many possible routes to quantum computing have been suggested, but the most promising are solid-state implementations — most famously, nuclear spins of phosphorus atoms in a silicon matrix[10] — because they can be scaled up to generate the massive parallelism required for useful computation.

The counter-intuitive rules of quantum mechanics imply that, unlike classical computers, quantum computers should perform best with a slow clock speed[11] (in other words, the devices within them should switch slowly). This necessarily suggests that rapid decoherence of the quantum states encoding information is unacceptable. Entanglement between two solid-state quantum bits, or qubits, was reported for the first time at this conference — albeit with a rather rapid decoherence time of 300 picoseconds (J. S. Tsai, NEC). The qubits used were based on low-temperature superconducting tunnel junctions. Perhaps this breakthrough indicates where the future of quantum computing actually lies.

Another departure from conventional computing philosophy would be to work with light rather than electrons. Whereas the periodicity of the structure of crystalline materials is comparable to the wavelength of mobile electrons, advanced materials techniques enable periodic structures to be produced in which the repeating unit matches the wavelength of light — these are photonic band-gap materials. Complex structures formed with these advanced techniques (for example, ref. 12) could be used to manipulate light and form computer logic gates. Indeed, computer simulations suggest that light can bend around cleverly constructed corners with no discernible energy loss (S. John, Univ. Toronto).

The conference was also presented with some aspects of nanotechnology that could have an indirect impact on tomorrow's computers. For example, the issue of heat dissipation mentioned earlier could be locally monitored using a 75-nm-diameter carbon nanotube containing the liquid-metal gallium, which would act like a nanoscale mercury thermometer[13] in the 50–500 °C range (Y. Bando, National Institute for Materials Science, Tsukuba). Or perhaps computerized devices such as gas-specific sensors will rely on specially adapted nanotube elements — such devices can detect as little as 0.02% H_2 (G. Gruner, Nanōmix, Inc. and UCLA). Or perhaps computer display devices will use electron emission from nanotubes (P. Legagneux, Thales) such as those shown in Fig. 1 — in fact, Samsung have this year reported a proof-of-principle display unit[14].

So where will it all end? The graphics of S. John were reminiscent of the best that Hollywood can achieve, and the many talks relating to biology could at times make this physicist feel that he had come to the wrong conference. The nanoscale therefore seems to be the length scale at which science has become truly interdisciplinary. The question is, will it reconcile science fact with science fiction? ■

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Ecology

Biodiversity in the scales

Nicholas J. Gotelli

Scaling coefficients can reveal nonlinear relationships among biological variables. The approach has now proved fruitful in exploring the relationship between diversity at different taxonomic levels.

Species diversity is central to ecological studies. But it is a challenging parameter to measure because diversity is organized hierarchically: individual organisms are classified into species, species into genera, genera into families, and so on. As a consequence, patterns of diversity at one level (genera, for instance) are linked statistically and by evolutionary history to the patterns at higher and lower levels (such as families and species). On page 610 of this issue[1], Enquist and colleagues describe tight scaling relationships between species richness and diversity among the higher taxa (genera or families), in both living and fossil plant communities. These patterns should eventually help in understanding how species diversity is controlled and how total biomass is partitioned among coexisting species.

Enquist *et al.*[1] used allometric scaling equations that have traditionally been applied to problems of body size and relative growth. In mammals, for example, a power function[2] describes the relationship between brain size (x) and body size (y):

$$\text{Brain size} \propto \text{constant} \times (\text{body size})^z.$$

The exponent z is the scaling coefficient, and describes whether y is increasing faster ($z > 1$) or more slowly ($z < 1$) than x. On a log–log scale, these relationships plot as straight lines for which the scaling coefficient is the slope. In previous work, Enquist and colleagues[3–5] successfully applied allometric models to general patterns of biomass, body size and growth form in plant and animal assemblages. Here, they extend this approach to describe patterns of taxonomic and biomass partitioning in different tree communities. They analysed a high-quality global data set, collected by the late Alwyn H. Gentry, that includes 227 sites, each one-tenth of a hectare in area, from six continents. A database of plant fossil communities from the Tertiary period included 29 samples from sites in western North America.

For both the living and fossil tree communities, Enquist *et al.* plotted the logarithm of the number of higher taxa against the logarithm of the number of species, and discovered a tight relationship that explained more than 90% of the variance (although the fit to the Gentry data was not strictly linear). In other words, the number of higher taxa in a community is highly predictable from the number of lower taxa. In one sense, this is not new. Ecologists and biogeographers established long ago that the diversity of higher taxa changed predictably in large communities compared with small ones[6]. As more species are drawn randomly from a regional source pool, the number of higher taxa rises steeply at first as common taxa are added, and then more slowly as progressively rarer taxa are added[7]. The power function transforms this sampling curve into an approximately linear allometric relationship over limited regions of the curve.

Could taxonomic scaling be the inevitable consequence of random sampling from a large regional or global species pool? The answer seems to be no: the exponents for randomly constructed communities were consistently larger than those found by Enquist and colleagues. This result means that higher-level diversity in communities accumulates relatively slowly. Put another way, communities consist of slightly more species per genus or species per family than would be expected by chance, a pattern first noted in the 1940s by the statistical ecologist C. B. Williams[8].

