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NATURAL FOCALITY OF VIRAL INFECTIONS TRANSMITTED BY MOSQUITOES*)

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Abstract. A brief survey of the most important peculiarities of the natural focality of viral infections transmitted by mosquitoes is given: rapid circulation of the virus, irradiation of the virus from the natural focus, possibility of an outbreak of large epidemics, mobility of the borders of natural foci, specific composition of vertebrate hosts of the virus.

The theory of natural focality of transmissive diseases was developed and worked up by E. N. Pavlovsky, first on the basis of the studies of tick-borne encephalitis and tick-borne relapsing fever. Also the data on the foci and vectors of plague, tularemia and cutaneous leishmaniasis were considered. At the beginning of the study on natural focality, as well as in the following years, most attention was given to the infections transmitted by ticks and such blood-sucking parasites as fleas and partly mosquitoes (Pavlovsky 1964).

During the last decade the knowledge on the problems of arboviruses has been considerably enlarged. As it is known, arboviruses are those viruses which multiply in the organism of arthropods and are transmitted to the vertebrates through the saliva, i.e. during their feeding on the animals or man. According to the data from 1967 (Taylor (ed.) 1968), a total of 204 viruses were known, 137 of them were isolated from mosquitoes. Fourty-five of these viruses are reliably known as causative agents of human diseases (Mattingly 1969). This number is rapidly increasing, because every year further viruses of this group are found. As far as it is known, the causative agents of all arthropod-borne viral diseases can circulate in nature irrespective of man, i.e. all infections caused by arboviruses are characterized by natural focality.

Natural laws in the natural focality of viral infections transmitted by mosquitoes differ from one another in specific features which are connected with the biology of vector: rapid circulation of the causative agent, irradiation of the causative agent from the natural focus, possibility of an outbreak of large epidemics, mobility of the borders of natural foci, specific composition of vertebrate hosts of the virus.

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RAPID CIRCULATION OF THE CAUSATIVE AGENT

As soon as the mosquito receives the virus when feeding on an animal (or man) host, the virus starts multiplying in the organism of the insect, supposing, of course, that the mosquito species is susceptible to the infection by the respective virus. The multiplied virus is accumulated in the salivary glands of the mosquito in an amount sufficient for infection of the susceptible animal or man; the quantity is of greatest importance here. This process lasts 7—10—15 days, sometimes longer, depending on the species of the causative agent and vector, as well as on the temperature. After this time the mosquito acquires infective properties, i.e. ability to infect the vertebrate host. This ability is maintained usually up to the end of its life. The mosquito, however, does not live long, usually about one month, sometimes one and half or two months, but on the average less than one month. At the temperature of 26 °C and 80% of relative humidity one half of experimental *Aedes togoi* (Theobald) lived 23 days, *Aedes albopictus* (Skuse) 44 days and *Eretmapodites chrysogaster* Graham 27 days (Hylton 1969). Under natural conditions they evidently die sooner.

No reliable evidence was given on the transmission of virus from the infected mosquito to the progeny. The period of viremia in vertebrates (i. e. the average time for which the virus circulates in the blood in an amount sufficient for infection of the vector) is usually not long, sometimes some days only. Therefore the virus can be maintained in the focus only under condition of a relatively rapid circulation. If a mosquito generation dies without having transmitted the virus to susceptible vertebrates, the circulation of the virus is cut off. This is an important peculiarity for the causative agents of "mosquito infections". As a rule, several cycles of virus transmission are completed during a season.

