THE CONCEPT OF VECTOR IN PARASITOLOGY, ECOLOGY OF AGENTS, EPIDEMIOLOGY AND EPIZOOTOLOGY

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Dedicated to Prof. V. V. Kucheruk, on the occasion of his 70th birthday

Abstract. The concepts of "host" and "vector" are compared in application to arthropods which are capable to transmit pathogens to man and animals. The paper shows that these concepts are not identical. The function of such arthropods as hosts of microorganisms, as well as their possible importance in population ecology, epidemiology and epizootology are discussed. The system of different concepts corresponding to the tasks of these scientific disciplines is also considered.

Arthropods transmit many pathogenic agents to man and animals, such as viruses, rickettsiae, bacteria, protozoans, helminths. The classification of features characterizing the relationships between arthropods and those microorganisms, the systematization of variants of vector transmission of agents and detection of corresponding types of vectors invariably attracted interest of many researchers (Huff 1931, Leach 1940, Pavlovsky 1947, Beklemishev 1948, 1955, Dick 1957, MacLeod 1961, Gutsevich 1967, Alekseyev 1964, 1965 etc.). Different, not always consecutive views were expressed, and in many cases they were mutually incompatible. However, it is not the task of the present paper to compare and analyze them in detail, as this has been done only recently in a special paper by Kryuchekhnikov (1988). He clearly showed that there are considerable discrepancies in the very interpretations of terms and concepts which have been widely used in the field for many years. Among them the most important is the term "vector" and the concept of "specific vector".

Vector is a blood-sucking arthropod capable of transmitting an agent from donor to recipient under natural conditions (Kucheruk and Rosicky 1984). However, other definitions of this term are known which are very close in their meaning. It should be emphasized that the most important function of vector, as most researches see it, and its main feature differing it from other arthropods is its capability to transmit a certain agent. Such an approach seems to be justified and should not give rise to any doubt. However, the published data show that in many papers the concept of "vector" is identical (partly or completely) with the important parasitological concept of "host" and sometimes this is done quite deliberately. Thus, for example, Garnham (1964) considered the concepts of "host" and "vector" to be of the same meaning and therefore the term "vector" undesirable.

Quite clearly this confusion of the functions of the arthropod as host and as vector becomes evident in the traditional interpretation of the concept of "specific vector". The tendency connected with the notions of general parasitology has become well-known: according to them the vectors are regarded as specific or biological ones in case that the organisms transmitted by them multiply in the arthropods or undergo in them a certain stage of their life cycle. If these phenomena do not happen in the vectors, they are considered to be unspecific or mechanical (Beklemishev 1948, 1955, Alekseyev 1982, Tarasov 1981 etc.). Such a double interpretation of the functions of specific vector led to the emergence of many supplementary inaccurate ill co-ordinated
terms and expressions. In the recent publications of Alekseyev (1984, 1985), for example, which are specially devoted to the characterization of the vector—agent interrelationships, there are, apart from the term "specific vector", the following expressions: specific vector, accidental transfer, specific transmission, mechanical transmission, specific way of transmission, specifically effective way of transmission, specifically effective mechanism of transmission, specificity of the agent reproduction in vector, specificity of agent-vector relationships interaction. In one of these papers the author (Alekseyev 1984), discussed the problem of specificity of arthropods as vectors of agents, but in Balashov's (1984) opinion the problem dealt with in it is the specificity of agents to vectors, which constitutes one of the manifestations of the general phenomenon of parasite-host specificity.

The glossary of Kucheruk and Rosický (1984), however, devoted to the interpretation of basic concepts in the field of natural faculty of diseases, does not contain at all the term "specific vector". With detailing of the world "vector" only three following concepts are mentioned in it: primary, secondary and incidental vector.

The existing confusion is not merely a specific terminological issue. It considerably aggravates the understanding and interpretation of different biological phenomena connected with arthropods as vectors of agents causing diseases in man and animals, which are dealt with by several scientific disciplines: general parasitology, populational ecology of agents, epidemiology and epizootiology. The concept "vector" is applied in almost in all these disciplines. It is not identical with the concept of "host", and its more accurate definition by various adjectives should be coordinated with the objectives of the given scientific discipline and with those phenomena the knowledge of which should be promoted by terminology (Table 1).

