SPECIAL ARTICLES.

CHARACTER OF THE BACTERIAL FLORA OF CARNIVOROUS AND OF HERBIVOROUS ANIMALS.

IN the course of the study of anaerobes of the human intestine it appeared desirable to learn something about the characters of the bacterial flora inhabiting the large intestine of various domestic and wild animals. It was noticed that in the dog, which is frequently exclusively carnivorous, the intestinal contents often showed the presence of large numbers of spores, spore-bearing bacilli and vegetative forms of anaerobes. The numbers present in the feces were noted to be especially large in some animals which had been exclusively fed on meat. A study of a grown cat fed upon raw meat showed the presence of Gram-positive vegetative anaerobes from one end of the digestive tract to the other. Flora derived from the stomach, small intestine and large intestine were inoculated and grown in bouillon flasks and showed an abundant production of methyl mercaptan as well as hydrogen sulphide. The numbers of colon bacilli present in this case were relatively small as compared with the anaerobes. The study of the colonies obtained on anaerobic plates showed that a large portion of the organisms present in the intestinal tract were *B. aerogenes capsulatus*. Intravenous infusion of these organisms into a rabbit which was afterwards killed and incubated showed in a high degree the typical gas-formation.[1]

Observations on other cats showed the presence of considerable numbers of spore-holding bacilli and free spores, sometimes in chains, in addition to vegetative forms of anaerobes. The position of these spores and spore-holding bacilli has not been established in a bacteriological sense. Observations were also made upon the intestinal contents of the wolf, tiger and lion. Several different tigers were studied and the observations were not confined to the examination of one lion and one wolf. The material from the lion showed the presence of many free spores. It also showed the presence of considerable numbers of Gram-positive bacilli, suggesting *B. aerogenes capsulatus*. Gram-stained preparations from wolves showed findings similar to those observed in the lion except that the spore-holding bacilli were more numerous. The findings in the case of supposedly healthy tigers were not essentially different from those in the case of the wolf and lion. In the case of one tiger, suffering from osteomalacia, greatly impaired nutrition and loss of strength, the microscopical fields derived from several different samples of feces revealed the presence of immense numbers of free spores and smaller numbers of immature Gram-negative spore-holding bacilli. These spores developed into organisms which possessed all the generally known cultural and biochemical characters of *B. aerogenes capsulatus*, including the ability to develop a high grade of gas-formation in rabbits injected and incubated.

It was found that bouillon cultures of the mixed fecal flora from the lion, tiger, wolf and cat all developed quickly a sufficient quantity of methyl mercaptan to give promptly a very well developed reaction with isatin-sulphuric-acid.

Experiments were made with the mixed fecal flora from these carnivorous animals to determine their pathogenicity when injected into the subcutaneous connective tissue. It would have been better to have worked with pure cultures of the anaerobes in question, but opportunity has not yet arisen to isolate them. The result of the inoculations into guinea-pigs was the same in each instance. The animals died within twenty-four hours and usually in fifteen to eighteen hours. At autopsy the subcutaneous connective tissues

[1] The incubation method of Welch and Nuttall is based on their observation that the gas bacillus produces gas abundantly in the blood, organs and tissues of rabbits killed a few minutes after intravenous injection. Here the blood and tissues of the rabbit act as a peculiarly favorable culture medium for the growth of the gas bacillus, the latter having been thoroughly spread by the blood through the body, and the conditions being anærobic. A suspension of the feces to be tested is prepared by grinding 1 gram of the fresh material with 9 c.c. of 0.85 per cent. salt solution and filtering through absorbent cotton. One or two cubic centimeters of this suspension are then injected intravenously into a rabbit which is quickly killed and incubated for five hours at 70°C.

were hemorrhagic, œdematous and showed necrotic changes which extended in some instances to the muscles. Gas-formation was not usually noted as a prominent feature. These pathological alterations were not confined to the site of inoculation but had extended to the subcutaneous connective tissues throughout the body and were especially pronounced in the axillæ and in the groin. It is unnecessary to enter here into the details as to the character of the organisms recovered from these lesions.

We may contrast with these findings the observations made upon herbivorous animals, including the buffalo, goat, horse, elephant and camel. In the case of the camel, elephant and horse the preponderant bacteria in the Gram-stained fields were small Gram-negative organisms which were regarded as special forms of *B. coli*. In the case of the goat the fields contained some Gram-positive bacteria and of the Gram-negative ones a considerable number were of considerably greater length than the dominant small forms which were regarded as belonging in the class of colon bacilli. In the case of the buffalo, mixed fields were found as regards the Gram-staining and many of the positive organisms were found to be small diplococci and small bacilli. In none of these animals were seen any organisms suggesting *B. aerogenes capsulatus* excepting in the case of the buffalo where the number of bacilli of this type was very small. Spore-holding organisms were not observed, but moderate numbers of free spores were noticed in all the fields except those from the elephant. In the fields showing the largest number of spores their occurrence was far less frequent than in the lion, tiger, wolf or cat.

