THE RELATIONS BETWEEN A CARNIVOROUS DIET AND MAMMALIAN INFECTIONS WITH INTESTINAL PROTOZOA.*

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(Received for publication March 31, 1924.)

The original observations on carnivorous animals described below, previous experiments on the effects of a carnivorous diet on rats, and a review of the literature on intestinal protozoa, all indicate that a carnivorous diet is unfavorable for entozoic protozoa that inhabit the digestive tract.

1. *Effects of a carnivorous diet on rats.* In a previous publication (Hegner, 1923) the following data were reported. Three rats that had been fed during their entire lives (174 days) on a carnivorous diet that resulted in good growth and reproduction were entirely free from the flagellates, *Giardia muris* and *Trichomonas muris;* one was free from *Hexamitus muris;* and the other two contained only a few specimens of this species; whereas other rats from the same colony that had been fed on various diets, largely carbohydrate in nature, were well provided with all three of these flagellates.

Fifteen control rats fed principally on vegetable proteins and carbohydrates when compared with fifteen experimental rats fed on a carnivorous diet for 7 to 8 days gave the following results.

	Incidence of infection.			Comparative numbers present.†		
	Giardia	*Hexamitus*	*Trichomonas*	*Giardia*	*Hexamitus*	*Trichomonas*
Controls.....	100	87	100	1.2	1.2	91.2
Experimental.....	93	93	93	0.12	1.7	1.7

No conspicuous difference in the incidence of infection resulted

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† A definite quantity of material from the intestine was spread out under a cover, 22 mm. square, and the number of organisms was counted in ten different fields, using a No. 10 ocular and 4 mm. objective. The numbers given in the table are the average per field.

from this diet, but the number of giardias and trichomonads decreased remarkably. An increase occurred in *Hexamitus muris;* this fact and the observation that two of the three rats mentioned above contained specimens of this species indicate that a carnivorous diet is not unfavorable for this flagellate. No species of the genus *Hexamitus* has been reported from man. Why a carnivorous diet brings about a reduction in the numbers of giardias and trichomonads has not been definitely determined. In the case of trichomonas it seems to be due to the unfavorable environment brought about by a change in bacterial content. The predominant bacteria in control rats are of the acidophilus type, whereas in rats fed for a week on a carnivorous diet the putrefactive type is predominant. Apparently the trichomonads are unable to withstand the products of decomposition of the latter.

2. *Intestinal protozoa of carnivorous animals.* There are two sources of information on this subject; (1) the results of studies of intestinal protozoa contained in the literature, and, (2) original studies of carnivorous animals.

(1) The literature of protozoology is very extensive and widely scattered, but fortunately monographs on many special groups are available. The principal groups of protozoa of mammals that are usually considered intestinal are the ciliates, amoebae, flagellates, and coccidia. At least two types of organisms are represented in these groups with regard to their relations to their hosts; (*a*) organisms such as *Endamoeba coli* which apparently lives largely as a scavenger on the intestinal contents, and (*b*) other species such as *Endamoeba histolytica* which seem to require tissue elements for nourishment. Various degrees of tissue invasion by the protozoa are represented by different species. For example, among human protozoa the ciliate *Balantidium coli* is probably able to exist without access to the tissues. but frequently invades the intestinal wall where "nests" are formed in the mucous and submucous tissues. The host cells are utilized for nourishment, and submucous abscesses and open ulcers may result. *Endamoeba histolytica* apparently cannot exist without living tissue for food. In most cases the tissues destroyed are regenerated by the host and no clinical symptoms result. The cells of the intestinal wall appear to be cytolysed by the amoebae and in some cases, when the submucous layer is broken down in this way, an amoebic ulcer results. Access is gained to the circulation by the destruction of blood-vessels in the intestinal wall and specimens are then carried to various parts of the body. Secondary infections in the liver are not uncommon and amoebic abscesses of the lungs and brain sometimes occur.

The relations of intestinal flagellates to the tissues of the host are not definitely known. Giardia has a sucking disc with which it attaches itself to the epithelial cells, and, according to certain investigators, may invade the tissues. The trichomonas with five flagella, *Pentatrichomonas,* has been observed to devour red-blood cells, and other trichomonads have been accused of penetrating the intestinal wall. More careful investigations, however, are necessary to establish definitely the tissue invasive powers of these flagellates, and until further evidence is forthcoming it seems best to consider them as inhabitants of the lumen of the intestine.

A high degree of tissue invasion occurs in coccidial infections, and it is very doubtful whether the members of the group Coccidia should really be included among intestinal protozoa, since they become intracellular soon after they emerge from the spores and do not escape from the tissues of the host until they reach the oocyst stage; at this time they are passive and are simply carried out of the host's body with the intestinal contents.

