these basins, gravity and seismic refraction surveys were now being superseded by seismic reflexion work. In the East Midlands many pre-Permian folds had been discovered by this method and afterwards confirmed by drilling. A smaller number of pre-Albian folds had been found in Hampshire and Dorset and the margins of the basin more accurately delimited.

Dr. W. Bullerwell described the results of aeromagnetic surveys over central, eastern and southern England carried out under contract for the Geological Survey. Regions of positive anomaly were located in the northern parts of Leicestershire and Northamptonshire, in the area surrounding The Wash, along a magnetic 'ridge' extending roughly from Reading to Birmingham and in the English Channel south-east and south-west of the Isle of Wight. Comparison of the magnetic map with the gravity map of the same area, based upon data provided by the Geological Survey, University of Cambridge and the British Petroleum Co., revealed many regions in which gravitational and magnetic anomalies showed clear positional relationships, either directly or inversely correlated as regards amplitude. The general picture of the sub-Mesozoic surface of central England was suggestive of a block pattern in which the trends of such familiar structural lines as the Lickey, Nuneaton and Charnwood 'axes' were discernible.

The combined gravity and magnetic data, supported by the evidence of deep boreholes, afforded a suggestion of a sub-Mesozoic surface of acid igneous material at relatively shallow depth between Market Harborough and Bedford; and of a north-westerly trending geosyncline filled with Lower Palæozoic sediments beneath southern East Anglia, an interpretation in harmony with views previously expressed by Sir Edward Bullard and others after seismic investigations in this area[8].

Recent research, outlined by Prof. W. B. R. King and Prof. W. F. Whittard, supplemented previous knowledge of the geological history of the English Channel and Western Approaches[9-11]. In the central and eastern Channel, seismic work had proved high-velocity rocks at much less depth than anticipated. It appeared that the Paris Plage Palæozoic ridge was of greater extent than formerly thought and must virtually have separated the Hampshire and Paris basins. Probably the Trias was absent over this ridge and the Jurassic succession much thinner than that in the Portsdown and Henfield borings to the north and the Pays de Bray to the south. In the Western Approaches, Prof. Whittard inferred a series of tongue-shaped outcrops ranging from Upper Cretaceous to late Tertiary, with the younger formations appearing progressively towards the south-west. On the continental slope indurated blocks of chalky material containing Recent, or at earliest Pleistocene, Foraminifera had been dredged from a depth of 500 fm.

Among other contributions dealing with marine geophysics was one from Dr. R. F. King describing seismic, gravity and magnetic surveys in the northern part of Cardigan Bay, supplementing previous work by Dr. D. W. Powell[12]. The density and seismic velocity of the upper layers suggested the presence of clays of late Mesozoic or Tertiary age. Mr. G. Armstrong described the use of the sub-bottom depth recorder (or 'sparker'), essentially a broad-band, high-powered, echo-sounder, using as a sound source either an electric spark or a small explosion. With this instrument the National Coal Board had obtained a reasonably comprehensive picture of the fault pattern, disposition of strata and distribution of igneous dykes off the coast of Northumberland and in the Firth of Forth. An oblique echo-sounder system which recorded reflexions from the sea-bed from a low-angle beam had been successfully applied for geological purposes in Weymouth Bay by Dr. D. J. Donovan and Mr. A. H. Stride.

A feature of the symposium was the variety of the techniques discussed and the complementary nature of the geological evidence obtained by different methods. It was noteworthy that many of these (aeromagnetic, aeroradiometric, 'sparker', 'oblique asdic') employed continuous recording along a chosen profile. Increasing use of such methods is an important trend in applied geophysics at the present time and their advantages both in speed of operation and for interpretation were pointed out towards the close of the evening by Dr. Bullerwell.

