NEWS & VIEWS

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EVOLUTIONARY BIOLOGY

Geography and skin colour

Jared Diamond

Human skin comes in many different shades. Recent studies of geographical differences in skin colour open up the subject scientifically by offering sophisticated accounts of the basis of this variation.

The most obvious — and most discussed — aspect of human geographical variability is skin colour. Most people would say that skin colour becomes darker towards the Equator to give more protection against tropical sunlight. But that claimed correlation of skin colour with latitude is riddled with exceptions, and that functional interpretation of the correlation is debated. Most scientists shy away from the whole subject because it so interests racists, and the motives of scientists studying it become suspect.

Jablonski and Chaplin[1–3] have now brought order to this confused field, starting with quantitative measurements of skin colour and sunlight. By convincingly identifying the strongest correlate of skin colour, they open the door for anthropologists to explore other correlates and exceptions.

Skin colour was formerly described qualitatively by matching it against coloured tablets, but Jablonski and Chaplin tabulate numerical values, obtained by skin reflectance spectrophotometry. And instead of using latitude as a proxy for sunlight, Jablonski and Chaplin tabulate ultraviolet radiation (UVR) itself at the Earth's surface. UVR does decrease with latitude, because at high latitudes the oblique angle at which sunlight falls on the atmosphere results in a longer atmospheric path, and hence more absorption and scattering of UVR. But the correlation of UVR with latitude is imperfect: UVR also increases with altitude owing to atmospheric thinning (for example, UVR is high on the Tibetan and Andean altiplanos); it also decreases with atmospheric water vapour in the form of rain, clouds or humidity (UVR is higher in the Atacama Desert, southwestern United States, and the Horn of Africa, than in adjacent, wetter areas to the west or east).

In this quantitative database, variation in UVR proves to be the strongest predictor of skin reflectance, explaining 77% (Northern Hemisphere) or 70% (Southern Hemisphere) of its variation. The causes of this correlation have been the subject of many theories, such as protection against skin cancer, protection against overproduction of vitamin D, and camouflage in tropical jungles.

Jablonski and Chaplin prefer a combination of two selective factors involving several costs and one benefit of UVR. The costs involve the destructive photolysis of many compounds, of which Jablonski and Chaplin attach particular importance to the B vitamin folate. Everybody requires folate, so everybody would have dark skins (to screen out UVR and reduce photolysis) if there were no other selective factors. However, UVR also provides a benefit: catalysing the synthesis of vitamin D. Hence skin colour evolves as a compromise between skins light enough to permit UVR penetration for vitamin D synthesis, but dark enough to reduce folate photolysis.

This compromise results in paler skins, to permit vitamin D synthesis, at high latitudes with low UVR levels. Albino schoolchildren in South Africa need less dietary vitamin D than normally pigmented children to attain target serum levels of calcium and vitamin D. Women in all populations tend to have paler skins than men, presumably through natural selection owing to their greater need for calcium and vitamin D during pregnancy and lactation. This difference may be reinforced by sexual selection.

Although the harmful effects of UVR are often taken to be especially associated with skin cancer, Jablonski and Chaplin minimize the importance of this aspect on the grounds of the late age of onset, after some or most of a couple's children have been born. Most geneticists similarly minimize the selective importance of damage or disease late in life.

Here, I am sceptical. This common view may be valid for mammal species in which parent–offspring ties are severed soon after weaning, but it overlooks three of the most distinctive features of human life-histories in traditional societies: the long post-weaning dependence of offspring on parents for learning and then for social status; the large contribution of hunter-gatherer grandmothers to their grandchildren's food supply[4]; and the dependence of an entire band or village on its oldest people as the repositories of knowledge in a preliterate society[5]. It would be interesting to try to estimate the selective importance of skin cancers for skin-colour evolution from this perspective: data on skin-cancer incidence (for example of Europeans in tropical

Australia) could be combined with estimates of the three contributions of 'post-reproductive' adults to the status and survival of their children and grandchildren.

Now that the strongest correlation of skin colour (with UVR) has been established, we can look for the exceptions, and the other factors involved. Jablonski and Chaplin have made this easy, by providing a table (Table 6 on pages 74–75 of ref. 3) listing residuals between observed skin reflectances and those predicted by UVR alone, for 85 indigenous human populations representing all continents. I predict that this table will be one of the most frequently cited features of their paper for anthropologists, geneticists, historians and linguists. The following correlates of tribal histories and lifestyles leap out from even a cursory examination of these residuals.

The fourth largest negative residual of skin reflectance (skin is darker than expected from UVR considerations alone) is for a Greenland Inuit population. These people 'can get away with unexpectedly dark skins' because they traditionally obtained their vitamin D from a diet rich in marine mammals. As a result, modern Inuit, subsisting instead on supermarket food, suffer from one of the world's most severe incidences of vitamin D deficiency. Conversely, three of the nine most positive residuals (skins unexpectedly pale) are for populations from the interior of Asia, remote from any seafood.