In a recent monograph on the intestinal ciliates of man and other mammals, Buisson (1923) gives a list of all these organisms reported up to this time. Twenty-five different species of mammals are listed by Buisson as hosts of intestinal ciliates. Seven of these are rodents (agouti, capybara, gondi, cavies (2), rock-rabbits (2)); twelve are ungulates (ox, camel. horse, goat, sheep, rhinoceros, tapir, pig, elephant, llama, reindeer, roe-deer); and six are primates (man, chimpanzee, gorilla, orang-outan, baboon, monkey (*Macacus cynomolgus*)). To these should be added the Brazilian monkey, *Cebus variegatus,* in which a Balantidium was found by Hegner and Holmes (1923). Species are especially numerous in the ox, camel, horse, goat, llama, sheep, and reindeer—all herbivorous ungulates. At least 21 species belonging to 10 genera have been recorded from the caecum of the horse alone. Fewer species occur in the rodents, the largest number being 8 belonging to 5 genera in *Cavia aperea.* No more than one species has ever been recorded from any primate [1] and one species only, *Balantidium coli,* has been reported from the pig.[2] Five of the primates (man, orang-outan, baboon, *Macacus cynomolgus,* and *Cebus variegatus*) harbor only one species, *Balantidium coli.* The other two primates harbor a single genus and one species each,—the chimpanzee

[1] As many as nine species have been described from man, but only one, *Balantidium coli,* has been well established.

[2] Recently McDonald (1922) has described what he believes to be a second species of Balantidium, *B. suis,* from the pig.

with *Troglodytes abrassarti* and the gorilla with *Troglodytes gorillae*. The results of this survey are quite striking. There is not a single carnivorous animal among the hosts, and the strictly herbivorous species are most abundantly infected. The primates and pig may be listed among the omnivorous mammals, and the animal food they ingest may be sufficient to prevent the continued existence of ciliates in their intestines. The occasional presence of *Balantidium coli* in primates may be due to the fact that this species is to a greater degree a tissue parasite than are the other intestinal ciliates.

An adequate idea of the distribution of intestinal amoebae among mammals may be obtained from the work of Hassall (1913), Hartmann (1913), Dobell (1919), and Nöller (1922). Five well recognized species occur in man, *Endamoeba histolytica, E. coli, Endolimax nana, Iodamoeba williamsi,* and *Dientamoeba fragilis;* at least three live in monkeys, *Endamoeba nuttalli, E. pitheci,* and *Iodamoeba kueneni;* three species occur in rodents, *Endamoeba muris, E. cobayae,* and *E. cuniculi;* and four in ungulates, *Endamoeba suis,* and *Iodamoeba suis* in the pig, *E. bovis* in the ox and *E. ovis* in sheep. Dogs and cats can be infected in the laboratory and may exhibit spontaneous infections, but the latter are probably due to the ingestion of human cysts.

It is more difficult to state definitely the relation of intestinal flagellates to carnivorous animals, because data regarding this group are so widely scattered through the literature. Fonseca (1915) in his monograph on the parasitic flagellates of the mammals of Brazil examined five species of carnivores (coati, bear, grison, dog and cat) with negative results. In one of three species of monkeys he found giardias; five species of bats were uninfected; only one of thirteen species of rodents was negative; three of eight species of ungulates were infected; one species of edentate was positive; and two species of marsupials were uninfected. There are at least five species of intestinal flagellates in man, *Chilomastix mesnili, Trichomonas hominis, Giardia lamblia, Embadomonas intestinalis,* and *Enteromonas hominis* (see Hegner and Taliaferro, 1924). Trichomonas has been reported from the cat, dog, and fox as well as from omnivorous animals including man, the monkey, and pig; from rodents, such as rats, mice, guinea pigs and rabbits, and from the ox. Chilomastix has been found in the dog, and giardias in cats and dogs, although they are apparently rare in these animals and common in rodents. Giardias have been reported from several ungulates including the pig, sheep, horse, and ox. Cats

and dogs under domestication are really omnivorous animals and the fox feeds largely on insects. Furthermore, these three carnivores appear to be very rarely infected with intestinal flagellates, and it seems safe to conclude that carnivorous mammals are not as a rule subject to flagellate infections.

We may conclude from this review of the literature on the intestinal protozoa of mammals that these organisms are most abundant in rodents and ungulates which feed almost exclusively on vegetation; that they occur frequently in primates which are largely vegetable feeders; but that only very rarely have they been reported from carnivorous animals. The cat, dog and fox have been reported positive for intestinal protozoa, but these animals, as pointed out above, are really omnivorous, especially the cat and dog under conditions of domestication.

(2) Examinations of fecal specimens from carnivorous mammals. Fecal specimens from twelve carnivorous mammals belonging to ten species were obtained from the zoological garden in Druid Hill Park in Baltimore. These were collected when still fresh, and three smears from each specimen were carefully examined for protozoa. Owing to the irregularity that has been observed in the appearance of vegetative and cyst stages in fecal material from other animals known to be infected, specimens were obtained at intervals over a period of seventeen days. The data secured are presented in the accompanying table. No protozoa of any kind were found except giardia cysts in a wild cat. This animal had been fed principally on bread and fish with a small amount of meat occasionally, so that its diet was really omnivorous. The fact that these animals were being kept in captivity may have had some influence on the presence of intestinal protozoa, since certain animals, e.g., the frog, lose their parasites when brought into the laboratory. But it is at least interesting to note that nine of these ten species of carnivores appeared to be free from intestinal protozoa and that the tenth was infected with a giardia, resembling in this respect the domestic cat in which giardias are rarely found.

