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THE RELATIONSHIPS BETWEEN PROTOZOA AND VIRUSES

1. PROTOZOAN VIRUSES

Protozoa appear to be partners of symbiosis to very many microorganisms. The symbioses of protozoa have been described with bacteria, Spirochaetas, Rickettsias, algae and lower fungi, as well as with protozoa themselves.

A number of survey articles and monographs dealing with this problem (Kirby, 1941; Ball, 1969; Preer et al., 1974; Margulis, 1975; Осипов, 1981; Lee et al., 1985*a*, *b*; Corliss, 1985) reveal that as a result of consistent studies of the morphology, function and systematics of the symbioses between protozoa and other microorganisms it has been proved that characteristic of both ecto- and endosymbionts of protozoa is their strict specificity, fixed location in the host cell and a determined effect on the life cycle of the host. The latter is influenced, first of all, by endosymbionts or xenosomes residing inside the nucleus and in the cytoplasm, which often cause the death of protozoa.

Similar effect on protozoa may also have their symbiontic or endogenic viruses, which were discovered in the USA in 1972 in the organism of *Entamoeba histolytica*, a pathogen of the amoebiasis widely spread in tropical and subtropical regions.

The idea of seeking viruses in this protozoon was brought about by L. S. Diamond's (1968) observation, which he made during consecutive passaging of an axenic culture of a strain of *E. histolytica in vitro*. He noticed that from time to time there was an inexplicable deterioration in multiplication of the amoeba, which, as a rule, was accompanied by mass lysis of amoebae.

After the cultures had gone through the "crisis", the amoebae continued to grow fast and stabilized further on. Still, some irregular periods of growth regress without apparent reason could be seen. One of those axenic strains (ABRM strain) was isolated with a rectoscope from an ulcer of the large intestine of a patient suffering from amoebiasis, and L. S. Diamond began to study it together with virologists. He at once found out that the growth regress of amoebae in axenic cultures was accompanied by the lysis of protozoa, which, in his opinion, was caused by viruses (Diamond et al., 1972). To prove that the established phenomenon was caused by viruses, L. S. Diamond and his coworkers carried out a series of experiments, using a complicated scheme.

In the first test series the ABRM strain was studied with transmitted light, inverted and electron microscopes, and with the help of cell cultures and various culture media. There were neither viruses, virus-like particles nor bacteria in the axenic cultures of the strain. But when lysates, filtrates and supernatants of those cultures where growth of amoebae had been interrupted and lysis observed were added to amoebae of the same strain with already stabilized growth, growth regress and lysis of amoebae were observed in the latter. In the following test series L. S. Diamond used the ABRM strain as a donor strain causing restrained growth and

lysis to infect some recipient strains of *E. histolytica* (strains HK-9, NIH, HB-301 and F-22). Purified from associating microflora, these strains multiplied in axenic cultures throughout 684 passages without the least signs of restrained growth or lysis of the amoebae.

Thus, adding filtrate of freeze-thawed amoebae or supernatant of the donor culture ABRM to the culture of the recipient strain HK-9, L. S. Diamond et al. did not notice any deviations from normal growth by light microscope in 96 hrs, but already its first subculture showed restrained growth and mass lysis after 76 hrs of observation. The authors now continued their work mainly on the subsequent subcultures of the same culture and, simultaneously, on cultures of the recipient strains of *E. histolytica* 200: NIH, F-22 and HB-301. These strains, in their turn, were infected with the filtrate of destroyed amoebae from subcultures of the recipient strain of HK-9 culture (induced with the material of the donor ABRM strain). At the end of this test series the authors added filtrate of amoebae from the 41st subculture of the recipient strain of HK-9 to the culture of the donor ABRM strain, the growth of which had by then stabilized, i. e. amoebae were multiplying in this culture without restraint and lysis.

