asexual strain reached only 80%. These results clearly support Weismann's hypothesis.

The history of ideas about the functional significance of sexual reproduction is remarkable. For a long time Weismann's theory was widely accepted. But in the 1970s several difficulties with his explanation were identified[6,7]. First, genetic recombination will tend to break up favourable combinations of genes that have accumulated by selection, which may slow down adaptive evolution rather than speed it up. Second, in organisms with male–female differentiation, there is a so-called twofold cost of sex. If males do not contribute resources to offspring, a mutation to asexuality, causing females to produce only daughters, will — other things being equal — quickly increase in frequency. This is because sexual females produce only half the number of daughters compared to the asexual mutants, 'wasting' half their reproductive output on sons.

Decades of intense theoretical exploration ensued, aimed at discovering potential benefits of sex that are large enough to overcome these and other disadvantages. Many different hypotheses were advanced, most of them not mutually exclusive. The result was confusion and frustration rather than illumination. By 1993, hypotheses had become so numerous and diverse that a classification of them became necessary[8]. Since then, theoretical analysis has progressed further and has resulted in several plausible and general explanations, again not mutually exclusive, and roughly belonging to two categories: either sex increases the rate of adaptive evolution, or it is more efficient in eliminating deleterious mutations[2,3].

The solution to the evolutionary riddle of sex has to come from empirical tests of the various theories, and experimental studies have been increasingly devoted to the problem[9]. However, clearcut comparisons between sexual and asexual reproduction are hampered by confounding factors. The paper by Goddard and colleagues[1] is exemplary in this respect, owing to the excellent possibilities offered by their yeast system.

Nonetheless, we are still far from a definitive answer to the question of why sexual reproduction is so common. For one thing, yeast has no male–female distinction, so the twofold cost of sex does not apply, which prevents a straightforward generalization of the conclusions to most animals and plants. Moreover, the experiment provides no information as to why the sexual population is more efficient in adapting to the harsh conditions than the asexual population. Is it because sex has brought together different beneficial mutations that have arisen in separate lineages, or because sex has liberated beneficial mutations from unfavourable genetic interactions with other genes? Further genetic characterization of the mutations responsible for the adaptation to the harsh environment would be a first step to distinguishing between these possibilities. ■

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Aceh–Andaman earthquake

What happened and what's next?

Kerry Sieh

The huge earthquake of 26 December 2004 and ensuing tsunami were caused by a submarine rupture running from offshore Aceh, Indonesia, to the Andaman Islands. A clearer picture of events is starting to emerge.

As the human drama of the Aceh–Andaman earthquake and tsunami unfolded in the last days of 2004, laymen and scientists began scrambling to understand what had caused these gigantic disturbances of Earth's crust and seas. One of the earliest clues was the delineation, within just hours of the mainshock, of a band of large aftershocks arcing 1,300 km from northern Sumatra almost as far as Myanmar (Burma)[1]. This seemed to signal that about 25% of the Sunda megathrust, the great tectonic boundary along which the Australian and Indian plates begin their descent beneath Southeast Asia, had ruptured. In less than a day, however, analyses of seismic 'body' waves[2] were indicating that the length of the rupture was only about 400 km.

This early controversy about the length of the megathrust rupture created a gnawing ambiguity about future dangers to populations around the Bay of Bengal. If only 400 km of the great fault had ruptured, large unfailed sections might be poised to deliver another tsunami. If, on the other hand, most of the submarine fault had broken,

100 YEARS AGO

***Philosophy as Scientia Scientiarum and a History of Classifications of the Sciences*.**
The relation of science to philosophy is, in theory, filial. It is, perhaps, no contradiction of the filial relationship that in practice it has an unfortunate tendency to run to mutual recrimination. The man of science too often ignores the philosopher, or despises him as an obscurantist who habitually confounds abstraction with generalisation. To the metaphysical philosopher, on the other hand, the typical specialist in science is a variety of day-labourer, dulled by the drudgery of occupational routine… Prof. Flint's new book should serve as a mediating influence between philosophical and scientific interests. It brings together into one convenient source the leading attempts made, from Plato to Karl Pearson, towards a classification of the sciences… How invaluable a service Prof. Flint has thus rendered to future investigators, can be appreciated only by those who have tediously toiled at the scattered literature of this subject. Its bibliography appears hitherto to have been left unorganised — having escaped even the ubiquitous zeal of German scholarship.
From *Nature* 30 March 1905.

