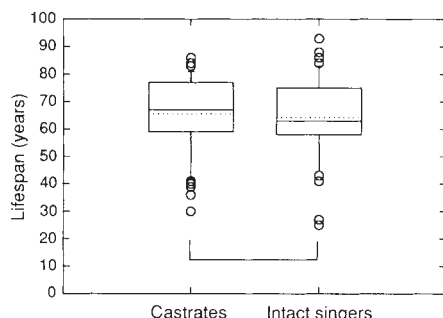


Lifespan and testosterone

SIR — Coronary heart disease and atherosclerosis are the most frequent causes of death among men. Because these conditions occur more frequently in men than in women, it is often assumed that androgens play a causative role. Indeed, correlations between circulating testosterone levels and coronary heart disease have been made, as have negative correlations between blood lipids and androgens, in particular between high-



Lifespan of castrate and intact singers displayed as box plots (matched pairs, 50 in each group). The boxes encompass the 25th–75th percentiles of the data, with the median shown as the solid horizontal line and the mean as the broken line within the box. Whisker caps indicate the 10th and 90th percentile points of the data. Data outside that range are displayed individually. The groups were compared by unpaired *t*-tests and the differences were not significant ($P = 0.65$).

density lipoprotein cholesterol and testosterone¹.

This hypothesis that testosterone may contribute to men's shorter lifespan is difficult to prove experimentally, not least because ethical considerations preclude many obvious tests. But from the sixteenth to the middle of the nineteenth century it was common practice in some European cultures to castrate prepubertal boys to prevent mutation of the voice and thus produce soprano and alto singers. Biographical data of these singers, when compared to those from a control group, should provide information on the influ-

ence of testosterone or — more generally speaking — the presence of testes on longevity.

From encyclopaedias and biographies^{2–9}, we have identified 50 castrates with outstanding reputations as singers born between 1581 and 1858. To establish a control group, we extracted from the same sources the names and dates of 200 'intact' male singers (bass, baritone or tenors) born during the same period and who had achieved comparable fame during their careers. We paired 50 of these singers with the castrates by selecting those with the most closely matched year of birth.

Over 277 years (1581–1858), there was no trend towards a change in lifespan in either group. The mean lifespan of the castrate singers was 65.5 ± 13.8 years (mean \pm s.d.) and of the intact singers 64.3 ± 14.1 years, which is not significantly different (see figure).

These data show that prepubertal re-

moval of the testes had no influence on the longevity of men. But because people living at the time of our sample lived less long, on average, than today, the possibility remains that androgens and other testicular hormones may be of importance during the extra years of life expectancy this century. The latter assumption receives some support from a study reporting a longer lifespan in castrated than in intact mentally disabled patients living in this century¹⁰. But it is difficult to draw conclusions for the general population from a study of institutionalized mentally retarded patients. The possibility remains that the difference in life expectancy between men and women may be related to another factor, probably Y-chromosome-mediated, rather than to testosterone and the testes.

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Upside-down pendulums

SIR — The inverted pendulum, made stable by rapid vertical oscillations of its pivot, is a well-known curiosity of classical mechanics. It does not seem to be widely known, however, that an inverted double, or even triple, pendulum can be stabilized in the same way, despite theoretical work dating back to 1909 (ref. 1) and a few practical demonstrations^{2,3}. We have performed systematic experiments on these inverted systems and have compared the results with the predictions of a recent theorem⁴.

The pendulums themselves were made from thin-walled stainless steel tubing (3.175-mm diameter), and the couplings had small (7-mm diameter) bearings incorporated which helped to restrict out-of-plane motion while providing only light damping. The length l of each pendulum was 19 cm, so the total length of the triple pendulum, including the intervening bearings, was 57 cm.

The pivot, to which we attached one pendulum on a double-bearing arrangement, was oscillated vertically by an eccentric sliding crank mechanism which provided a reasonable approximation to sinusoidal motion. A powerful d.c. servo-controlled motor provided the drive and the frequency of the applied motion was monitored using an optical shaft encoder.