As a result of these sophisticated experiments (their detailed description cannot be given here because of space limits) the authors (Diamond et al., 1972) established that the donor ABRM strain of *E. histolytica* had been infected by two different types of viruses. But since the ABRM strain itself proved to be relatively resistant to the damaging effect of these viruses, the presence of the particles was detectable only on the recipient strains of amoebae infected with filtrates of the donor ABRM strain. The proof was provided by growth regress and lysis of amoebae in all the cultures of recipient strains of *E. histolytica*, induced by filtrates of amoebae or supernatants of the cultures of either the immediate donor ABRM strain or of the recipient HK-9 strain, infected with lysates of the amoebae of donor strain cultures.

Further evidence of the presence of viruses in the organism of *E. histolytica* was a discovery of large clusters of virus-like filaments by electron microscopy. The filaments were about 10 nm in diameter, located in the nuclei of the protozoa of recipient cultures, which had been induced with the donor ABRM strain. After the rupture of the nucleic membrane caused by lysis of amoebae, small clusters of such filaments could be found also in the cytoplasm, and after the destruction of the cell membrane even extracellularly.

Beside such filamentous particles the authors found also polygonal particles with the diameter of 70—75 nm in the perinuclear zone of amoebic cytoplasm. Usually these particles, reminding of polyhedral viruses were empty, but there were also such ones where an electron-dense nucleoid could be detected. As a rule, polygonal particles appeared in the amoebae of the recipient culture in no less than 12 hrs after inoculation of the infectious material of the donor strain of *E. histolytica*, whereas in the next 12 hrs the number of such particles grew noticeably and thereafter decreased again. Simultaneously with the appearance of polyhedral virus-like particles in the cytoplasm of the amoebae the morphology of protozoa also underwent some changes. They became round, vacuolized and lysed at last, whereas in the case of finding only filamentous particles in the nuclei of the amoebae the authors established no changes in the morphology of the protozoa.

It should be mentioned that beside the amoebae of recipient strains induced with filtrates of the donor ABRM strain, the authors detected polyhedral particles also in amoebae of one of *E. histolytica* strains (HU-21), which, during its purifying from associating microflora had

been grown in nutrient medium containing agar, and after that was passaged in a medium without agar. A a result of such change in cultivation conditions the growth of amoebae became abruptly worse, giant forms and lysing individuals appeared in the culture, and from the 7th passage on in an agar-free medium in the cytoplasm of lysing protozoa polyhedral particles were constanly found.

Having convincingly proved the presence of two different forms of virus-like particles in the organism of *E. histolytica*, research was continued in the same laboratory both on nature and ultrastructure (Mattern et al., 1972) as well as the biochemistry (Hruska et al., 1973, 1974) of these formations. Soon it became evident that two different types of viruses were involved. The initial supposition that filamentous particles might prove to be predecessors of the polyhedral virus (Diamond et al., 1972) was refuted since no populations of amoebae were found which produced one of these forms of virus-like particles only. Thus, the authors came to a conclusion that *E. histolytica* can be infected both with polyhedral viruses, replicating in the cytoplasm, and filamentous ones, the replication and pathogenicity of which is connected, first of all, with the nuclei of amoebae. The authors considered the effect of both virus types on the recipient strains of *E. histolytica* to be the same — leading to the lysis of protozoa in the end. But in a few years C. F. T. Mattern et al. (1977) reported on discovering a third type of virus in *E. histolytica*, which had a distinct structure and was, like the filamentous virus, found in the nuclei of amoebae, where it replicated.

All the three viruses turned out to be DNA-viruses, unknown before (Hruska et al., 1973, 1974; Mattern et al., 1977), which may be present in the organism of *E. histolytica* either separately or all together (Diamond et al., 1976).

