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predicted by many opponents of neutral theory, who generally argue for ecological building 'rules' that culminate in similar communities repeatedly being constructed in the same habitat.

The main alternative to neutral theory is niche theory, which explains relative species abundance in a community in a far more complex fashion[6]. In this theory, species have evolved adaptations to different environmental conditions and sort themselves out along 'niche axes'. These environmental conditions are both abiotic (water temperature and rainfall, for example) and biotic (competition, food supply, predation, symbiosis and so on). All else being equal, species adaptations to the environment should lead to more closely similar communities occurring over time and space than those generated by neutral theory. So, at first glance, the limited similarity in coral community composition observed by Dornelas *et al.* cannot easily be explained by traditional niche theory.

What, then, can explain this marked spatial dissimilarity in community composition? The authors suggest that environmental variability has a strong influence (Fig. 1), even though they intentionally sampled consistently similar reef habitats. Their hunch is that local communities still experience considerable fluctuations in environmental conditions. Many disturbances on coral reefs, such as cyclones, outbreaks of crown-of-thorns starfish and coral bleaching, can be quite localized, so even adjacent parts of the same reef can have very different environmental histories. Thus, the low level of community similarity might relate more to the relationship between sequential changes in communities and the time since disturbance than to random demographic processes. Although this does not show that niches have no role in species coexistence, it does place fluctuation-mediated coexistence in a stronger light[7].

Perhaps the most instructive part of the new study is the amazingly high similarity and low variance among computer-simulated neutral-theory communities. Dornelas *et al.* tried fiddling with the parameters of neutral theory, such as migration rate and species turnover, to decrease the community similarity and increase its variance, but the simulated neutral communities remained far less variable than their real counterparts. We will have to ask some hard questions about how to interpret this result. What are the implications of a neutral model that presupposes no role for inherent differences among species, but leads to greater order and predictability in community composition than nature can provide? Will Dornelas and colleagues' conclusions hold up when the observed community similarity is much higher or less variable over different spatial[8] or temporal[9,10] scales? Previous authors have shown that there is less variation among communities than expected under neutral theory[8–10]. Dornelas *et al.* have now demonstrated that there is too much. Neutral theory is caught in the middle. This, perhaps, shows the strength of a null model. By making clear predictions, we can explore deviations in both directions from a point of neutrality.

Dornelas and colleagues' study[1] will invigorate debate over the importance of biological details in determining the coexistence of species within communities. Their fresh and falsifiable approach leads us farther down the path to merging neutral theory and niche theory — a process that bears striking similarities to its evolutionary counterpart of successfully integrating theories concerning neutral genes and natural selection. ■

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DEVICE PHYSICS

Electrical solitons come of age

Thomas H. Lee

Individual packets of light energy, known as optical solitons, have long been the darlings of communications engineers. Finally, their electrical siblings are getting a look in — and could become the new favourites.

Digital communication systems seem so robust that many of us take their reliability as an axiom of modern life. That reassuring façade, however, belies a surprising fragility: in practical communication systems, impairments of a distinctly analogue nature can affect the propagation of digital pulses. Nonlinear effects, for instance, amplify the low- and high-amplitude portions of a signal differently, and so distort the signal's shape. And even without amplitude nonlinearity, the signal shape can still be distorted if the elements of different frequency of a signal wave — its so-called Fourier components — propagate at different velocities (as they do in most practical media). This kind of dispersion limits signalling to rates at which the smeared-out trailing edge of one pulse only negligibly perturbs the leading edge of the next.

The quest to mitigate effects that distort the shape of digital signals has been an obsession for communications engineers. Their efforts have paid off handsomely: modern communication channels using optical fibres can sustain data rates greater than 50 gigabits a second over a distance exceeding that between Earth's poles. That's fast enough to transmit the entire print collection of the US Library of Congress in about half an hour.

