that the same techniques will necessarily work in humans, because we know from comparative studies that humans are already endowed, for good evolutionary reasons, with much better maintenance systems than shorter-lived species. By analogy, a design modification that boosts the performance of my own modest car will not necessarily make a Maserati go faster, as the Maserati is engineered for peak performance already. But we can try.

Did the 1939 Cancer Act play much part in creating the relatively mature discussion and media reporting of advances in cancer research? Given that it was specific to Britain, I suspect that a deeper common sense prevailed. Let us hope that similar common sense can be harnessed to take us forward more responsibly than at present into a world in which life-span and health-span are both likely to increase further. ■

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Anticlimax

The Case of the Female Orgasm: Bias in the Science of Evolution
by Elisabeth A. Lloyd
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Olivia P. Judson

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DARREN STAR PRODUCTIONS/KOBAL COLLECTION

For men, orgasm is an intimate part of reproduction: ejaculation doesn't usually happen without it. Presumably, male orgasms evolved because, in the past, males who experienced sexual pleasure were more likely to have sex, and so were more likely to sire children. But what about orgasm in women? Women can become pregnant without orgasm; indeed, some women bear lots of children without ever experiencing one. So how has the female orgasm evolved?

There are two basic possibilities. The female orgasm may have evolved under natural selection on females, which is to say that females who have the capacity to reach orgasm have historically had more surviving children than females who do not. Alternatively, it may have evolved as a by-product of natural selection on something else. A number of evolutionary biologists have hypothesized about the former, imagining various ways that orgasm might have enhanced female reproductive success. Elisabeth Lloyd, a philosopher of science at Indiana University, prefers the second.

In *The Case of the Female Orgasm*, Lloyd champions the notion — first advanced by Donald Symons in 1979 — that orgasm in women is an accidental consequence of the fact that the clitoris develops from tissue that in a male embryo will become the penis. This would mean that women have orgasms just because men do, not because it enhances their reproductive success. Lloyd also mounts a scathing attack on those who have speculated about how orgasm might have been subject to natural selection on females. She accuses them of failures of logic, shoddy data analysis, and a tendency to ignore data they don't like. She says they commit these sins because they are hostage to a variety of unexamined assumptions, the most egregious being 'adaptationism' — an (in her view) absurd and unjustified commitment to natural selection as an explanatory force in evolution.

Lloyd cites several facts to support her contention that female orgasm is a by-product. First, there are no data showing that women who reach orgasm during sex have greater reproductive success than women who do not; moreover, orgasm is unnecessary for conception. Second, during the past 50 years, surveys of Western women have found that although a minority always reach orgasm during copulation, some never do, and everyone else does only sometimes. Third, most women find it easier to reach orgasm through manual stimulation than through stimulation from the penis. Finally, some other female primates, such as the stump-tailed macaque, the bonobo and the chimpanzee, can reach orgasm.

But none of these comes close to dealing a hammer blow to natural selection. Consider the fact that the clitoris develops from the same tissue as the penis. This tells us something about the origin of the clitoris, but little about why it is still here. Once something has arisen, it can still be subject to natural selection. It may be that the clitoris has been modified to help women achieve orgasm. Then again, it may not: we don't know.

Or consider the matter of orgasm and reproductive success. There are no data showing that orgasm enhances reproductive success; but nor are there data showing that it doesn't. What conclusion can we draw? None: absence of evidence is not evidence of absence.

Or consider the fact that not all women experience orgasm during sex. Lloyd equates variation in phenotype with proof that natural selection has not acted. But this need not be so: we all have eyes, yet we cannot all see equally well. No one would argue that eyes have not evolved under natural selection on vision.

The sad fact is that, for now, all statements about the evolution of the female orgasm are conjectures in an empirical vacuum. To advance the debate, we need data.

The most obvious approach would be to ascertain whether there is (or was) a link between orgasm and reproductive success. Measuring the relationship between a given trait and reproductive success is difficult in any organism. It is obviously impossible to know whether orgasmic women have tended to have more children than anorgasmic women. The best we can do is try to infer.

The fact that orgasm is not necessary for conception rules out the obvious way that orgasm could enhance reproductive success — but it could have more subtle effects. For example, could orgasm during sex induce ovulation? In mammals such as ferrets and cats, ovulation is induced by stimulation from the male; might it be facultatively induced in humans? As far as I know, such an effect has not been reported for any primate, but then, as far as I know, no one has looked for it.