IRRADIATION OF THE VIRUS FROM NATURAL FOCUS

A characteristic feature of most species of mosquitoes is the wide range of vertebrates they can feed on, without a narrower food specialization. Many species of mosquitoes (but by far not all) attack both man and domestic or wild animals. The wide range of hosts is characteristic for such important vectors of viruses pathogenic to man as *Aedes aegypti* (Linnaeus) (Mc Clelland and Weitz 1963), *Culex tritaeniorhynchus* Giles (Pennington and Phelps 1968), *C. tarsalis* Coquillett (Tempelis et al. 1965). Some species of mosquitoes, e.g. *Culex pipiens* Linnaeus and *Aedes aegypti*, not only fly to populated areas, but reproduce in masses in the villages and towns. On the other hand, some viruses pathogenic for man can circulate in the blood of man in an amount sufficient for infection of mosquito vectors. In this case man can be not only a recipient but also a donor of the virus. In some infections man can become the major or even — temporarily, in a certain focus — the only reservoir of the infection of mosquitoes (yellow fever, dengue). This is what E. N. Pavlovsky called "irradiation of the virus from natural focus".

The ways of such irradiation have been studied in particular on the example of yellow fever. At present there are no permanent human foci of this disease, but in the extensive areas of the tropical zone of Africa and South America there are natural foci which represent a permanent threat to the inhabitants of the respective territory. The recent epidemics in Sudan, Ethiopia and Senegal are supposed to be a result of the irradiation of virus from the natural foci. During the largest epidemic of the yellow fever in the last decade in Ethiopia in 1960—1962, when about 200 thousand people fell ill (Haddow 1969), the major vector seems to have been *Aedes simpsoni* (Theobald). The mosquitoes of this exophilic species occur not only in free nature, but also in the

vicinity of villages and sometimes fly into houses; they attack both monkeys and man. *A. simpsoni* can therefore form the link between the natural foci of yellow fever and contigency in man. The participation of other mosquito species in the transmission of the virus could not be excluded.

Somewhat different was the case of the last major epidemic of yellow fever in Senegal in 1965 (Cornet et al. 1968). The main vector was allegedly *Aedes aegypti*. While in non-African countries it is known as house insect, in its native country in Africa this mosquito lives in free nature. There exists the possibility that the mosquitoes received the yellow fever virus from monkeys and transmitted it to man. The virus was then disseminated by mosquitoes without participation of monkeys.

Other variants of virus irradiation from natural foci have also been reported. In the foci of the western equine encephalomyelitis the major vertebrate hosts of the virus are birds. The main vector is *Culex tarsalis*, from which hundreds of strains of the mentioned virus have been isolated. This species of mosquitoes feeds on birds, both wild and domestic, as well as on mammals and man. The role of the link between the infected bird and mammals (man) can be also played by mosquitoes of the genus *Aedes: A. vexans* (Meigen), *A. dorsalis* (Meigen), *A. flavescens* (Müller) (Shemanchuk 1969). Unlike to the preceeding case (yellow fever), the human organism is an impasse for the virus of equine encephalomyelitis. Analogically, the major vertebrate hosts of the Japanese encephalitis virus are the birds in nature and the domestic animals, especially pigs, in the settlements. The most important virus vector, *Culex tritaeniorhynchus*, occurs widely in the countries of the East and South Asia. This mosquito attacks both birds and mammals, especially pigs, and also man, whereby the virus is easily disseminated in the settlements and even in large towns.

POSSIBILITY OF AN OUTBREAK OF LARGE EPIDEMICS

If the virus irradiates from the natural focus and starts to disseminate through the mosquitoes from man to man, there arises the possibility of infection of a large number of people at the rapid circulation of the virus. In the last decade the largest mosquito-borne viral infections were the epidemics of dengue and o'nyong-nyong fevers.

The natural focality of dengue has not been studied sufficiently. The monkeys are supposed to be the primary vertebrate hosts of the virus. It is transmitted by two species of mosquitoes, *Aedes aegypti* and *A. albopictus*, which seem to complete one another as a link in the circulation of the virus. The former (an endophilic one) occurs mostly in towns in the non-African countries. The latter (rather exophilic) prefers the suburbs and villages (Gould et al. 1970). When these two species of mosquitoes are abundant, under conditions of a hot climate, the virus can be easily disseminated among the inhabitants. This has already happened in many countries, particularly in the South-Eastern Asia.