As was ascertained at the further detailed investigation of the established biocoenoses, these three virus types usually caused no harm to the donor, i. e. "host" strains of *E. histolytica*, although they intensively replicated in the amoebae of these strains. However, their replication was not always of the same intensiveness. When the viruses were intensively replicating, the recipient strains of *E. histolytica* were infected with them even as a result of one-time contact with the supernatant of the donor culture, but in order to infect recipient strains with slowly replicating viruses, it was necessary to lyse the amoebae of the donor strain and thereafter concentrate the released from protozoan organism viruses by centrifugation. At that it was noticed that outside amoebic organism the viruses were inactivated relatively fast (Diamond et al., 1976). Thus, for instance, while lysing amoebae by freezing with the mixture of dry ice and alcohol at −79° and subsequent thawing at 37°, the lysis of cells was practically total, covering 99 to 100 per cent of amoebae, but the activity of the polyhedral virus dropped even to 99 per cent. The same decrease in the activity of viruses was also observed while lysing amoebae by hypotonic shock, and only at shaking amoebae for 3—4 minutes in a mixer with glass beads, the loss in the activity of viruses was comparatively smaller, making up as much as 90 per cent of the total activity.

The viruses of *E. histolytica* proved to be quite sensitive to temperature. Thus, at 37° in 24 hrs about 90 per cent of viruses were inactivated, whereas at 56° in one hour almost all of them (99.9 per cent) were inactivated. The viruses were relatively stable to the effect of ether and chloroform (Diamond, Mattern, 1976).

By the present time more detailed research has been done into the physical properties and morphology of the polyhedral virus. This virus is an icosahedron having three axes of rotational symmetry (5:3:2), whereas the structure of the DNA-virus proved to be unique for its folded

arrangement (Mattern et al., 1974). In the author's opinion such composition of nucleic acid distinguishes the polyhedral virus of *E. histolytica* from any other virus of bacteria and algae, although the rest of their properties are to a great extent similar. Thus, for example, icosahedral DNA-viruses of algae of about 60 nm in diameter, but also various polyhedral bacteriophages with the diameter of 50 to 100 nm, morphologically remind of the polyhedral virus of amoebae, which, according to C. F. T. Mattern et al. (1972, 1974) may have a tail characteristic of many bacteriophages and viruses of cyanobacteria.

It was more difficult to study the morphology of the filamentous virus of *E. histolytica*, since it could not be separated from the polyhedral virus even by using antiserum to the polyhedral virus (Diamond, Mattern, 1976). As was mentioned above, the diameter of separate virus filaments reached *ca* 10 nm, but their length could not be established because of its longitudinal temporariness. Filaments of this virus form a cluster that is considered unusual for viruses of animals but is typical of many plant viruses and some DNA bacteriophages.

According to C. F. T. Mattern et al. (1977) the third type of *E. histolytica* virus has the most unique morphology. It has a linear structure of 235 nm in length and consists of 14 distinct substructures with the diameter of *ca* 19 nm, which are placed at a distance of 25—30 nm from the nearest parallel line each. Electron microphotos reveal a regular arrangement of these structures, which form hexagonal zones. Often there were rows of the beaded virus consisting of 28 beads. As to the size of separate beads they remind of parvoviruses of vertebrates (Fenner, 1975/1976), but unlike the latter, having a single-stranded DNA molecule, the beaded virus of *E. histolytica* has, according to C. F. T. Mattern et al., most probably a double-stranded DNA molecule.

It is not clear yet what role these three above-described virus types of *E. histolytica* play or what effect they have on the life cycle of the given protozoon. According to preliminary suggestions of J. F. Hruska et al. (1973), relationships of *E. histolytica* with its endobiotic viruses are expressed either by classical lysogeny or persistence in a host cell. In the first case the balance of the participants in the system is kept, as is known, by some anti-virus substances, specific antisera, interferon or even some hereditary resistance of host cells. In case there is a lysogenic system, amoebae infected with viruses do not lyse, and the viruses can get out of the organism of such protozoa only by their artificial destruction.

In order to find out whether in the given case there is lysogeny (or persistence) of viruses involved, a number of interesting experiments was carried out (Hruska et al., 1973), which proved that all the three types of viruses and their host *E. histolytica* were in a relatively stable balance. Regardless of a rather intensive replication of viruses in the amoebae the authors observed no cytopathic changes in these axenically cultivated unicellular organisms neither by light nor electron microscopy.