As two recently published papers[1,2] remind us, such achievements are the result of a rare suspension of Murphy's law that anything that can go wrong will go wrong. Specifically — and remarkably — it is possible for the shape distortion produced by nonlinearity to cancel that produced by dispersion. The result is a single pulse of stable shape, dubbed a soliton. Writing in *IEEE Transactions on Microwave Theory and Techniques*, Ricketts, Li and Ham[1] show that this fortuitous cancellation does more than simply allow the faithful propagation of digital pulses: in fact, it can be used as part of an electrical oscillator to generate pulses in the first place. And in a paper in *Physical Review Letters*, Wu, Kalinikos and Patton[2] describe a related system that deliberately provokes inherently nonlinear dynamics to produce chaotic soliton oscillations. Both of these systems are purely electronic; their relative ease of manufacture gives them many advantages over the 'photonic' devices, involving light waves, that currently dominate soliton research.

These modern developments ultimately trace their origins to an observation made in the early nineteenth century, when, two decades before Louis Pasteur uttered the words, the Scottish naval engineer John Scott Russell found that chance does indeed favour the prepared mind. As Scott Russell watched a barge being pulled along Edinburgh's Union Canal one August day in 1834, the rope from the barge horses suddenly snapped. He noticed that the wave produced by the prow's rapid drop onto the water's surface propagated quickly down the canal with negligible change in shape over a distance of several kilometres — as he convinced himself by pursuing the wave crest along the side of the canal on horseback.

Scott Russell was certain that the abnormally low attenuation and dispersion of this 'wave of translation' revealed principles of fundamental importance, and constructed a large water tank in his back garden to prove it.

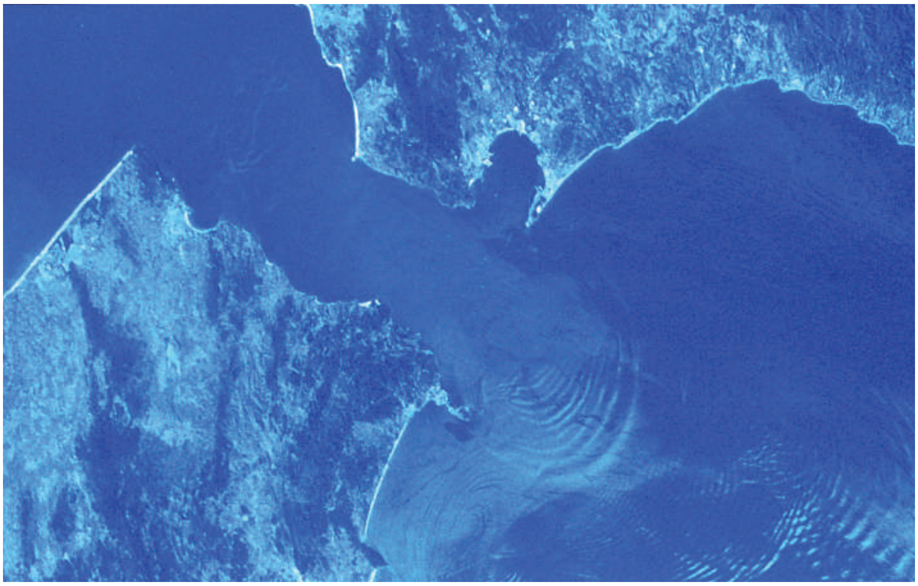

Figure 1 | Keep on waving. This image of solitons propagating out from the Straits of Gibraltar was taken by NASA's STS-41G space shuttle mission in October 1984. Lighter, fresher Atlantic sea water (which accelerates through the narrow straits from top left) compresses and upwells as it makes contact with the denser, more saline water of the Mediterranean Sea. The resulting sets of solitary waves propagate without distortion on the open sea over great distances.

Alas, he was virtually alone in this belief. Despite their appearance in various guises in nature (Fig. 1), the lack of any practical significance of such 'solitary waves' — solitons — meant that the subject would remain largely ignored for more than a century. Not until the 1960s did theoretical studies resume in earnest and reveal the conditions under which amplitude nonlinearity counteracts dispersion to permit the creation and propagation of solitons. These studies coincided with the development of lasers, whose high power density provides a practical means of teasing nonlinear behaviour out of optical fibres. It is these photonic descendants of Scott Russell's fluid solitons that have revolutionized long-distance digital communications in the past decades.

