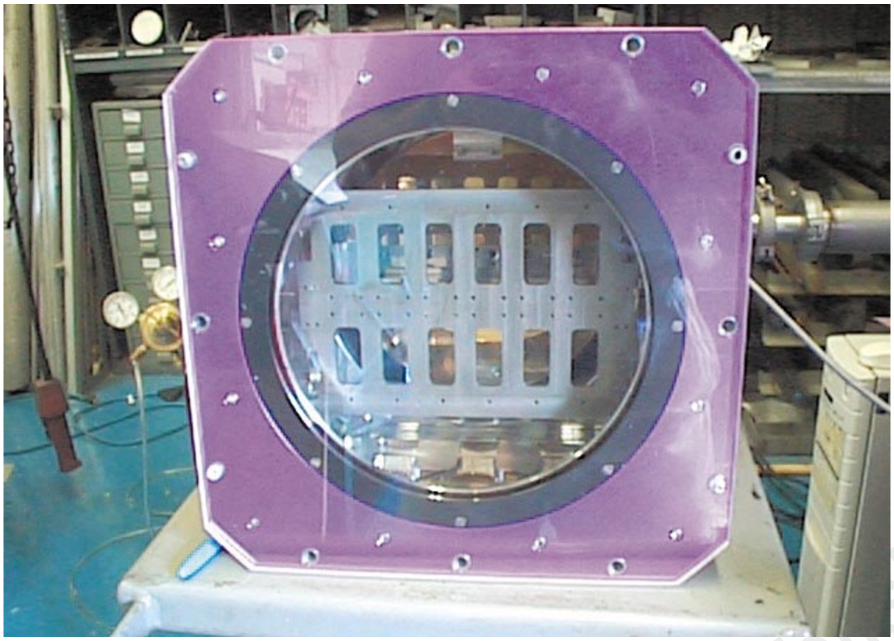
CANADA–FRANCE–HAWAII TELESCOPE

Figure 3 **The Canada–France–Hawaii Telescope's large-area camera. This device is carrying out a survey to look for the oldest white dwarfs in our Galaxy, which may form much of the 'dark' matter in the galactic halo. The 12 openings each contain a CCD with eight million pixels. The whole camera covers about 0.3 square degrees of the sky at once, and about 80 different pointings will be made.**

implying that the lenses were very low mass stars — perhaps even brown dwarfs, which are too low in mass to ignite nuclear burning in their interiors.

It turns out that there are a lot of lensing events, and the lenses appear to constitute a large fraction of the mass of the Galactic halo — but, surprisingly, the lensing objects are around half the mass of the Sun. If these lensing objects were typical hydrogen-burning stars they would appear as a glowing halo around our Galaxy, which is not observed. The three other possibilities are that these lenses are neutron stars (unlikely, as the heavy metals produced by the neutron stars' precursors would have polluted the Galaxy more than is observed), primordial black holes (also unlikely, but not yet ruled out), or white dwarfs.

If a large fraction of the dark matter resides in white dwarfs it will be possible to observe them. But we must have reliable theoretical models to compare with observations. Current models appear to work fine for white dwarfs younger than about 10 billion years[4], but our Galaxy is about 12–14 billion years old, so the oldest white dwarfs must be about that age. The new models[1] bridge this gap.

Successful searches for these old white dwarfs will be made not with the Hubble Space Telescope, as its field of view is too small, but using ground-based telescopes. One large-area survey, now being performed with the Canada–France–Hawaii Telescope (Fig. 3), will cover 25 square degrees of sky to a sensitivity of 25th magnitude. If the entire halo of our Galaxy consists of 12–14 billion year old white dwarfs, all with hydrogen atmospheres, and if Hansen's new models are basically correct, more than 1,000 old white dwarfs will be found. They will be easily separated from the myriad of old red dwarf stars simply by their colour.

Old white dwarfs can also play an important part in establishing the age of the Universe. One way to determine this age is by measuring the expansion of the Universe; another is to set a lower limit by establishing the age of the oldest stars in our Galaxy. The numbers derived by these independent techniques do not agree. Conventionally derived expansion ages for the Universe are around 9–10 billion years, whereas the oldest star clusters in the Galaxy are 12–14 billion years old[5].