50 YEARS AGO

The Piltdown saga has now been concluded. The British Museum (Natural History) has brought together under the title "Further Contributions to the Solution of the Piltdown Problem"… the views of a large number of specialists who have described their work on the specimens — work which has resulted in demonstrating without any doubt that the whole thing was a hoax… Dr J. S. Weiner's book, "The Piltdown Forgery", deals rather with the many personalities in the case… The story unfolds with the discovery of Piltdown I, and we find not a few of the local amateurs a little suspicious that all is not as presented. We now have evidence for staining of specimens; we have the 'happy' find of Piltdown II which was to clinch the matter… It all reads like a novel, and I have no intention of spoiling it for others by saying more. It is a book to be read with interest and profit. Such a hoax nowadays is impossible; but it was one actually perpetrated and it was a great success.
From *Nature* 2 April 1955.

K. SIEH

K. SIEH

Figure 1 **Evidence of uplift — here about 1.5 m. This aerial photo shows new land that emerged on the southwest coast of Simeulue island, above the southern edge of the megathrust rupture that caused the Aceh–Andaman earthquake. The wide strip of land consists of a former fringing coral reef; what was previously a beach (far left) has been left high and dry. Inset, a field of fire-coral heads on a neighbouring coral reef that rose about a metre during the earthquake.**

then the chances of such a disaster were much smaller.

In this issue, Ni, Kanamori and Helmberger (page 582)[3] explain why early analyses grossly underestimated the rupture length, and they present an analysis of high-frequency (2–4 Hz) seismic signals that clearly shows northward propagation of the rupture for a distance of about 1,200 km. Also in this issue, Stein and Okal (page 581)[4] argue that early estimates of the magnitude[1,2] were far too low. Using extremely long-period seismic 'normal mode' waves, they calculate that the earthquake's magnitude was 9.3, about three times larger than initial estimates of 9.0 (given the logarithmic nature of earthquake-magnitude scales). This much larger size is consistent with slip averaging about 13 m along a 1,200-km rupture, assuming that much of the slippage occurred too slowly to be seen in shorter-wavelength seismograms. Thus, they claim the long-versus-short rupture controversy is solved and that there is no need to worry about another giant earthquake and tsunami originating along this long section of the fault.

These two reports[3,4] are among the first published analyses of what is destined to be one of the most important earthquakes of the century. Over the next year or two, figuring out what happened will be a showcase both of what modern observations and analysis can do and of the multidisciplinary nature of modern earthquake science[5]. In the months ahead, much more will be learned about this giant event. Satellite imagery and field measurements of dramatically uplifted and submerged coastlines (Fig. 1)[6,7] and the movement of Global Positioning System geodetic stations[8], as well as tsunami records, will all add constraints on the areal extent of the rupture and the magnitude and sequencing of slip: these, in turn, will be essential to understanding the tsunami.

If all of the megathrust between northernmost Sumatra and Myanmar has produced its once-a-millennium giant earthquake, why should we have any immediate concern about another giant quake or tsunami in the Bay of Bengal? McCloskey *et al.*[9] offered one answer by estimating the stresses imposed by the giant 2004 rupture on the two big faults farther south. It seems that the section of the Sunda megathrust immediately to the south, off the coast of northern Sumatra, is now closer to failure. Likewise for the nearest portion of the great San Andreas-like Sumatran fault, which runs through Banda Aceh and down the backbone of the Sumatran mainland.

The critical question is how close to failure the 2004 rupture has moved these two big faults. This will be moot until more is known about the history of their past ruptures. It will be necessary to learn how the Sumatran parts of the megathrust are segmented structurally, and how they have behaved in the past. Immediately south of the 2004 rupture, for example, it appears from the historical record that there were very large earthquakes in 1861 and 1907[10]. Where on the megathrust were these ruptures, and how often and how regularly do they recur? Palaeoseismic data are available only for a 700-km-long section farther away, from about 1° to 5° south of the Equator. Giant earthquakes and tsunamis occur there about every 200–230 years, sometimes as a single giant earthquake, sometimes as two in relatively quick succession, as happened in 1797 and 1833[11,12].

Big faults on the northern flank of the 2004 rupture also pose a hazard; the northern extension of the 2004 rupture continues for another 1,000 km, up the west coast of Myanmar, well past Bangladesh to the eastern end of the Himalayas. Too little is known of its long-term history to provide a meaningful assessment of its future behaviour. Moreover, long sections of the enormous thrust fault along which India is diving down beneath the Himalayas have not failed for centuries and are only one to three fault-lengths away from the 2004 rupture.

It is sobering to realize that big earthquakes sometimes occur in clusters (for example, seven of the ten giant earthquakes of the twentieth century occurred between 1950 and 1965, and five of these occurred around the northern Pacific margin)[13]. Because many of the giant faults in the Aceh–Andaman neighbourhood have been dormant for a very long time, it is quite plausible that the recent giant earthquake and tsunami may not be the only disastrous twenty-first-century manifestation of the Indian plate's unsteady tectonic journey northward. ■

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