The drive amplitudes ranged from 1.1 to 1.75 cm, and the drive frequencies ranged up to 45 Hz.

First, we balanced the pendulums in the inverted position using forefinger and thumb. After the motor was switched on, if the frequency was high enough, the

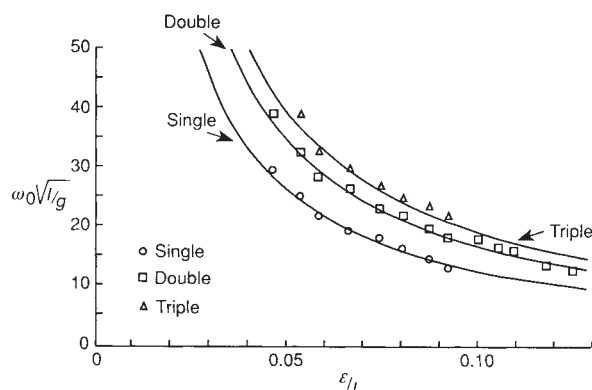


FIG. 1 Comparison between theory (curves) and experiment (points) for the critical value of the drive frequency ω_0 needed for stability of the inverted state. (Some of the higher values of ϵ/l for the double pendulum were attained by using shorter pendulums, with $l = 14$ (rather than 19) cm.)

single and double pendulum inverted states readily became stable. Initial stabilization of the triple pendulum was more troublesome, as out-of-plane motions became very substantial in the high-frequency ranges, but with some practice the simple method described above provided the stable inverted state, which we tested by leaving the system running for several hours.

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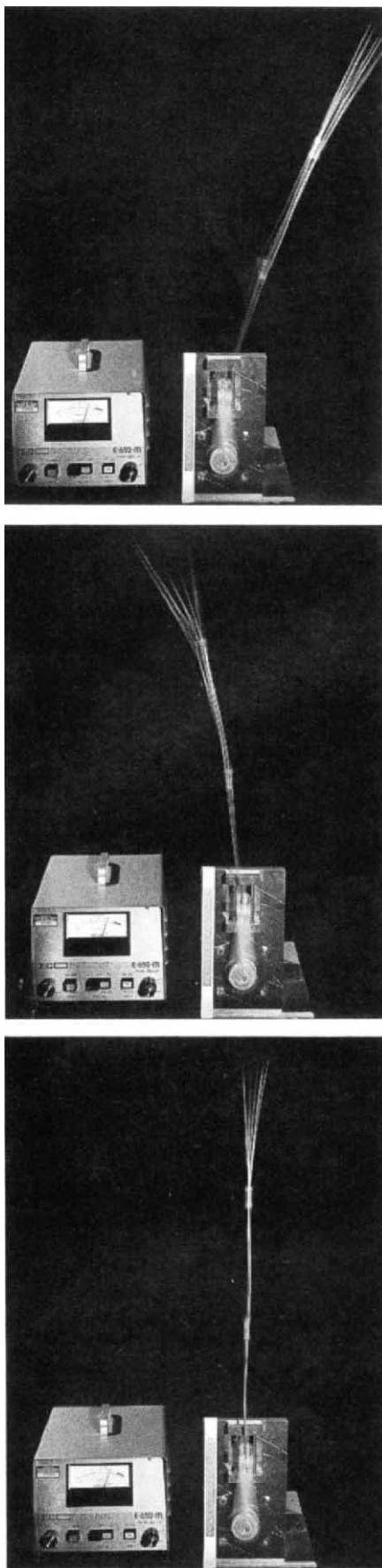


FIG. 2 An inverted triple pendulum returning to the upward vertical after a large initial disturbance. ϵ , 1.4 cm; frequency, ~ 35 Hz.

Once the inverted position had been established, we reduced the frequency of the drive in small steps until the system collapsed. In the case of the single and double pendulums, this was usually preceded by a distinctive lean to one side, which is presumably due to a symmetry-breaking bifurcation close to the limit point of stability. The collapse of the triple pendulum was more sudden and was in some cases accompanied by an oscillation.

