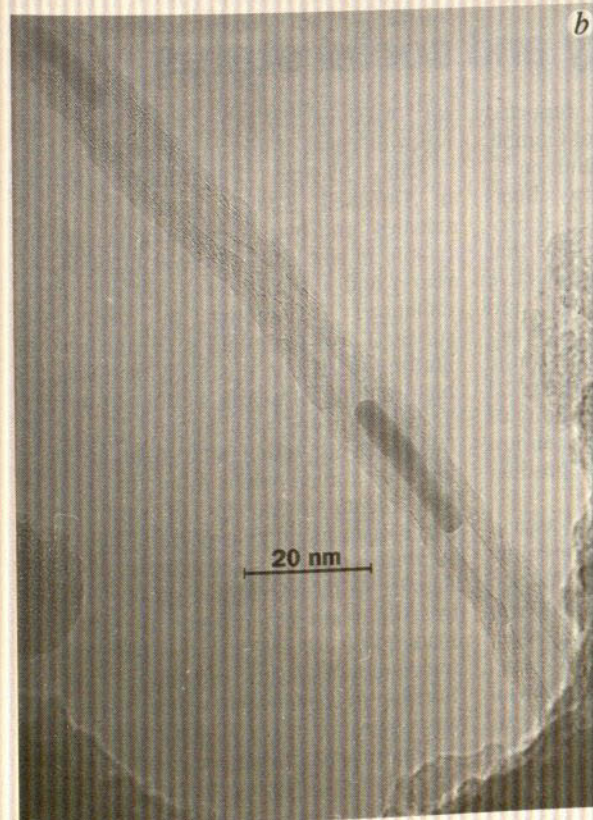
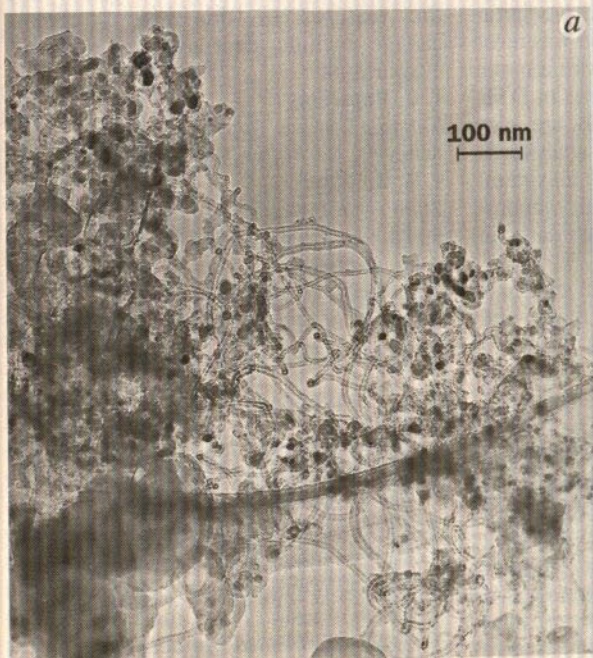
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Evaporation losing its strength

SIR — Over the past several decades, the observed increase in mean temperatures over much of the world has been a result of a disproportionate increase in nighttime temperatures¹. Here we show that, in the United States and the former Soviet Union, the evaporation of water, as measured by pan evaporimeters — simple devices consisting of a pan of water, a device to measure the water needed to return the surface to a predetermined level, and a rain gauge — has decreased. These decreases seem to be closely related to the same factors that are causing the trends in temperature.

Pan evaporation is a simple measurement of complex meteorological interactions. Although pan evaporation cannot fully represent lake evaporation and is even less indicative of ground evapotranspiration, analysis of observed trends in pan evaporation can provide considerable insights into current climate change and the impact this change may be having on agriculture and water resources.