After the treatment of the amoebae with an antisera against endogenic viruses, the titre of the latter in cultures of the donor strain of *E. histolytica* dropped a little, but later on the virus replicated as intensively as before. The balance in the system *E. histolytica*—endogenous viruses could not be broken even by superinfection of the given virus, as the titre of the virus after a temporary rise as rapidly dropped to the initial level.

Proceeding from the results obtained, the authors (Hruska et al., 1973) considered the phenomenon of lysogeny more probable in the system under investigation. But it seems that in the given case instead of lysogeny one may use a better term suggested by C. A. Knight (1975), namely virogeny, although not so widely used as yet. According to J. F. Hruska

et al. (1973), lysogeny as a mechanism of persistence of viruses in normal cultures of *E. histolytica* well explains the phenomenon under investigation by these authors (Diamond et al., 1972; Mattern et al., 1972; Hruska et al., 1973), since in amoebic cultures, similarly to the bacterial lysogenic ones, intensiveness of replication of viruses depends upon the density of the host's culture. Two facts testify in favour of lysogeny — the resistance of *E. histolytica* to its endogenous viruses for the detection of which a recipient, i. e. the indicator strains of *E. histolytica* had to be used, and the impossibility to remove the viruses by treating amoebae with antisera, specific of the given virus.

In spite of a number of arguments proving that relationships of *E. histolytica* with its endogenous viruses are expressed by lysogeny, there are also facts contradicting that phenomenon. Thus, J. F. Hruska et al. (1974) ascertained that it is impossible to provoke lysis of *E. histolytica* by ultraviolet irradiation, iododeoxyuridine, bromodeoxyuridine or mitomycin, which usually cause the lysis of bacteria induced with bacteriophages, and that contradicts lysogeny. Therefore a suggestion was made (Diamond, Mattern, 1976) that if viral DNA did not totally integrate with amoebic genome, viruses might be in the organism also in the form of episomes or plasmids. Consequently, viruses are transmitted in amoebae by heredity, and *E. histolytica* strains, once infected with viruses, never get rid of such endobionts.

According to L. S. Diamond and C. F. T. Mattern (1976) all the three virus types they established in cytoplasm and nucleus of *E. histolytica* are able to penetrate and affect only this unicellular organism. All the attempts to infect various cell cultures and bacteria, as well as experimental animals with these virus types, led to no success. Unfortunately the researchers systematically studying viruses and protozoa, have paid, as much as is known to us, very little attention to the questions of the effect of viruses on the pathogenicity as well as other biological properties of their hosts. We could find only three publications (Mattern, Keister, 1977*a*, *b*; Mattern et al., 1979) where the pathogenicity of the donor ABRM strain and recipient strains of *E. histolytica* on newborn mice and hamsters were compared. Only the donor strain proved to be pathogenic for experimental animals, although all the recipient strains, too, had been infected with viruses.

Thus, regardless of establishing even three different types of viruses in the organism of *E. histolytica*, two of which have been listed in the official catalogue of viruses (Fraenkel-Conrat, 1974), up to now their role in the biology of this amoebae species as well as in the pathogenesis of the amoebiasis of man has still remained unclear. All surmises of the dependence of the virulence of *E. histolytica* on the viruses of this amoebae are still only indirect grounding either on the results obtained by L. S. Diamond, C. F. T. Mattern et al. in the laboratory of Parasitic Diseases of the Institute of Allergy and Infectious Diseases, in the laboratory of Virus Infections of Hygiene Institute of Bethesda, USA, or on the data obtained by electron microscopic studies of these amoebae. R. Elsdon-Dew (1976), having studied the works of the above-mentioned group of authors, put forward a hypothesis that amoebiasis might be caused by transformation of the commensal *E. histolytica* into a pathogenic protozoon after introducing some virus-like agent into its organism. The hypothesis is supported by the generally known phenomenon of turning avirulent bacteria into virulent ones, as it was established, for example, in *Corynebacterium diphteriae* under the influence of a prophage.