Figure 1 shows, for each inverted system, the observed critical drive frequency for various different drive amplitudes ϵ . The theoretical curves are based on the stability condition⁴

$$\omega_0 > \frac{\sqrt{2}g}{\epsilon\omega_{\min}} \quad (1)$$

Here, g denotes acceleration due to gravity, $\epsilon \cos \omega_0 t$ is the imposed vertical displacement of the pivot, and ω_{\min} denotes the smallest of the natural frequencies of oscillation of the whole system in its undriven, non-inverted (downward-hanging) state. The values of $\omega_{\min}/2\pi$ for our single, double and triple pendulum systems were 1.227, 0.935 and 0.824 Hz, respectively, and these were determined experimentally by exploiting a well-known parametric instability of the non-inverted state⁵ which occurs when ω_0 is increased from zero to twice ω_{\min} . The stability condition (equation (1)) clearly predicts well the observed critical drive frequency for the inverted state. We note, however, that the theory⁴ also predicts the appearance of an oscillatory buckling instability when ϵ/l exceeds 0.091 for the double pendulum or 0.044 for the triple pendulum, yet we saw no clear sign of this comparatively high mode, which may have been damped by frictional effects in the bearings.

We regard the experimental confirmation of equation (1), which is based on linear stability theory, as significant, for one could easily imagine that these inverted pendulums would be unstable to finite disturbances exceeding some very small threshold value. In fact, we find that provided the pendulums are roughly aligned with one another at the start, and equation (1) is satisfied, they will withstand very large initial angular displacements of up to 45° or so, and will gradually wobble back to the upward vertical (Fig. 2).

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Muzzle length and heat loss

SIR — In his interesting News and Views article on the evolution of hominid bipedalism, Wood¹ revives Wheeler's² speculation that elongation of the muzzles of baboons is a thermoregulatory adaptation. According to this suggestion, long muzzles evolved in baboons to provide an expanded surface area of nasal mucosa through which venous blood could flow, thereby cooling the brain with a nasal countercurrent heat exchanger.

Several lines of evidence argue against this interpretation. The muzzles of baboons of the genus *Papio*, unlike those of other savannah-dwelling mammals, contain simple, gently curved nasal conchae that support the nasal mucosa. There is no evidence of an enlargement or an increase in geometric complexity of these surfaces that one might expect if the nasal mucosa were being recruited as a heat exchanger. Nor are there in *Papio* the other conspicuous anatomical adaptations of animals that use a nasal countercurrent heat exchanger: enlarged Steno's glands to provide the water for evaporative cooling from the nasal mucosa or an epiglottic valve to allow the mucosa to be bypassed during rapid thermal panting³. In animals that use the nasal mucosa as an evaporative surface, total ventilation must be increased without increasing alveolar ventilation, as the latter precipitates respiratory alkalosis³. This is accomplished by increasing the dead space in the lungs, a response that does not occur in baboons. Further, with a nasal heat exchanger, baboons would suffer a higher heat loss at all times, including on cold nights, and thus be disadvantaged in the colder or more high-altitude portions of their range.

If muzzle elongation were part of a common adaptive complex for all savannah-dwelling monkeys, one would predict its evolution in non-baboon species occupying hot environments, and that long-nosed species would have lower rates of cutaneous evaporative cooling than short-nosed ones. This prediction is not borne out in, for example, the patas monkey (*Erythrocebus patas*) or the vervet (*Cercopithecus aethiops*). *Theropithecus oswaldi*, a species of large, savannah-dwelling monkey whose remains are found in the same deposits as those of African Plio-Pleistocene fossil hominids, far from showing a trend toward elongation of the muzzle in response to conditions of increasing aridity, showed a progressive reduction in muzzle length over time⁴.

Long muzzles are not restricted to savannah-dwelling *Papio*, but occur in the forest-dwelling mandrill (*Mandrillus sphinx*) and drill (*M. leucophaeus*). All