In the aspect discussed general parasitology regards arthropods primarily as hosts of different agents including, among others, agents causing diseases in man and animals. One of the main tasks consists in the detection of natural laws governing the host—parasite interaction. (We use this expression here only as an established term in parasitology, but have put the word "parasite" in inverted commas, because we are of the opinion that parasitism represents one of the forms of symbiosis. Actually involved are symbiotic relationships between arthropod and microorganism. In this connection a great importance is given to capability or incapability of microorganisms to infect and reproduce in an arthropod, to undergo or not undergo in it a certain stage of life cycle, to do or not to do harm, and to other signs constituting a complex of biological phenomena determining the character of these interrelationships. Depending on their characteristics, the arthropods of a certain species, in agreement with the terminology established in general parasitology can be biological, primary, supplementary, definitive, intermediate etc. host of a concrete species of microorganism. The phenomenon of their "transfer" in this number of biological concepts has not been actually involved and not a single feature mentioned is a specific sign of vector. Nevertheless, it is customary to designate the arthropods which, as a matter of fact, are biological hosts of arthropods transmitting them, as "specific (biological) vectors". Although this term has been widely used in the sense, we consider it unjustified because involved here is the concept of "host" common in general parasitology. It should be said that the term "mechanical vector" (in contrast to the "biological" one, see above) does not reflect the essence of phenomenon at all, because the possibility of transmission of microbial flora by "mechanical vector" is determined by complicated ecological as well as physiological-biological factors which depend on the enzym system of microorganisms and arthropod, and on the food components of the latter (Lindsay and Scudder 1956).

An independent number of biological phenomena maintaining the existence of microorganisms on populational level is treated by populational ecology. For those
microorganisms whose life cycle includes an obligatory transmission by arthropods, of primary importance is the degree of regularity of such a relation. The arthropod, acting as a microorganism from donor to recipient, plays the role of the essential factor in the vector transmission. With respect to the microorganism the arthropod can be a specific vector or a non-specific one. A vector, however, without which its natural reproduction and under given conditions as biological species practically impossible, is specific vectors. In our opinion the use of the given terms is rightful for the designation of only this number of phenomena.

In this respect, if the vector is not a biological host of the microorganism, but maintains its existence by "mechanical transfer", it specific role in the life schema of microorganism is quite evident and beyond any doubt. Thus, for example, the rabbit flea *Spilopsyllus cuniculi*, the only vector of the myxomatosis virus infecting rabbits in England (Day 1957), is not its biological host, but undoubtedly must be considered as its specific vector. The bed bugs (Cimex lectularius) easily become infected with *C. burnetii* while feeding on both the infected animals and the sick people. For a long time they are able to retain the bacteria which can multiplication them, feeding on the transstadial and transovarian passage and shed in them (Balashov and Daiter 1973). Nevertheless, in our conception the bed bug is not a specific vector of *C. burnetii*, due to the number of ecological peculiarities of these resident vectors and bedbugs themselves. The latter cannot guarantee a long-term existence of the given population of the infected microorganism. There are other similar examples concerning different categories of vectors: groups of vectors and objects of their transmission and we shall revert to them later.

Very topical and insufficiently treated has been the question why one or another species is a specific vector of a concrete microorganism. However, the discussion of this question exceeds the limits of the present communication. In general terms it may be added that this problem that a regular transmission is ensured by a certain set of relationships for each variant of vector—microorganism. Their most important characteristics, contributing to, or vice versa, hindering the given species to become a specific vector, may manifest themselves at different integration levels of biological systems: from the molecular (e.g. mechanism of adhesion of procyrtic cell) to the biogeocenotic one.

This means that there is none and cannot be a universal explanation which would in all cases enable us to understand why the given arthropod has become or has not become a specific vector.