The opinion that viruses of *E. histolytica* may prove responsible for virulence of these amoebae is shared also by R. G. Bird and T. F. McCaul (Bird et al., 1974; Bird, McCaul, 1976). The conclusion was based on

L. S. Diamond's, C. F. T. Mattern's and their coauthors' results as well as on their own data obtained at investigating virus-like particles in the organisms of *E. histolytica* and *E. invadens*. In the cytoplasm of 12 different *E. histolytica* strains and one *E. invadens* strain the mentioned authors established the structures of 250 nm in length and 90 nm in diameter that reminded of the rhabdovirus. The researchers supposed that those virus-like particles described by them were RNA-viruses. But as far as we know they have not yet convincingly proved the viral origin of these formations. Therefore the question of the role of virus-like particles in virulence of amoebae also remains unanswered, the more so because the authors have not studied virulence of these protozoa. Neither can one be certain of the origin of fibrillar virus-like particles of 9 to 14 nm in diameter, discovered by R. Michel and E. Schupp (1975) in the cytoplasm of *E. histolytica*, which the authors considered different from the filamentous viruses established by L. S. Diamond et al. (1972).

For the time being there are no convincing data either on that the virus-like particles detected in the organisms of *E. histolytica* and *E. invadens* by electron microscopy appear to be really viruses, or that these particles are namely endobiotic viruses, which had penetrated into these protozoa from outside and replicated or persisted in them (Kovács, Bucz, 1967).

Anyway, proceeding from the above-given data one may be sure that beside the viruses of man, animals, birds as well as, most probably, fishes and plants, which are capable of penetrating into protozoan organism, replicate and persist there, protozoa like any other protista have also their own endobiotic viruses, discovered by L. S. Diamond, C. F. T. Mattern et al. in *E. histolytica*.

Regardless of the fact that this discovery intrigued many scientists to search for endobiotic viruses in other protozoa as well, it took almost 15 years before new associations of that kind were found.

Another species infected with viruses of protozoa appeared to be *Trichomonas vaginalis*, a widely spread parasitic protozoon parasitizing in the urogenitary tract of man. The search for endobiotic viruses in this protozoon was grounded, first of all, on the formation of metronidazole resistant strains of *T. vaginalis*. In order to explain its nature more profound investigations of trichomonads' biological properties, among which also the concentration of RNA and DNA were started. In the course of almost simultaneous research work in the USA and Czechoslovakia with the application of different methods it was ascertained that some examined strains of *T. vaginalis* contained not only ordinary but also double-stranded RNA which refers to changes in the genome of the protozoon.

Thus the Czech scientists (Flegr et al., 1985) found that some strains of *T. vaginalis* contained not only high molecular weight DNA and ssRNA but also five or six other distinct populations of nucleic acid molecules. Electrophoretic bands of these molecules were DNase-I resistant and RNase-A sensitive, they were detectable by ethidium bromide but undetectable by desoxyribonucleic acid specific probe. After staining with acridine orange these bands gave bluish fluorescence suggesting a double-stranded form of the molecules. The double-stranded form of these molecules was also confirmed by electron microscopy. Under the nondenaturing condition of the aqueous protein monolayer technique, the main component of DNase-treated nucleic acid extracts were linear molecules of uniform length of about 1.7 μm. After differential centrifugation of the cell homogenate the main part of the dsRNA was found in large granule fraction.

The occurrence of dsRNA elements in *T. vaginalis* strains was rather

frequent. Six out of sixteen examined strains contained these elements. The total amount of dsRNA as well as the relative amount of dsRNA in particular electrophoresis bands varied among the strains, but were rather conservative within the strain. The strain specific pattern was unaffected by long term cultivation or selection for a drug resistance. In the opinion of the authors these elements can be assumed to be dsRNA plasmids or genome of dsRNA viruses comparable to some myxoviruses and reoviruses respectively.