J. H. TAYLOR

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EVOLUTION OF ARBORVIRUS DISEASES

THE arborviruses (*ar*thropod-*bor*ne viruses) are those animal viruses which multiply in the tissues of the arthropod host and are transmitted in its saliva. The purposes of a symposium which had been arranged by the Royal Society of Tropical Medicine and Hygiene, and was held in London on January 21, were as follow: (1) to try to fit the arborviruses into current evolutionary theory; (2) to review current knowledge of arborviruses and suggest profitable lines of thought and investigation; (3) to interest workers in related disciplines, notably zoologists.

The first two papers dealt mainly with the origin and long-term evolution, the third mainly with evolution observable in our own time.

Prof. C. D. Darlington discussed the relationship between heredity and infection in plant, insect and animal viruses. Human viruses are particularly fruitful for study because while viruses are the most rapidly evolving of parasites, man is the most rapidly evolving, most varied and most widely distributed of higher organisms. Because viruses are wholly parasitic we have to consider the relations of harm or benefit between hosts and parasite. At the viruslevel, the fundamental distinction in the basis of propagation is between the nucleic acids involved. In plants the two extreme forms of ribonucleic acid particle are the purely hereditary plasmagene of male fertility and the purely infectious particle of tobacco mosaic virus. Particles which are artificially transmissible by grafting, but not spread by natural infection, may be called proviruses, while viruses which apparently appear spontaneously or by chemical or physical treatment may be called new viruses. When vectors transplant viruses to new species the behaviour of the virus may change greatly, and when a vectored virus is artificially transmitted in series it may lose the capacity to infect the vector. A virus can become a harmless nucleoprotein (become latent): or something hereditarily transmitted in the cytoplasm or generated by the cell in development may become infectious. Latent viruses which resemble the plasmagene in behaviour may arise from active viruses either in the capital host or the vector and may or may not be transmitted through the egg. Further evolution may lead to loss of infectiousness, as with Kappa in *Paramecium*, or the hereditary vector stage may be lost and only direct infections between capital hosts remain. Phages have evolved on a basis of alternating heredity and infection and it is possible that some viruses of higher organisms may also have done so. Heredity and infection seem, however, to be strict alternatives, for the viruses of higher organisms and hereditary particles are likely to persist only when they confer a benefit on the host. On the other hand, infectious particles owe their maintenance to the benefit they extract from the host, and harm to the host is relatively unimportant. The selection pressures are, therefore, opposed and when a hereditary particle becomes infectious they are switched.

Mr. P. F. Mattingly presented the view that the evolution of arborviruses has depended very largely on the ecology of their arthropod and vertebrate hosts. Despite their isolation in host tissues, each individual virus may be credited with an ecology of its own, just like other organisms. To appreciate this, secondary accretions such as adventitious transfer to man and occurrences in atypical hosts or vectors must be disregarded. When it was introduced into the New World, yellow fever rapidly found an ecological milieu very closely resembling that from which it had been liberated in Africa. The need seems to have been primarily for arboreal primate hosts. *Haemagogus* were available, in place of forest *Stegomyia*, and adaptation to these may have been relatively easy. Similarly the principal vectors of Wesselsbron virus in the low and high veldt (*Neomelaniconion* and *Ochlerotatus* respectively) are taxonomically distinct, but phenologically closely similar.

