survivorship curve technique of population ecology, which is a simple plot of the proportion of the original sample that survives for various intervals of time. The use of a logarithmic ordinate ensures that the slope of the curve at any given age is proportional to the probability of extinction at that age. Van Valen's analyses of numerous taxa showed almost uniform linearity in the survivorship curves, allowing for sampling error. This is rather surprising, because it requires that the probability of fossil discovery does not decrease appreciably with the age of the strata, as has been argued by Raup in an article in *Science* (**117,** 1065; 1972); also because, for living taxa, both constant origination and extinction rates are implied. Van Valen is led on to propose a new evolutionary 'law', that extinction in any adaptive zone occurs at a stochastically constant rate. Exceptions to the 'law' are considered to be either spurious, rare or doubtful. He also proposes a new unit to measure the rate of extinction, the macarthur, named after a well known American evolutionary ecologist.

Raup, Gould, Schopf and Simberloff adopt a different approach in the *Journal of Geology* (**81,** 525; 1973) to the more general question of diversification and extinction, by using a computer to generate phylogenetic diagrams, or cladograms. The lineage of each clade, or monophyletic subunit, was generated by the computer program and caused to terminate or branch in order to produce a hypothetical phylogeny, with the termination and branching events being stochastically controlled using random numbers. Part of the input dealt with the establishment of an equilibrium diversity, in accord with modern evolutionary theory. The cladograms so produced exhibit a great variety of shapes: some underwent early exponential increase in diversity and then declined gradually to extinction (the trilobites); others showed a gradual diversity increase followed by a rapid extinction (dinosaurs) or passed through a near-extinction phase to develop a new phase of high diversity (ammonites). The average extinct clade increases in diversity up to the mid point of its stratigraphical range and then declines in diversity until extinction. When faced with such variation in pattern many palaeontologists have been inclined to suspect or postulate that the organisms in question were inherently different in evolutionary potential. The observed variation does not exclude, but nor does it demand this. Comparison with a real example, the fossil record of the reptiles, shows good general agreement but also some interesting differences. Thus the late Cretaceous extinctions showed more coincidence between different groups than predicted from the computer model.

It seems therefore that an exceedingly simple stochastic model can produce branching and diversity patterns very similar to those described in the real world; also that the taxonomy utilised by palaeontologists imposes various constraints similar to those used in the logic of the computer program. The question arises, where does one go from here? In the first place palaeontologists should be even more suspicious of any glib deterministic explanation of the diversification and extinction of any particular fossil group. More positively, there is a more sophisticated tool for investigating the extent to which the coincidence in time of extinction of different fossil groups departs from randomness. This should be easy to demonstrate for the striking mass extinctions at the end of the Permian and Cretaceous, but what of the other geological periods?

Two dimensional rotons

from Peter V. E. McClintock
Condensed Matter Correspondent

A ROTON in a two-dimensional assembly of helium atoms has a smaller energy than a roton in three dimensions, according to a calculation by Padmore of Erindale College, University of Toronto (*Phys. Rev. Lett.*, **32,** 826; 1974).

The thermodynamic properties of bulk liquid helium below its superfluid transition temperature can be understood reasonably well on the basis of a model, due to Landau, in which it is assumed that the thermal energy is all in the form of a gas of particle-like excitations moving through the superfluid, which plays the part of an inert background or aether. There are two main types of excitation: phonons, which are quantised sound waves much like those occurring in solids; and rotons, which are peculiar to liquid helium and are believed to correspond to some sort of stirring motions on the atomic scale, such as microscopic vortex rings. There is, as yet, no agreement as to the precise physical nature of rotons, but their detailed energy–momentum relationship, known as the excitation spectrum, has been established through neutron scattering experiments and is consistent to a high precision with the measured heat capacity of the liquid.

Although attempts to deduce the excitation spectrum theoretically from first principles for an assembly of weakly interacting helium atoms have not been very successful, Feynman and Cohen (*Phys. Rev.*, **102,** 1189; 1956) managed to derive a spectrum of the correct general shape and approximately in quantitative agreement with experiment, by using quantum mechanics. Their approach involved to a considerable extent the use of physical intuition to develop a wave function able to describe the superfluid background, and they then used a so-called trial wave function, not specified in detail, in order to describe the elementary excitations. A variational method was used to investigate how the trial wave function should be modified in order to minimise the energy of the whole assembly, and thus discover the true wave function from which the excitation spectrum could then be derived. Padmore has extended the Feynman and Cohen approach in an attempt to derive theoretically the excitation spectrum of a two-dimensional (2D) assembly of helium atoms.

Assemblies which are effectively 2D occur where one of two atomic layers of helium are deposited on a solid surface. The helium atoms are held in place by the attractive Van der Waals force which prevents them from moving in a direction perpendicular to the surface; but they can remain completely free to move parallel to the surface. Under appropriate conditions of density and temperature, such assemblies have been shown to form either 2D crystalline solids, or liquids, or gases. By using, for the substrate, materials such as exfoliated graphite or Vycor glass which have very large surface areas in relation to their volumes, it is possible to measure the heat capacity of 2D liquid helium, and experiments have shown that the heat capacity appears to be anomalously large. A possible explanation lies in the idea that rotons can still exist in a 2D assembly, but with smaller energies than they have in 3D. A neutron scattering experiment to measure the excitation spectrum does not seem possible because of the random orientations of different sections of the substrate, so a calculation of the spectrum is therefore of particular interest.

The most important conclusion which emerges from Padmore's calculation is that the energy of a roton in 2D is indeed considerably less than in 3D. Although the calculated roton energy, is, as in the 3D case, still somewhat larger than would be consistent with the measured heat capacity, the change in energy in going from 3D to 2D seems to be in excellent agreement with the relatively few experimental data at present available. Padmore also reports his calculated characteristics for rotons in 2D helium at a number of different densities, so no doubt there will soon be reports of further experiments aimed at checking these more detailed conclusions.