The largest epidemic of mosquito-borne viral infections was the epidemic of o'nyong-nyong fever in East Africa in 1959—1960. The disease, unknown up to that time, appeared in Uganda and then quickly spread to the south-east. According to some approximate data available, about 5 milion people fell ill (Andrewes 1969). Unlike in most of mosquito-borne infections, the vectors of the virus were the anopheline mosquitoes, *Anopheles funestus* Giles and *An. gambiae* Giles, from which a number of virus strains were isolated. These mosquitoes are widespread in Africa, to the south of Sahara. They are very numerous in settlements, often penetrate into the houses and bite people, thereby causing the rapid dissemination of the infection (Corbet, Williams and Gillet 1961).

MOBILITY OF THE BORDER OF NATURAL FOCI

While studying this question, the data on the flight range of the mosquitoes should be considered. As a rule, they do not fly farther than 2—5 km from the breeding site. Under certain conditions, however, they can migrate over a large distance, 10—20 km and more, which has been proved by labelling of insects with a dye or radioisotopes.

A case of extension of the border of natural focus of yellow fever from the Panama Canal to the southern border of Mexico was reported in the years 1950—1957. This was evidenced by the study of monkey carcasses, illness of people and detection of specific antibodies in the blood of man and animals. During the 7 years the borders of the natural focus reached about 1400 km, i.e. they extended for 200 km per year on the average. Also other data are available on the rapid shifts of the border of natural foci of mosquito-borne infections. The causes of these shifts have not yet been elucidated. They may be associated with the migration of not only mosquitoes as the vectors, but also of vertebrates as hosts of the virus. The question of the possible role of bird migration in the dissemination of arboviruses has not been considered here. This problem has been dealt with in a number of papers, e.g. in those from the V International Symposium held in Novosibirsk in 1969.

SPECIFIC COMPOSITION OF THE VERTEBRATE HOSTS OF VIRUSES

During the previous studies of the natural focality of arthropod-borne diseases conducted by Soviet workers, the major vertebrate hosts of the causative agents were found to be the small mammals, especially rodents. However, in the viral infections transmitted by mosquitoes the greater role is played by birds. The connection of mosquitoes with the birds as a source of blood is very old and very close. In the zone where a large number of various arboviruses were found — under conditions of a moist tropical forest — the mosquitoes live in the hollows of trees and other microreservoirs of water in the vegetation in the stalks of bamboo, in the leaf sheats of bromeliads, etc. Hundreds of mosquito species of various genera are associated with the "wood reservoirs". The pertinent species of mosquitoes live in the tops of trees and feed primarily on the birds and also on mammals living in the trees.

The origin of viruses transmitted by mosquitoes, especially of the group "B", is supposed to have been connected at the beginning with the mosquitoes of the genus *Culex*. The first vertebrate hosts of these viruses were birds (Mattingly 1960). In the infections such as Japanese encephalitis, western equine encephalomyelitis, Saint-Louis encephalitis, Western Nile fever, the basic path of circulation of the virus in natural foci includes birds and mosquitoes of the genus *Culex*. The role of mammals as hosts of viruses transmitted by mosquitoes should also be taken into consideration. Data on the importance of mammals involved in the infections of mosquitoes by the viruses of the California encephalitis group have been recorded in the recent years (Iversen et al. 1969; Arboviruses of the California complex, Proc. of the Symp. 1969).

These are the most characteristic peculiarities of the natural focality of viral infections transmitted by mosquitoes. These peculiarities have been outlined only schematically but even this survey shows that the study of the natural laws in the circulation of viruses transmitted by mosquitoes gives a substantial material for the investigation of the general questions of the natural focality of diseases.

ПРИРОДНАЯ ОЧАГОВОСТЬ ВИРУСНЫХ ИНФЕКЦИЙ, ПЕРЕДАВАЕМЫХ КОМАРАМИ

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Резюме. Краткий обзор важнейших особенностей природной очаговости вирусных инфекций, передаваемых комарами: быстрый темп циркуляции возбудителя, легкость иррадиации возбудителя из природного очага, возможность возникновения больших эпидемий, подвижность границ природных очагов, особенности состава позвоночных хозяев вируса.

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