Epidemiology deals with arthropods as one of the factors of pathogen transmission to man, along with other factors: air, water, soil, foodstuffs, objects of environment. Every agent is transmitted when certain factors of transmission are present, which are almost invariably in their absence. They are usually designated different groups of microorganisms distinguished from unspecific ones for the given agent. The latter may facilitate the transmission, but do not ensure its maintenance as a biological species (Control ... 1969, Gromashevsky 1965). From the aspect of epidemiology both the lice transmitting typhus fever *Rickettsia* and the ixodid ticks transmitting tick-borne encephalitis virus, and the fies disseminating the virus of epidemic conjunctivitis, are specific factor of transmission of these diseases, despite considerable differences in the character of association of each microorganism with the mentioned arthropods and despite the difference in the mechanism of the agent's penetration into the recipient's organism. In other words, all relevant vectors of transmissible diseases are specific vectors of their transmission. Consequently, the terms "specific" or "non-specific" are related in epide-
cannot exist for a long time only owing to this species. Finally, in all continents
within the distribution area of the yellow-fever virus the mosquitoes *A. aegypti* transmit
it from the sick to the healthy man, performing the function both of the specific and
primary vector in anthropogenic or even synanthropic foci which simulates
accident. The type of transmission anthropophobos. It is extremely demonstrative
that all the mentioned mosquito species, despite the differences in their importance
for the existence of the yellow fever agent, and for the epidemiology and epizootology
of the infection, are biological hosts of the virus. A similar situation occurs with a number of
mosquito species of the genus *Aedes*, the vectors of the causative agent of dengue fever.
In polyvectors transmits anthropophobos, for mosquitoes of the different
mosquito species of the genus *Anopheles* may become specific vectors of the agent.
Depending on the numbers and ecological peculiarities of a certain species ensuring the
frequency of its trophic contacts with man, it may become primary or secondary vector.
The importance of a certain vector in the epizootology and epidemiology of infection
does not always coincide. The tick *Arausa persica*, a specific and primary vector of
*Boophilus microplus* birds, may be indicated as an extreme variant of such a discrep-
ancy. However, this tick is not a vector of human diseases, because it does not attack
man and consequently cannot transmit *Borreli* nor any other agents to man. The above
dependence shows that correlations between the concepts characterizing the role of vector
in the ecology of agent, as well as in the epidemic and epizootic processes, can be very
different.

We consider it important to discuss briefly also correlations of the concepts of
"biological host" and "specific vector", although this problem has been partly discussed
above. Four variants of such correlations are a priori logically possible: 1. an arthropod—
biological host of microorganism is its vector; 2. host is not a vector; 3. a vector
of organism is its biological host; 4. a vector is not a host. In what variants 1, 2, 3 and 4 are identical in meaning. Such a correlation of the discussed concepts is typical of most arthropods associated with microorganisms
causing transmissible diseases in man, animals and plants today. Apparently this is the
very reason why some researchers do not see any difference between the concepts of
"biological host" and "specific vector". However, these functions could have arisen
during the evolution of arthropods and in different ways. There are grounds to assume
that the function of vectors of many rickettsiae pathogenic to mammals could have arisen in ixodid ticks which already were biological hosts of rickettsiae-like symbionts. Likewise the sandflies, the vectors of pathogenic leishmaniasis,
appeared to have been originally the hosts of monoxenophage flagellates. On the other hand,
human live the function of vectors transmitting pathogenic rickettsiae and apolo-
phage evidently preceded to arise simultaneously with the formation of the function of
hosts. This is also an evidence that in application to arthropods the concepts of
"host" and "vector" are not identical.

If concrete transmissible infections of vertebrates existing at present are in question,
the combination in which the arthropod—the biological host of microorganism is its
the vector (variant 2), is impossible of course, because without the transmission
the existence of the pathogen as a species is inconceivable. However, it is well known
that in arthropods of medical importance there is quite a number of obligate symbionts
among protozoans, bacteria, rickettsiae and viruses, whose hosts represent.
For instance, rickettsiae of the genus *Wolbachia* in ixodid ticks and bloodsucking mos-
quitos, bacteriosis of triatomin bugs, a number of togaviruses, bunyaviruses, etc. Since the organisms the microorganisms are not pathogenic to man and vertebrates, the arthropods are not their vectors in epidemiological and epizootological aspects. The variant 4, in which specific vector is not biological host
of the agent, has been discussed above (rabbit fleas and myxomatosis in England).
In conclusion it should be noted that the authors do not claim at all to have exhausted
the full scale of the problems discussed. They only wished to direct attention of re-
searchers to the fact where the agent and the concepts of "host" and "vector" are far from identical and
that the same species of arthropods—vectors can have a different meaning for the micro-
organism: as its host, in its ecology, as well as in epidemiology and epizootology of a given
infection. Moreover, one and the same arthropod species may be a highly effective specific
vector of the agent in some cases, and in others it may be a poor vector or is not
the vector of the same agent at all. In other words, the ability of the arthropod to be a vector depends among other things on the development of the disease. Therefore, if only a system of
different concepts is used for the assessment of varied associations of arthropods
with pathogens, their true complexity can be comprehended.

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