A. L. Wang and C. C. Wang (1985) also identified double-stranded RNA (dsRNA) of *T. vaginalis* ascertaining electron microscopically the evidence of linear double stranded structure 1.5 μm in length, with no apparent hairpins or loops. The boiling of dsRNA in 30% dimethyl sulfoxide denatured it into single strands of 1.5 μm and shorter fragments. It consists of 23.4% G, 23.4% C, 23.0% A and 30.3% U and melts at a transition temperature of 81.7 °C in 75 mM NaCl and 7.5 mM sodium citrate, pH 7.0, with 7—15% hyperchromicity. The ^{32}P-labeled dsRNA hybridized specifically with *T. vaginalis* DNA fragments in a single DNA band from Eco RI digest and two DNA bands from Hind III digest. Of the 33 different strains or isolates of *T. vaginalis* examined, all contained this dsRNA.

In the course of further experiments A. L. Wang and C. C. Wang (1986*a*) succeeded in ascertaining that dsRNA of *T. vaginalis* is largely intact in ribonuclease-treated homogenate of 12000 x g and further purified in CsCl buoyant density gradient centrifugations. The purified sample contains the dsRNA as well as one major protein with an estimated molecular mass of 85 kDa in NaDodSO$_4$/PAGE. Electron microscopic examinations indicated the presence of icosahedral virus-like particles of 33 nm diameter in the purified preparation. The exact location of the virus in *T. vaginalis* is not clear, except that it is not found in the nuclear fraction and is probably membrane-band. No free virus can be recovered from the culture medium of *T. vaginalis* and no successful infection of virus-free *T. vaginalis* strains by purified virus has been accomplished. There is no viral genomic sequence identifiable in host DNA. The absence of a viral genomic sequence in the host DNA suggests a lack of reverse transcription and integration of the viral genome.

Soon after the discovery of the endovirus of *T. vaginalis* the same authors (Wang, Wang, 1986*b*) identified dsRNA virus also in *Giardia lamblia*. First of all the authors established that nucleic acid samples purified from trophozoites of *G. lamblia* Portland I strain contain an ethidium-stainable band, which comigrates with 7.0 kilobase DNA in agarose gel electrophoresis. The band was degradable by alkali, ribonuclease A and ribonuclease T_1, but the susceptibility toward the ribonucleases decreased with the increasing ionic strength, suggestive of dsRNA. This identification was confirmed by electron micrographs of the purified samples, which showed linear double-stranded structures with an estimated average length of 1.5 μm. In crude homogenates of *G. lamblia*, this dsRNA was protected against added ribonuclease A but disappeared when adding sodium dodecyl sulfate or proteinase K. Differential centrifugations suggested an association of the dsRNA with the nuclear fraction, but it was freed to the 109 000 x g pelletable fraction with increasing homogenization. The dsRNA was purified by CsCl buoyant density gradient centrifugations in a distinct band with a p value of 1.368 g ml^{-1}.

Electron microscopy revealed spherical virus particles with a diameter of 33 nm, which were also identified in the nuclei of sectioned *G. lamblia* trophozoites. The established virus particles yield a major protein with an estimated molecular weight of 66.000 in sodium dodecyl polyacrylamide gel electrophoresis. These virus particles are abundant in the culture

media of stationary phase *G. lamblia* Portland I strain and are able to infect the *G. lamblia* strains free of the virus. There is no sequence homology between the dsRNA and the nuclear DNA of *G. lamblia* and thus no apparent integration of viral genome into host DNA.

These three species of protozoa, i. e. *E. histolytica*, *T. vaginalis* and *G. lamblia* are, to our knowledge, the only ones in which the presence of endobiotic viruses has been ascertained so far, although virus-like particles as well as cytopathogenic, probably viral, agents have also been found in the organism of other protozoan species.

