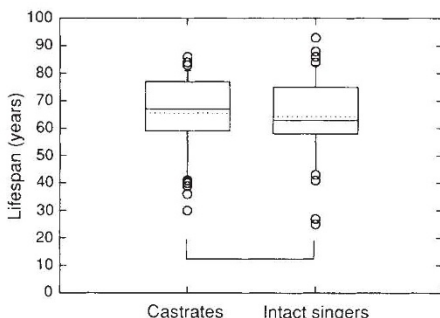


# Lifespan and testosterone

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 testosterone<sup>1</sup>.

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<sup>2–9</sup>, 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  $65.5 \pm 13.8$  years (mean  $\pm$  s.d.) and of the intact singers  $64.3 \pm 14.1$  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 century<sup>10</sup>. 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<sup>2,3</sup>. We have performed systematic experiments on these inverted systems and have compared the results with the predictions of a recent theorem<sup>4</sup>.

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

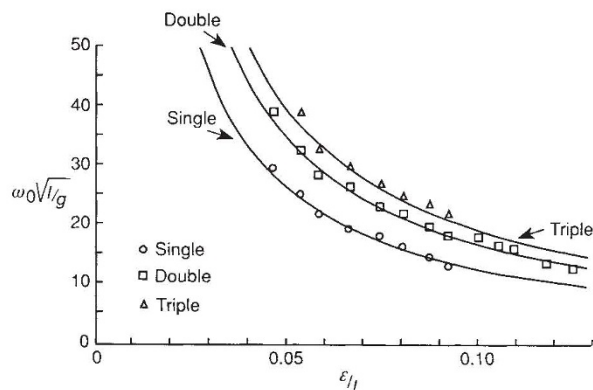


FIG. 1 Comparison between theory (curves) and experiment (points) for the critical value of the drive frequency  $\omega_0$  needed for stability of the inverted state. (Some of the higher values of  $\epsilon/l$  for the double pendulum were attained by using shorter pendulums, with  $l = 14$  (rather 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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