The present-day requirements for the establishment of a mosquito-borne virus appear to be the coexistence of warm-blooded vertebrates, angiospermous plants and blood-sucking mosquitoes. The two former are known to have evolved more or less together during the latter part of the Mesozoic and the viruses and their mosquito vectors probably evolved with them. The necessity of fitting into a complex ecological system may have slowed the rate of evolution compared with some other viruses. The fact that primate malaria can be transmitted only by anopheline mosquitoes while bird malaria is readily transmitted by culicines in the laboratory and, presumably, also in Nature, suggests that the anophelines originated as mammal feeders and the culicines, at least in part, as a bird-feeding group. The few known cases of virus transmission by anophelines, other than *Kerteszia*, appear to be adventitious or secondary. Basic maintenance cycles involve culicines only, except possibly in the subgenus *Kerteszia* which in some ways are more culicine than anopheline in their ecology. These facts suggest that the primitive mosquito-borne viruses were bird rather than mammal viruses. *Aëdes*-borne viruses are confined to the tropics. In the subtropics they are replaced by *Culex*-borne viruses and these in turn are replaced by tick-borne ones in the northern steppes. The explanation seems to be that *Aëdes* hibernate and æstivate in the egg, *Culex* as adults. In the relatively severe conditions prevailing in the subtropics hibernating adult mosquitoes appear to be necessary for the maintenance of virus. Farther north, only the resistant egg will serve for hibernation and *Aëdes* become the dominant mosquitoes. But in the absence of trans-ovarian transmission these are unsuited to the maintenance of virus, and mosquito-borne viruses are replaced by tick-borne ones. On the assumption that West Nile is the most primitive of the group *B* viruses, a picture can be drawn of invasion from subtropical swamp habitats to the northern steppes on one hand, and to a variety of tropical habitats on the other, with transfer to ticks and to *Aëdes* respectively. A simpler and more coherent picture would result from the assumption that the Russian spring–summer viruses were the most primitive, and the arguments previously adduced are worth reconsideration on this basis.

Dr. C. E. Gordon Smith concentrated mainly on the effects of intentional or unintentional human interference on the short-term evolution of arborviruses. About a third of the known arborviruses cause human disease ranging from severe encephalitis to mild fever—the remainder are still in search of a disease, but there are also many human febrile diseases which may be in search of a virus. Arborviruses are most numerous in the tropics and become progressively fewer as we go north or south to subtropics and temperate zones.

The viruses are usually maintained in their wild reservoirs without overt signs, and infections of man, and epidemics in man, spill over from these reservoirs under suitable conditions. Such infections are, however, without significance to the continued survival of the virus.

When a virus is in equilibrium with its hosts and environment (endemic or enzootic), the strain present is the one whose characteristics most perfectly fit the particular ecological complex. Under such conditions a virus mutant is very unlikely to be better adapted for survival than the parent form and is unlikely to succeed. Any change in the number or species of hosts or in the environment, however, provides conditions which may favour a new mutant, which may, by chance, be more or less virulent for man than the parent form. The sudden appearance of Kyasanur Forest disease in western India in 1955, and of a hæmorrhagic 'dengue' in the Philippines and Thailand in 1956, suggest that changes of these sorts must have occurred.

Among man's major activities the clearance of forest and introduction of new hosts to cleared areas are of outstanding importance. Unsuspected viruses may be liberated to establish themselves elsewhere. Russian spring–summer encephalitis became an important disease in Russia only when the taiga forests were cleared and settled.

Irrigation and subsequent agriculture in California brought changes in the flora and fauna which were responsible for epidemics of encephalitis, and increased agricultural activity in Tongaland appears to have led to greatly increased arborvirus activity there.

With the widespread use of insecticides, resistant arthropod strains emerge, and it is unlikely that they do not also differ from the parent form in other respects, such as vector efficiency for arborviruses. Arthropods do not appear to be adversely affected by arborvirus infection and it is not known whether their defence mechanisms interact with the viruses. In vertebrates the specific defence is antibody formation, but there are also the non-specific processes of inflammation and fever. Inflamed tissue is acid, thus a strain of virus with greater resistance to acid and which multiples better over 100° F. may prevail. In the arthropod, the length of the extrinsic incubation period is dependent upon temperature; thus, on the other hand, viruses which multiply better at, say, 70° F., might have an advantage.

A strain of virus capable of remaining latent in vertebrates for long periods might be maintained through periods when arthropods are not sufficiently numerous. Such latent infections with western equine virus have been demonstrated in birds and the stress of migration or ovulation might permit the virus to circulate when mosquito populations are becoming active in a temperate climate.