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ALGLOOMADE JA VIIRUSTE VAHEKORD

1. Algloomade viirused

Protozoad ehk algloomad on sümbioosipartneriteks väga paljudele mikroorganismidele. Nii on kirjeldatud algloomade sümbioosi bakterite, spirohheetide, riketsiate, vetikate ja alamate seentega, samuti algloomade endiga. Nagu nähtub seda probleemi käsitlevatest ülevaateartiklitest ja monograafiatest, on algloomade ja teiste mikroorganismide vahelise sümbioosi morfoloogia, funktsiooni ja süstemaatika järjekindla uurimise tulemusel kindlaks tehtud, et niihästi algloomade ekto- kui ka endosümbionte iseloomustab range spetsiifilisus, kindel lokalisatsioon peremeesrakus ja determineeritud toime peremehe elutegevusele. Viimast mõjustavad eelkõige tsütoplasmas ja tuumas elunevad endosümbiondid ehk ksenosoomid, mis põhjustavad sageli algloomade surma.

Algloomadele toimivad ka nende sümbiootilised ehk endogeensed viirused, mis avastati Ameerika Ühendriikides 1972. aastal troopiliste ja subtroopiliste piirkondade elanike hulgas väga laialdaselt levinud amöbiaalse düsenteeria tekitaja *Entamoeba histolytica* organismis.

Hiljem on endogeensed viirused kindlaks tehtud veel inimeste urogenitaaltraktis parasiteerival, kogu maailmas väga levinud *Trichomonas vaginalis*'el, samuti kosmopoliitsel parasitaarsel *Giardia lamblia*'l.

Vaatamata sellele, et seni on endogeenseid viirusi leitud ainult algloomade kolmel liigil, on põhjust arvata, et viirustega võivad olla infitseeritud ka algloomade paljud teised liigid. Eelkõige räägib selle võimaluse poolt niihästi viirusesarnaste organismide kui ka tsütopatogeense, tõenäoliselt viirusliku agendi leidumine ainuraksete organismide mitmetel liikidel.

Юри ТЕРАС, Лейда КЕСА

ВЗАИМООТНОШЕНИЕ МЕЖДУ ПРОСТЕЙШИМИ И ВИРУСАМИ

1. Вирусы простейших

Простейшие являются партнерами симбиоза для очень многих микроорганизмов. Так описаны связи одноклеточных организмов с бактериями, спирохетами, риккециями, водорослями и низшими грибами, а также с простейшими самими. Благодаря исследованиям морфологии, функции и систематики симбиоза установлено, что экто- и эндосимбионты простейших характеризуются строгой специфичностью и локализацией в клетке и детерминированным действием на жизнедеятельность хозяина. Последнее зависит прежде всего от обитающих в цитоплазме и ядре эндосимбионтов или ксенозомов, которые часто вызывают гибель простейших.

Так же могут воздействовать на простейших и симбиотические (эндогенные) вирусы, открытые в организме возбудителя амебиальной дизентерии *Entamoeba histolytica* (1972 г. в США).

При более детальном исследовании биоценоза выяснилось, что все три типа вируса, установленные в *E. histolytica*, специфичны, т. е. они способны реплицироваться в организме только этого простейшего. Все попытки инфицировать этими вирусами других простейших, бактерий, клеток ткани или подопытных животных оказались безрезультатными.

Открытие трех разных типов эндогенных вирусов *E. histolytica* побудило искать такие же вирусы в организмах и других простейших, но следующие подобные ассоциации были найдены лишь в 1985 г. Вторым видом простейших с установленными эндогенными вирусами оказался паразитирующий в урогенитальном тракте человека флагеллат *Trichomonas vaginalis*. Вскоре после этого эндогенные вирусы были изолированы и у другого, также очень широко распространенного во всем мире флагеллата — *Giardia lamblia*. Хотя эндогенные вирусы удалось до сих пор установить только у трех видов простейших, имеются основания предполагать, что вирусами инфицированы и многие другие простейшие. В пользу этого говорит, прежде всего, обнаружение как вирусоподобных частиц, так и цитопатогенных, по всей вероятности, вирусных агентов в организме разных видов простейших.