A wide variety of evaporation pans have been used in both Russia and the United States since the nineteenth century^{2,3}. Because pan type can affect the measurement, assessment of the homogeneity of the data is important before any trend analysis is carried out.



a. Low-resolution TEM image of a sample of the particulate material collected from the LiCl melt after electrolysis. The curly structure is typical. b. High-resolution TEM image revealing encapsulated material within one of the nanotubes.

SCIENTIFIC CORRESPONDENCE

For the former Soviet Union, analysis of station history documentation³ yielded a network of 190 homogeneous evaporation-pan reporting stations, with data starting in 1951. The digital US pan-evaporation network was determined to be homogeneous by the good agreement in trends between all 746 stations and a small subset whose station history indicated no possible inhomogeneity-inducing changes.

The data used are seasonal averages of mean daily pan evaporation from May to

September for the United States, and months when there was no ice in the pans for the former Soviet Union. Pan evaporation for four of five geographical regions show significant downward trends over the past 50 years (see figure). Area-averaged time series of pan evaporation for each of these regions were compared with similar area-averaged time series for various climatic parameters, including mean minimum temperature, mean maximum temperature, diurnal temperature range (DTR), total cloud cover, and precipitation. Of these, pan evaporation was most highly correlated with DTR, with a mean r^2 of 0.48. Widespread decreases in DTR over the past several decades are also among the primary findings of analyses of asymmetrical trends in daily maximum and minimum temperature¹. Pan evaporation and DTR have varied similarly in recent decades.

The downward trend in pan evaporation over most of the United States and former Soviet Union implies that, for large regions of the globe, the terrestrial evaporation component of the hydrological cycle has been decreasing. This partially explains increases in runoff over the past two decades in the European part of the former Soviet Union⁴ and the northern United States⁵, and corresponds well with both decreases in maximum summer temperatures over these regions¹ and a decrease in growing-season degree-days (annual sum of daily temperatures above

5 °C) over the Siberian and European former Soviet Union⁶.

Karl *et al.*¹ speculated that increases in cloud cover, especially low cloud cover, may explain the decreases in DTR. Our results support this speculation, as pan evaporation has been decreasing and is correlated negatively with cloud cover with a mean r^2 of 0.34 for the five regions. Aspects of the temperature and hydrological cycles have changed in tandem over the past 50 years, and the features of this recent climate change include decreases in potential evaporation.

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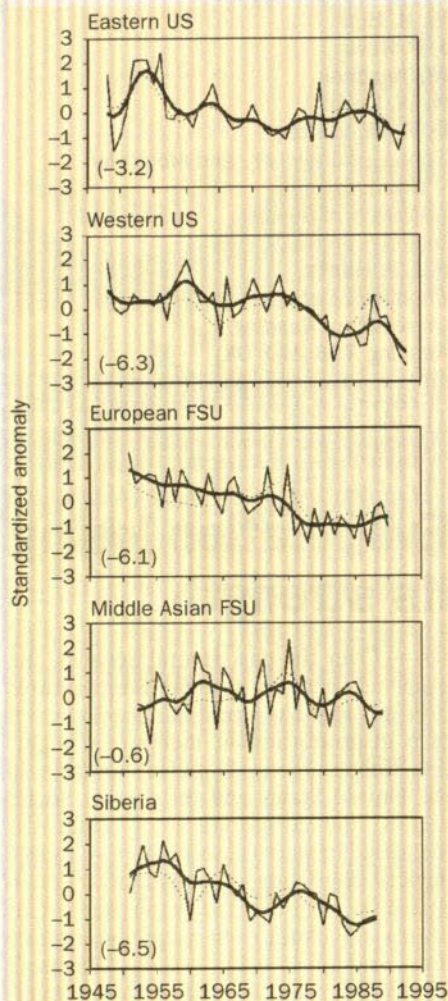
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Area-average pan evaporation (solid lines) and diurnal temperature range (DTR, dotted line, updated from Karl *et al.*¹) for three regions in the former Soviet Union and two regions in the United States. All time series are presented as standard deviation anomalies from the long-term mean values. The smooth curves result from 11-point binomial smoothing (for DTR only smoothed lines are presented). Linear trend estimates for these regions (in standardized anomalies per 100 yr) are shown in parentheses. They are significant at the 99% level except for the former Soviet Union Middle Asian region. The largest actual change in pan evaporation is in the western United States, where the area-averaged linear regression slope corresponds to a decrease in pan evaporation of 97 mm per warm season (May–September) during the past 45 years in a region with a mean pan evaporation of 1,130 mm per warm season.