Cluster ages are usually found by fitting evolutionary models to the stars that have just completed their hydrogen burning lives. But the physics of these models is quite complex, particularly the nuclear reaction rates, energy transport processes and sources of opacity. A different approach is to search for the least luminous and hence oldest white dwarfs, and calculate the time needed to cool to their present temperature. The physics in these models has its own complexities, but is more tractable than that in models of normal stars. According to the improved calculations of Hansen, these stars will now appear more luminous than we had thought (and therefore easier to find) and their blueness will distinguish them from the huge number of faint, unresolved red galaxies always found on long-exposure optical images.

A real test of Hansen's model will come in the next few years, when early results from the large-area surveys become known, and when images of the nearest old star clusters are taken with the Advanced Camera for Surveys[6], soon to be installed on the Hubble Space Telescope. □

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Evolutionary biology

The secrets of faces

Magnus Enquist and Stefano Ghirlanda

The human face is a bewildering source of information, and our abilities to read and remember faces and facial expressions are extraordinarily well developed[1]. How faces and our recognition skills have co-evolved, and what information a face can convey, offer many avenues for scientific study.

One thing that faces can tell us is the sex of a person. Although there are only two sexes, we experience many degrees of femininity and masculinity. Perrett and colleagues, reporting on page 884 of this issue[2], asked human subjects what these differences mean. They manipulated photographs of human faces by enhancing or diminishing differences between the sexes, then they let the subjects rate these manipulated images. The images were produced by first defining a number of reference points, such as the location of eyebrows, lips, nose and so on. The positions of these points differ in male and female faces, and these differences can be enhanced with computer graphics. For instance, males have bigger jaws than females. So, by increasing the size of the jaws, a more extreme male face is obtained. The authors produced images in which faces varied from feminine to masculine, in this sense, based on the faces of people from Scotland and Japan.

In four experiments, human subjects (men and women from both Japan and Scotland) were asked their opinion about the images with respect to attractiveness, as well as personality traits such as honesty, intelligence and dominance. Female faces were generally judged more attractive when they

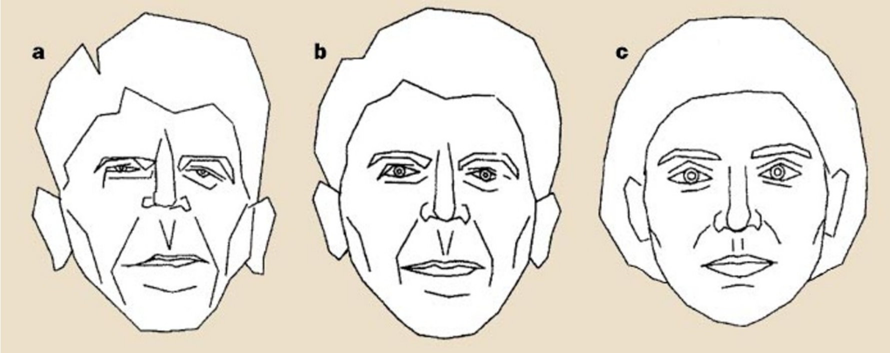

Figure 1 **Face to face — three caricatures showing different features. The supernormal caricature of Ronald Reagan** (a)**, produced by Susan Brennan's caricature generator, exaggerates features that are particular to Reagan's face** (b)**, in relation to an average face** (c)**. It is very difficult to give any biological significance to the 'Reagan-ness' of these faces, suggesting that principles of recognition are important in the evolution of signals.**

were made more feminine. In contrast, and surprisingly, both men and women preferred slightly feminized male faces over the original or more masculine faces. The Japanese and Scottish subjects more or less agreed in their judgements, with one interesting variation — both groups preferred more exaggeration in faces of their own nationality than in faces from the other country.