Opening the discussion, Dr. C. H. Andrewes suggested that there are two kinds of evolution to consider: the short-term with changes such as have been best seen in influenza, and the long-term, in which viruses as a whole may be very old and relatively stable. Viruses have a unique form of replication, which does not suggest that they are derived from host components. The ticks being probably more primitive than the mosquitoes might be more likely to have been the original hosts.

Several other speakers suggested pointers to the ticks as original hosts. Prof. D. S. Bertram pointed out that the one-layer covering of tick eggs may make them more susceptible to transovarial infection than mosquito eggs. Dr. M. G. R. Varma said that it appeared that while mosquito-borne viruses could multiply in ticks, tick viruses could not in mosquitoes. Dr. P. B. Stones suggested that if mosquitoes were the origin, then viruses ought to have been isolated from male mosquitoes: he reported an isolation of Semliki forest virus from a male *Eretmapodites* in Lagos.

Dr. J. S. Porterfield suggested that Semliki Forest virus may be the most primitive member of group *A* of arborviruses—a number of very closely related forms have now been isolated in Africa. He thought that Israel turkey virus may be a recent derivative of West Nile virus possibly resulting from man-made ecological changes.

On an analogy with transduction in bacteriophage, Dr. P. H. A. Sneath suggested that viruses are not true parasites, but may be partially derived from the reproductive mechanisms of their hosts.

C. E. GORDON SMITH

RED DEER AND VEGETATION IN NEW ZEALAND

AN expedition visited Lake Monk in the Cameron Mountains of Southern Fiordland, New Zealand, during March 26–April 5, 1957, to study the inter-relations of birds and mammals, particularly deer, with the vegetation (New Zealand Department of Scientific and Industrial Research, Bull. 135).

The vegetation was classed broadly into forest, scrubland, grassland and bogs. Mice and stoats are the only small animals in the area; the former are scarce and the latter are probably more widely distributed; from an examination of droppings they appear to be feeding mainly on birds. Red deer (*Cervus elaphus*) are thought to have reached the area about 1920, and to have built up a peak population between 1943 and 1950. They have since declined in numbers and are probably still declining. The population was composed of 50 stags to 35 fawns to 100 hinds, which are unusually low ratios; the deer were all in very poor condition.

The amount of grazing on the fern *Polysticum vestitum* was strongly correlated with the density of deer fæces, and could be used to provide an alternative index to deer abundance.

Counts of deer fæces showed that the animals in this area were spending more time in the forest than in the open grassland, although their preferred food at the time of year studied is grasses and forbs, but storms probably prevent the deer from spending as much time in the open as they would otherwise do. In the forest the beech seedlings are heavily grazed, but once established they continue to grow slowly. The saplings are hedged by deer; but the full amount of each year's growth is not removed and eventually a shoot grows above the browse-level There are sufficient pole-stage beech to replace the present generation of mature trees, and enough of the younger stage to ensure the continuance of the forest, although possibly with a lower density of trees.

The second-tier species in the forest, such as *Nothopanax colensoi*, *Griselinia littoralis*, and *Coprosma foetidissima*, have little resistance to browsing and the young stages of these species are only found in places inaccessible to deer. In the sub-alpine scrub there has been a widespread destruction of *Olearia colensoi*: grassland areas have been heavily used but show signs of recovery. On boggy areas the trampling of hooves has bared the ground around wallow holes.

The investigators concluded that red deer provide the dominant animal influence on the vegetation; but it is an influence superimposed on long-term trends due to climate and on short-term successional changes. The composition of the vegetation has been and is being altered by them in such a way that there is a marked increase in unpalatable plants, and a corresponding decrease in palatable plants. The resulting environment is relatively unfavourable to deer. In spite of these changes in the composition of the vegetation the forest, as a protective forest, is in no danger of being eliminated by deer; the total vegetative cover is not decreasing, and soil erosion in the area is negligible.

In the light of these findings an attempt is being made to define and clarify the wild-life problems arising from the use of this area as a national park.