Baboon fertility and social status

SIR—Packer and colleagues¹ reported that for the baboon population of Gombe, as for many other primate populations^{2–5}, high dominance status had salutary effects on several components of female reproductive success. They also reported that high status entailed certain reproductive costs, and proposed behavioural and endocrine mechanisms for their production. Here we address the generality of the costs reported, a potential methodological problem in the results, and the validity of the behavioural and endocrine assumptions of the proposed model of reproductive costs.

The conclusion that high rank is associated with increased risk of lifetime infertility¹ derived from the finding that, of Gombe females that had no successful pregnancies or matured extremely late, one was high-ranking, three had high-ranking mothers and the fifth was a 'social climber' who rose above her family to achieve high rank. The significance of the positive relationship between dominance and lifetime reproductive success was $P = 0.0675$ when all low-fertility females were included, and $P = 0.0354$ when the 2 of 37 females that never gave birth to live young were excluded from the data

set¹. Analyses for other sites^{3–6} have not reported cases of lifetime infertility.

Our 25-year longitudinal studies in Amboseli, Kenya, include 133 adult females in two wild-foraging groups (stable in size, 50% survival through two years) and a third that is partially food-enhanced (expanding in size, 90% survival). We have had only one case of lifetime infertility; this individual was not high-ranking. Similarly, neither of our two 'social climbers' was infertile. If individuals with non-lethal pathologies are more likely to survive when infant mortality is low, higher incidences of reproductive pathologies might be expected when infant survival is high. However, none of the 31 females in the expanding group has been infertile. Present evidence is, therefore, inadequate to determine either whether incidences of lifetime infertility or its relationship to social status differ significantly among groups or populations.

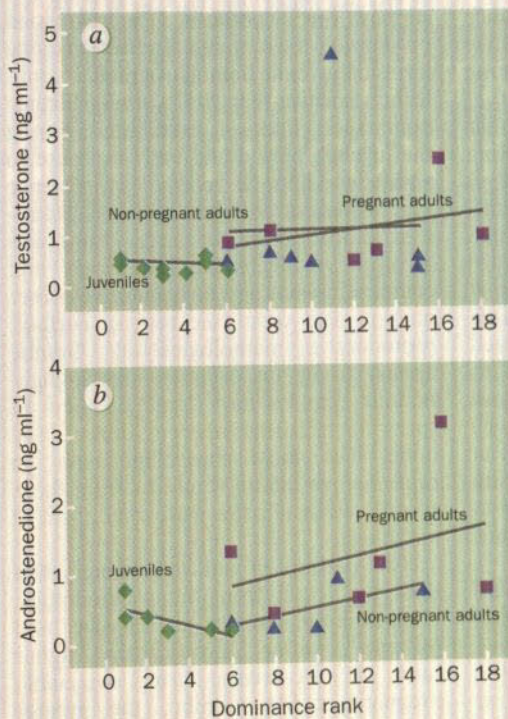
The most surprising observation made by Packer *et al.* was an association of high rank with high rates of spontaneous abortion¹, in contrast to a large literature that has implicitly or explicitly linked reproductive impairment and spontaneous abortion to the physical and

social stressors of social subordination⁷. Pregnancy was judged by the female's perineum turning pink¹, which is variable in timing and does not usually occur until 4–6 weeks into the 25-week gestation, precluding detection of early pregnancies and abortions. Therefore, while high status was clearly associated with mid- and late-pregnancy losses, the picture for early losses, and so total losses, cannot be discerned. Yet the bulk of pregnancy losses occur during this initial period and are those that seem to be most sensitive to stressors^{8,9}.