When both male and female faces were feminized, subjects rated the person behind the face as more honest, cooperative and emotional. But the result was mixed regarding parental abilities. Whereas the feminized male was rated the better father, the average female was rated a better mother than the feminized female. More masculine faces were thought to be more dominant and older, but judgement of intelligence did not depend on masculine or feminine appearance.

On the basis of these results, Perrett *et al.*[2] suggest that if a female chooses a male with feminine characteristics, she may get a more honest and cooperative partner who is a better father to her children. The authors also suggest that this might have limited the degree to which male and female faces differ in humans (sexual dimorphism). But masculinity may be an advantage in social competition and dominance — this might explain why male faces do not exactly match female preferences.

Perrett and colleagues have dealt with a classical subject, dating back to Darwin's theory of sexual selection[3–5], that is still not satisfactorily resolved. Why do sexual signals look the way they do, and what information do they convey? According to one opinion (favoured in the paper), sexual signals convey important information about the quality of a partner[4]. All aspects of the signal serve this function. This view holds that, during evolution, signals that are reliable cues for fertility, genetic quality (yielding high-quality offspring) and parental abilities have emerged. Males and females have evolved to respond accurately to these cues in partner choice.

A different opinion is that factors related to transmission and recognition are important for the evolution of signals[5,6]. According to this theory, biases in the sense organs or nervous system influence how we perceive and react to signals. So, sexual signals may just signal sex — the fact that we find some faces more attractive than others may be a by-product of recognition, and may not be linked to partner quality. For instance, it is well known that by altering specific aspects of a familiar stimulus, supernormal effects (stronger reactions)[7] can usually be produced, even when the new stimulus does not provide the receiver with more information.

As an example of this second view, Fig. 1 shows an average face, a faithful portrait of the former President of the United States, Ronald Reagan, and a caricature of him[8]. The caricature was produced by an algorithm similar to that used by Perrett and colleagues, exaggerating the differences between the average face and the face of Reagan. This caricature clearly captures and enhances some 'Reagan-ness' from the original portrait. But it is very difficult to ascribe a biological value to such a quality or to argue that we have evolved a Reagan-ness detector.

Thus, before we can distinguish between these two theories, we need to learn more. Studies of faces may provide an excellent testing ground for this. Perhaps the outcome will be a little of both — some aspects of sexual signals will give information about partner quality and others will not. But it is not enough to know what is preferred. We need to find out whether the emotions that faces evoke really do reveal qualities such as parental or social abilities, and we also need to know more about recognition. ☐

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Earthquakes

A deficit vanished

Steven N. Ward

The southern California earthquake deficit — "Now you see it, now you don't", according to an article in the *Bulletin of the Seismological Society of America*[1] by Stein and Hanks. Not done with smoke and mirrors, the vanishing act enlisted a careful revision of our understanding of twentieth-century historical seismicity, and it helped to spirit away a thorny issue that arose in 1995. This was the year that the Working Group on California Earthquake Probabilities[2] (WGCEP/95) published the report "Seismic Hazards in Southern California: Probable Earthquakes 1994–2024".

The WGCEP/95 document was remarkable because it struck a new path into earthquake hazard analysis. Previously, geologists and seismologists had independently staked out their own areas of earthquake rate estimation, the heart of hazard calculation. Geologists reckoned the recurrence interval and magnitude of earthquakes by locating active faults, mapping their length and total offset, and resolving their age. Seismologists concentrated on historical catalogues. Earthquake patterns of the past, they presumed, reflect where and how often earthquakes should strike in the future, and how large they will be. Early geological and seismological studies tended to be piecemeal with few cross-checks. Publication of WGCEP/95 brought order to the field by combining diverse information into a quantitative and consistent multidisciplinary assessment. Space geodesy catalysed the leap forward by providing accurate measures of the pattern and pace of tectonic strain that eventually manifests itself as earthquakes.

Of all the advances in WGCEP/95, one finding seemed to take on a life of its own — the preferred seismicity model predicted twice the number of magnitude 6 to 7 earthquakes than had actually been observed since 1850 (red area, Fig. 1, overleaf). The shortfall