Of the 12 most negative residuals (skins unexpectedly dark), the highest and four others are for Bantu-speaking southern African populations that migrated from the Equator towards high southern latitudes only 2,000 years ago. These populations have not yet had enough time for evolutionary loss of their equatorially adapted dark skins. Conversely, three of the nine most positive residuals (skins unexpectedly pale) are for peoples of the Philippines, Vietnam and Cambodia, who migrated towards the Equator from high latitudes only in recent millennia and have not yet evolved appropriately dark skins. But why do the people of Bougainville Island in the South Pacific, and why did the Aboriginal Tasmanians, have such dark skins, after more than 10,000 years of *in situ* adaptation?

As Jablonski and Chaplin point out, skin is by far the most extensive visible feature of our bodies, a signal advertising age, health and ancestry, and a poster board for decoration. I hope that their papers will convince more scientists not to be ashamed of being interested in skin colour. ■

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EARTHQUAKES

Future shock in California

Duncan Agnew

For California, probabilistic principles can be applied to the short-term forecasting of further ground-shaking following an earthquake. How such predictions will be used by the public remains to be seen.

"What can we expect next?" — this question is foremost in the minds of the public and news media following any widely felt earthquake. Put another way, for any person living near the earthquake the question is, "What does this earthquake mean for the earthquake risk in my locality?". The seismologist's usual reply is a vague comment that because all earthquakes are followed by smaller events (aftershocks), this one will be too, and that although earthquakes are sometimes followed shortly afterwards by larger ones, this is rare, so that the overall risk is essentially unchanged, except close to the epicentre.

Thanks to the work of Gerstenberger *et al.* (page 328 of this issue)[1], a much more precise answer can be given, at least for California. The procedures they describe also set a new standard against which to test future earthquake predictions, and as such they deserve to be adopted, with appropriate local modifications, in other earthquake-prone areas.

The simplest kind of earthquake forecast assumes randomness, with the probability of a particular-sized earthquake occurring in a particular place over (say) the next day being always the same. This is the Poisson model. Such a forecast also assumes (as is observed) that small earthquakes occur much more often than big ones, a rule that, when expressed more precisely, is known as the Gutenberg–Richter law. This simple forecast also needs to include a description of how the probabilities vary from place to place; this can be controversial away from the boundaries of tectonic plates, but in California can be reasonably estimated from what we know about past earthquakes and geologically active faults.

Gerstenberger *et al.*[1] add to this a sophisticated model for the other, well-established behaviour of earthquakes — that big events are followed by smaller aftershocks, at a rate that decreases with time. This is known as the Omori law, after the Japanese scientist who suggested it in 1895. An important element in Gerstenberger and colleagues' paper is to allow aftershocks to be of any size, including bigger than the original earthquake, using the Gutenberg–Richter law again to describe how likely the different sizes of aftershocks are[2]. This neatly unifies the common case of aftershocks with the much less common case of the first earthquake becoming, after a larger second one, a foreshock. The authors use a range of aftershock models to match the variability in observed aftershocks (Fig. 1); as the

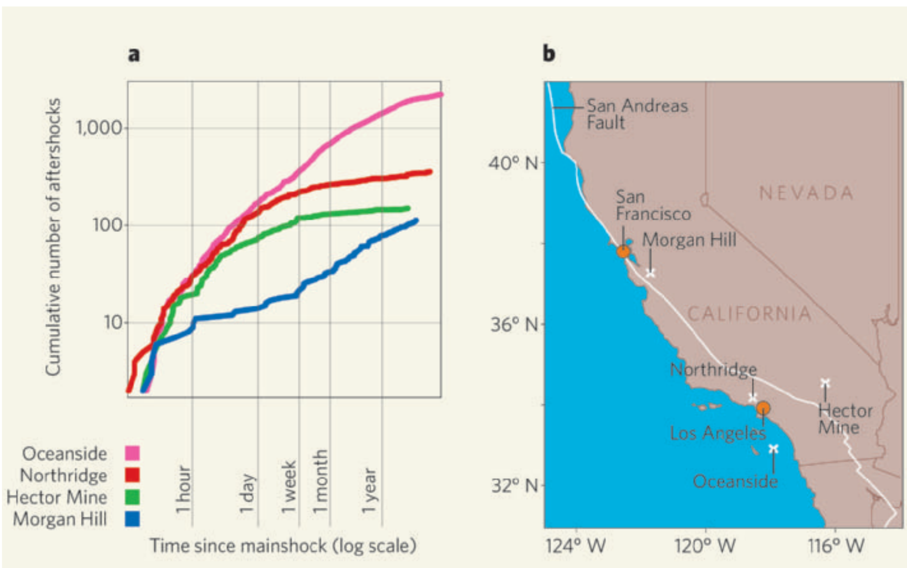

Figure 1 | Variability in aftershocks for four earthquakes in California. a, The cumulative numbers of aftershocks (within 3.5 magnitude units of the mainshock) against the log of elapsed time. **b**, The locations of the earthquakes, which are Oceanside (magnitude 5.4; July 1986), Northridge (6.6; January 1994), Hector Mine (7.1; October 1999) and Morgan Hill (6.2; April 1984). Gerstenberger and colleagues' forecasting procedure[1] automatically allows for the wide variability seen in the numbers and decay rates of aftershocks.