We also need to know far more about the nature of orgasm. Orgasm is the result of two phenomena: contractions in the pelvic region,

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and the perception of pleasurable sensations by the brain. Yet we have little understanding of how the two components relate to each other. Moreover, a distinction is often made between clitoral and vaginal orgasm. Whether these are physiologically different — let alone whether they evolved under different selection pressures — is unknown. Indeed, the neuroanatomy of the genital region is poorly understood, and we have scant data on how much it varies among women. Brain scans suggest that different parts of the brain may be involved in orgasm for males and females — which would be consistent with natural selection acting on females directly — but the sample sizes are as yet too small to draw confident conclusions.

To understand the significance of the variation in women's experience of orgasm, we need to know what causes this variation. Is it due to genetic differences in genital anatomy? To differences in the way brains perceive pleasure? To psychological or cultural factors? Or to a physical incompatibility between a woman and her partner(s)? In other words, do some women lack a capacity for orgasm, or is the capacity there but never realized? Again, data are lacking. A recent twin study (K. M. Dunn *et al. Biol. Lett.* doi:10.1098/rsbl.2005.0308; 2005) suggests there may be a genetic component — if your identical twin has orgasms it's likely that you do too — but whether the effect is due to physiology or psychology is unclear.

And we need to know more about when other primates experience orgasm. Do females in other species have orgasms with some males but not with others? No one knows. Here, too, we need to know how pelvic contractions translate into brain waves. And we need to investigate males as well as females: it is often simply assumed that males in other species have orgasms. Data on other primates will help us to understand the relationship between male and female orgasm, and whether the female orgasm evolved before the split between humans, chimpanzees and bonobos.

In short, it's time to collect data. Without it, the debate will remain like sex sometimes is: furious, empty and anticlimactic. ■

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SCIENCE IN CULTURE

Prussian precision

Anton Hallmann's technical drawings brought geometry to life.

Martin Kemp

Technical drawing lay at the heart of a flourishing of both the arts and the physical sciences in nineteenth-century Berlin. The precise lines of geometry obtained practical expression and gave shape to painting, sculpture and architecture. Yet the measured precision it allowed provided the basis for engineering and instrument-making, even the science of warfare. The mastery of perspective projection and the geometrical casting of shadows was central to it all.

The drawings of the architect Anton Hallmann — on show in the exhibition *Apoll im Labor* at the Berlin Museum of Medical History until 2 October — exemplify the heights reached by technical draftsmanship in the nineteenth century. Introduced to projective geometry at the Artillerieschule in Hanover, Hallmann became a master of precise architectural representation, and was best known for his depiction of buildings of classical antiquity. His drawings range from the meticulous perspectival rendering of the whole and parts of buildings to extraordinary abstract exercises in which he set geometrical bodies in measured spaces under specific illumination.

In the example shown here, he scatters a series of bodies across a stage-like ground on which two torches provide what are taken to be point sources of light. The shadows are observed in full geometric projection, as they cast a complex ensemble of angular and conic contours across the space. The relative intensities of the two overlapping shadow systems are meticulously computed, with often surprising results.

Hallmann's link with science is his friendship with Emil Du Bois-Reymond, the pioneer of electrophysiology and inventor of instruments for measuring biological forces. There is an obvious connection through Hallmann's drawings of the mechanical system of bones and muscles in the human body, but the affinity goes deeper than a common subject. What they and other Berlin practitioners of the arts and sciences shared was a passion for classical clarity.

Du Bois-Reymond depicted himself in an engraving as a semi-nude classical god using his *Multiplikator* — a precision galvanometer — to measure his muscular electricity (see *Nature* **436,** 27; 2005). He designed his own instruments, which were constructed and operated with a love of form and space in which the beauty of pure mathematics was conjoined with the practical measurement of the forces of nature. This was euclidian mathematics embodied in human form, as exemplified in ancient sculpture.

The network of relationships extends to Du Bois-Reymond's fellow members of the Berlin Physical Society, the psychologist Ernst Brücke and the physicist Hermann von Helmholtz, both of whom were keenly involved in the visual arts. Du Bois-Reymond had harboured ambitions to be a painter and taught anatomy to the students in Berlin's art academy. They all shared a vivid sense of the aesthetics of the powers of nature, as revealed through measurement and charted most potently on the curves of their graphs.

In Hallmann's primary field of architecture, the net extends to the classicist Karl Friedrich Schinkel, master builder and engineer, and his students at the Bauakademie, whose building he designed in a semi-industrial style in 1831. In the perspectival depiction of cityscapes, the net embraces Eduard Gärtner, master-painter of Berlin panoramas, and Johann Hummel, famed for his paintings' optical exactitude (*Nature* **395,** 649; 1998).

Within this Berlin nexus, whether you start with a physicist or a painter, you can connect to any other discipline in just two or three moves. No division into 'two cultures' here.

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