(3) Feeding experiments with cats. These experiments were not extensive, and not much importance is placed on them, but they are included here since they have a bearing upon the subject under discussion.

(*a*) Attempts to infect kittens with cysts of *Giardia muris* and the flagellate stage of *Trichomonas muris* from the rat. The feces deposited by six rats were collected daily in water and thoroughly

washed. Two kittens about five weeks old were fed daily on milk to which these washed cysts and flagellates had been added. The feces of the kittens were examined on each of two days before the feeding experiment was begun and every day thereafter with negative results. On the sixth day one kitten was killed and examined; no protozoa of any kind were found. The other kitten which died on the twelfth day was likewise negative for intestinal protozoa.

Results of examinations of fecal specimens from twelve carnivorous animals from the zoological garden in Druid Hill Park, Baltimore.

	Mar. 6	Mar. 7	Mar. 10	Mar. 13	Mar. 14	Mar. 17	Mar. 18	Mar. 19	Mar. 21	Mar. 22
Lion (male)	0	0	0	0	0	0	0	0		0
Lion (female)	0	0	0	0	0	0		0	0	0
Lion (young)	0		0		0	0			0	0
Tiger	0	0	0	0	0	0	0	0	0	
Polar bear	0	0	0	0	0	0		0		0
Grizzly bear		0	0	0	0	0	0	0		0
Black bear	0	0		0	0	0	0	0		0
Syrian bear		0	0	0	0	0		0		0
Gray wolf				0	0					
Gray fox	0	0				0				0
Red fox	0	0				0				0
Wild cat					*				0	

(*b*) An attempt was also made to infect kittens with cysts of *Giardia lamblia* from man. Washed cysts were fed to two kittens on two successive days and again after an interval of five days. Fecal specimens were examined daily with negative results and no protozoa were found in the kittens two weeks later.

(*c*) A third experiment was carried out with two cats, nine months and two years old respectively. Washed cysts of *Giardia muris* and living specimens of *Trichomonas muris* were fed to them twice a week for five weeks. No protozoa were recovered from their feces. Then during a period of six weeks each cat was fed eleven rats, ten of which were infected with *Trichomonas muris*, five with *Giardia muris*, and six with *Hexamitus muris*. Trichomonads were found in the feces of the younger cat two weeks before the end of this period and in the intestine of this animal at the completion of the experiment. The other cat remained negative throughout, and was free from protozoa when killed. It seems probable that the trichomonads recovered were

* Cysts of giardia were found in the feces from the wild cat on this date.

specimens of *Trichomonas muris* that had either passed through the digestive tract unharmed or had temporarily established themselves in the intestine. It is evident that cats can be infected with *T. muris* only with difficulty.

Summary and Conclusions.

(*1*) Three rats that were fed throughout their lives (174 days) on a carnivorous diet were found to be free from *Giardia muris* and *Trichomonas muris*. Two of these rats contained a few specimens of *Hexamitus muris*.

(*2*) Experiments have shown that when rats heavily infected with *Giardia muris*, *Hexamitus muris*, and *Trichomonas muris*, are subjected to a carnivorous diet for one week the incidence of infection falls off only slightly; the average numbers of *H. muris* increase, of *G. muris* decrease nine tenths, and of *T. muris* decrease to one fifty fourth of those in the controls. At the same time the bacterial content of the intestine changes from a predominantly acidophilus type to a predominantly putrefactive type. It seems probable that the products of decomposition of the putrefactive bacteria bring about an environment unfavorable for *T. muris*. This does not, however, account for the decrease in the numbers of *G. muris*, since this species lives in the duodenum.

(*3*) A review of the literature of protozoology reveals the fact that intestinal protozoa (amoebae, ciliates and flagellates) have not been reported from carnivorous mammals in nature except very rarely. Omnivorous mammals seem to be less frequently infected and with fewer species than herbivorous animals, and ungulates are more abundantly supplied with intestinal protozoa than rodents. Domestic carnivores (cats and dogs) may be infected experimentally with *Endamoeba histolytica* and may exhibit spontaneous infections, probably brought about by contamination of food with cysts from man. Giardias have been reported from cats and dogs. Chilomastix from the dog and trichomonads from the fox.

(*4*) Examinations were made of fecal specimens, at intervals during a period of seventeen days, from twelve carnivorous animals belonging to ten species (lion, tiger, polar bear, grizzly bear, black bear, Syrian bear, gray wolf, gray fox, red fox, wild cat). No protozoa of any kind were discovered except giardia cysts in the wild cat.

(*5*) Feeding experiments with cats indicate that these animals are difficult to infect with giardia cysts from man and rat and with tricho-

monads from the rat. One cat became infected with trichomonads, probably temporarily.

Data from the various sources described above seem to prove that a carnivorous diet is unfavorable for the intestinal protozoa of mammals. Work is now in progress designed to test the value of a carnivorous diet in cases of human amoebiasis, giardiasis and trichomoniasis.

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