Optical soliton systems exploit the nonlinearity of an optical fibre's refractive index, under high electric fields. In contrast, electronic soliton systems use a transmission line in which the amplitude of the response to an applied pulse is itself nonlinear. Purely electronic soliton systems offer the same theoretical advantages enjoyed by their optical cousins, but have the added appeal that they are simpler to produce, as they can be manufactured using standard integrated-circuit technology.

Ricketts and colleagues[1], for example, use the voltage-dependent capacitance of conventional semiconductor junction diodes to create a discrete nonlinear transmission line. They connect this transmission line around an amplifier to make a closed feedback loop that produces an oscillating electrical signal. Ensuring the stability of an oscillating circuit requires careful control of some appropriate system parameter. In this case, the authors adjust the amplifier's gain dynamically both to guarantee that oscillations start and to avoid the onset of chaos. The result is a stable, periodic train of self-generated solitons. The short-duration, periodic soliton train produced by the oscillator could be widely deployed in communication and instrumentation technologies.

Wu and colleagues[2] use a topologically similar arrangement, but bring about nonlinear feedback using a ferromagnetic film made of yttrium–iron–garnet. The complex properties of this material allow a rich variety of nonlinear behaviour, ranging from stable-amplitude oscillations to chaos. Rather than ensuring stable oscillations, Wu and colleagues operate their oscillator in a chaotic regime. The chaotic nature of the signal readily scrambles a message over a large bandwidth, and so reduces the probability that it can be detected or interfered with. Meanwhile, synchronizing a chaotic transmitter with its intended receiver permits unambiguous decoding of the original message[3]. Much effort is currently going into such chaotic, covert communication schemes. The convenience of having such systems in a flexible electronic form using electrical solitons will do much to accelerate their development.

From chance observation of a summer canal-side ride, to linchpin of new communications technologies: John Scott Russell would no doubt have been delighted to see his belief in the importance of solitons so vindicated. ■

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50 & 100 YEARS AGO

50 YEARS AGO

Marine biologists have been slow to recognize that the smaller phytoplankton elements which will pass through the finest nets are of great importance in the productivity of the oceans. In order to get some quantitative data on this subject for eastern Australia (lat. 33–34° S.), we have recently conducted experiments in which 44 gallons of sea-water were pumped into a drum and filtered through a phytoplankton net having 170 meshes per inch. The filtrate was collected and the particulate matter was spun out of 2-litre aliquots using a continuous centrifuge running at 13,000 rev./min... Both the net fraction and the centrifugate were examined microscopically, using the fluorescence of chlorophyll, to count the photosynthetic organisms... It has been found that the chlorophyll content of the centrifugate is 25–3,000 times as great as that of the net plankton, while the counts of organisms are 10–10^2 as high again... It is proposed to continue these studies over an annual plankton cycle, in an estuary, and in the open sea.

From *Nature* 3 March 1956.

100 YEARS AGO

A magnificent fireball was seen by many persons in the north of England on the evening of January 27 at 8h. 33m... Mr. H. Beckwith, at Hull, observed the meteor travelling horizontally between the "square" of Ursa Major and the Belt of Orion, while at Cheadle, Miss Blagg noted the path as just above ζ Leonis. Mr. R. Felton, at Patrington, estimated the brightness as quite equal to that of the full moon... The meteor gave a very brilliant flash near its end point, and the suddenness of its apparition startled many people... the height of the meteor was from about 59 to 45 miles over the North Sea immediately east of the Lincolnshire coast. The length of the observed path was approximately 42 miles, and probable velocity of the object 24 miles per second... In recent years fireballs have been very numerous this month, and especially at the epochs about January 9 to 13 and 24 to 29.

From *Nature* 1 March 1906.