If the overall rate of stress-induced pregnancy loss was higher in subordinate females (as expected from the existing literature), the authors' apparently opposite finding might have resulted from their detection method, which is nonrandom with respect to pregnancy stage. Nor does the absence of a rank-related statistical difference in cycling time¹ remove this possibility, as the interval difference resulting from these early losses would be small. Wasser⁶ reported the same association between high status and high rate of spontaneous abortion at Mikumi; however, this same pregnancy detection method was used (personal communication).

For 474 conceptions in Amboseli in which we identified pregnancies just over two weeks from conception (less than a week after expected implantation), no relationship was found between dominance rank and rate of spontaneous abortion ($P > 0.40$); in each group, higher-ranking females tended to have lower rates of fetal loss, not higher, as reported for Gombe and Mikumi.

Packer and colleagues speculated that high rank is associated with higher rates of agonistic encounters and, as a result, with high levels of circulating androgens which would produce the reported reproductive dysfunction of dominant adults¹. Although high rates of aggression might play a role in the initial establishment of dominance¹⁰, they are not normally associated with the maintenance of the stable dominance relationships^{10–12} characteristic of adult female baboons. Nor does high rank seem to be associated with high rates of agonistic inter-



The relationship between social dominance rank and serum androgen levels in female baboons (a, testosterone; b, androstenedione; diamonds, juveniles; triangles, non-pregnant adults; squares, pregnant adults). Dominance status is presented solely as status within age–sex class; an integrated female ranking would place juveniles scattered throughout the adult female ranking and reduce any slope and significance of status. Serum was collected and analysed as reported^{15,16}, with control for season, time of day and time from darting to blood drawing. Juveniles weighing less than 5 kg, females beyond the first half of pregnancy, and lactating females with young infants were not immobilized; the data, therefore, do not include individuals in these categories.

actions^{11,12}. Moreover, the literature does not support the notion that, among primates, increased levels of aggression within the normative range of social behaviour can raise androgen levels into a pathophysiological range¹³. Should such pathologically elevated androgen levels occur, all aspects of reproduction would be impaired¹⁴, whereas Packer and colleagues noted salutary effects of dominance on most measures of reproduction.

Packer and colleagues predicted that, over the entire rank range, higher

rank should be associated with higher androgen levels. No information exists regarding wild female primates. The closest approximations are our own limited data (see figure), in which no relationship of testosterone with rank is observed, while for androstenedione the pattern for juveniles supports this prediction ($P = 0.047$), but that for adults runs counter to it ($P = 0.17$). Thus, overall, the data give little support for the notion of dominant females being exposed to even slightly higher androgen levels than subordinates.

In conclusion, without dismissing the Packer *et al.* data or suggesting that high status is always advantageous, we note that dominance rank has almost always been found either to confer advantage or to be neutral with respect to a variety of fitness components, and the Packer *et al.* report provides some of the strongest evidence thus far for those advantages. Whether the higher miscarriage rates^{1,6} result from a methodological artefact or represent a difference among sites is unknown. In either case, neither the behavioural nor the endocrine hypotheses proposed to explain the apparent Gombe result are supported by available evidence, nor are the endocrine hypotheses proposed for Mikumi⁶ applicable to Gombe. Nevertheless, Packer and colleagues rightly insist that

any fitness relationship to dominance requires adequate physiological and behavioural mechanisms to arise and be maintained, a point often ignored in the evolutionary literature and a subject of much needed research.

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PACKER REPLIES — Altmann *et al.* imply that reproductive performance is always positively correlated with dominance rank, when neither of their principal references^{2,4} provide compelling evidence of an overall relationship between rank and lifetime reproductive success. Indeed, Silk² concludes her review with the statement, "The lack of consistency among these results has created consider-

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