If statistical sampling cannot entirely account for the pattern, what is the mechanism controlling taxonomic diversity? Previous applications of allometric scaling laws have been successful because they have often been derived from first principles of physical scaling laws, such as the hydrodynamic constraints that control the flow of fluids through plants[5]. Here, there are no such underlying first principles, and the mechanisms controlling taxonomic diversity are elusive.

Closely related species have similar dispersal abilities, so that communities might come to be dominated by families or genera that contain good dispersers, which would decrease the scaling coefficient. However, Enquist and colleagues' null model assumed that species colonize randomly and with equal probability, so it did not incorporate differences in dispersal ability among species or differences in total abundance among sites, which ranged from 52 to 1,005 individuals. Moreover, the fixed plot sizes in the Gentry data set will have sampled different proportions of species-poor and species-rich communities. As a consequence, the allometric coefficients measured by Enquist *et al.* are not constants and will change with plot size or sampling design. Variations in annual precipitation, site elevation and community age also contributed to deviations from the null-model predictions. Enquist *et al.* propose that local and regional processes control the pattern, but much more analysis will be necessary to identify the specific mechanisms responsible for this tight association.

Taxonomic scaling may influence other patterns. In previous analyses of the Gentry data, Enquist and Niklas[9] established that total biomass per plot varied surprisingly little across different communities. Consequently, as more species are added to a community, the amount of biomass partitioned to each species must inevitably decrease. This result appears to contradict studies in which total biomass increases when species are experimentally added to communities[10]. But there is enough scatter in the biomass partitioning data to accommodate both patterns. In contrast to the tight taxonomic scaling curves, the allometric relationship between biomass per taxon and total species richness explained little more than 50% of the variance in the data. For a given number of species in a community, biomass per species can vary tenfold. At smaller spatial scales, adding species to a community may indeed increase total biomass, even though biomass per species falls when communities are compared across large biogeographical regions.

The application of allometric scaling laws to patterns of taxonomic diversity has revealed surprising regularities in the diversity of plant communities. Moreover, the existence of such patterns in both fossil and living plant assemblages from different regions suggests that diversity might be regulated more by local processes, such as species interactions, than by historical factors, such as dispersal barriers or speciation. Teasing apart the specific biological and statistical mechanisms responsible for these patterns is a task for the future. ■

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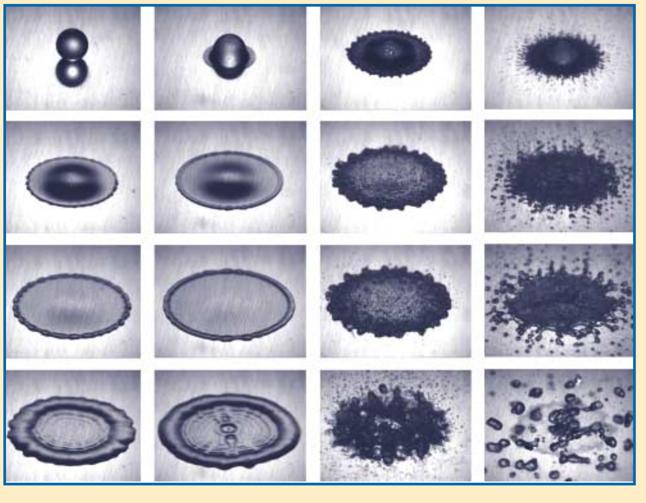
Fluid mechanics

Impact factors

Fire extinguishers, such as sprinkler systems, typically deliver a fine, pressurized spray of water droplets. Some of the smaller water droplets from a sprinkler may be deflected by the plume of the fire and so do little to extinguish it directly. But hot surfaces around the fire can be cooled by the evaporation of droplets that land on them, and the resulting vapour may also help to stifle the flames.

Because of environmental concerns, the widely used fire-quenching agent Halon 1301 was banned by international treaty in 1987. An alternative is to use water with some additive, such as sodium acetate trihydrate, that enhances its fire-quenching ability. How does that affect droplet behaviour?

Samuel L. Manzello and Jiann C. Yang (*Proc. R. Soc. Lond. A* **458,** 2417–2444; 2002) have investigated the collision dynamics of pure water droplets and droplets containing 30% (by mass) sodium acetate trihydrate as they impact on a hot metal surface. Whether each droplet spreads, splashes or rebounds depends on its impact energy as well as on the temperature and roughness of the surface.



Manzello and Yang recorded the collisions of 2.7-mm-diameter drops on a stainless-steel surface for a range of surface temperatures and impact energies — the latter quantified by the 'Weber number', related to the liquid's density and surface tension, and the velocity and diameter of the droplets. The images shown here were taken for Weber number = 181, at times (rows top to bottom) of 0, 1, 2 and 7 ms after collision and at surface temperatures (columns left to right) of 20, 104, 230 and 340 °C.

Compared with the behaviour of droplets of pure, distilled water, Manzello and Yang found that the presence of sodium acetate trihydrate made quite a difference to the collision dynamics at low impact (low Weber number), but less so for high-velocity impacts. In most fire-extinguishing systems the droplets are delivered from a pressure nozzle at high velocity, so the authors conclude that knowing how pure water droplets behave is a reasonable approximation to the behaviour of water with an additive.

They also note that, for high-impact collisions, a droplet forms a liquid film of greater diameter than in low-impact collisions, which increases its capacity for surface cooling. Although the relation of liquid-film diameter to surface temperature was clear for droplets of pure water, Manzello and Yang struggled to find such a correlation for water droplets containing the additive. More work, both theoretical and experimental, is needed here. **Alison Wright**