The mixed flora of these different herbivorous animals, grown upon peptone bouillon, failed to show the production of methyl mercaptan excepting in the case of the horse, where a moderate reaction was obtained.

Observations were also made upon the effect of suspensions of the mixed flora from herbivorous animals when injected subcutaneously. The quantities of suspension used were usually about twice as great as in the case of the suspensions from the carnivorous animals. With the exception of the suspensions obtained from the horse, the pathogenicity of these suspensions was found to be slight, the guinea-pigs frequently living two or three days or entirely recovering. In the horse were found hemorrhagic and œdematous lesions with necrosis, similar to those found in the carnivorous animals. These lesions were, however, less pronounced than in the case of the suspensions from the carnivorous animals. In the case of the elephant a considerable quantity of fibrinous exudate was found about the point of inoculation. No œdema or necrotic change was observed in the subcutaneous tissues.

A further confirmation of the radical differences existing in the intestinal tracts of carnivora and herbivora is furnished by a series of observations with the Welch-Nuttall incubation test. Suspensions were made from the feces of all the types of animals mentioned and equal quantities of these suspensions were infused intravenously into a series of living rabbits. The rabbits were then quickly killed and incubated. On examination after twenty-four hours it was found that all the rabbits infused with suspensions from carnivora showed in an extreme degree the characteristic putrefactive changes in the liver, cellular tissues, etc., induced by pure cultures of *B. aerogenes capsulatus* or of the bacillus of symptomatic anthrax. The rabbits infused with suspensions made from the feces of the herbivora showed similar but very much slighter changes in each case. The results for each group of animals separated the herbivora sharply from the carnivora. Examination of the livers showed the number of bacteria in the carnivorous series to be many times greater than in the herbivorous series. The microorganisms were regarded as being almost certainly *B. aerogenes capsulatus* on account of their morphology and failure to sporulate. The bacilli of symptomatic anthrax readily sporulate in the incubated rabbits. The gas-bacillus (*B. aerogenes capsulatus*) does not sporulate under these circumstances.

These differences in the appearance and behavior of the bacteria derived from typical

carnivora and herbivora suggest that the habit of living upon a diet consisting exclusively of raw meat entails differences in the types of bacteria that characterize the contents of the large intestine. The occurrence of considerable numbers of spore-bearing organisms in the carnivora points to the presence of anaerobic putrefactive forms in great numbers. The results of subcutaneous inoculations into guinea-pigs bear out this view and indicate that the numbers of organisms capable of producing a hemorrhagic œdema with tissue necrosis, with or without gas-production, are very considerable. Unfortunately, the data pertaining to the biological properties of these pathogenic anaerobes are at present insufficient to permit us to classify them or to say more of their nature than that they are organisms representative of a definite group of putrefactive anaerobes which make butyric acid and hydrogen and exert a peptonizing action upon living tissues. Nevertheless, the observations here recorded are of much interest in relation to the bacterial processes and nutrition of herbivorous[2] as distinguished from carnivorous animals and are significant furthermore for the interpretation of bacterial conditions found in man. The question arises whether the abundant use of meat over a long period of time may not favor the development of much larger numbers of spore-bearing putrefactive anaerobes in the intestinal tract than would be the case were a different type of proteid substituted for meat.

Inquiries made of Dr. Blair, the pathologist at the New York Zoological Park, elicited the fact that while, upon the whole, the carnivorous animals are apt to live somewhat longer than the herbivorous animals of about equal size, the carnivora are much more likely to develop conditions of advanced anæmia in the later years of their lives than is the case with the herbivora. Dr. Blair states that it is usual in the later years of life for the carnivora to show a much diminished volume of blood and at least a moderate fall in the hemoglobin. Instances are stated to be not uncommon in which a pernicious type of anæmia has developed in the carnivora. On the contrary, among the herbivora it is said that pronounced anæmias are very occasional. The examples of severe anæmia encountered among the herbivora were said by Dr. Blair to be in nearly all instances referable to gross animal parasites.

The information now available indicates that man occupies a position between the herbivora and carnivora with respect to the numbers of putrefactive anaerobes that are present in the digestive tract and their proportion to the total number of bacteria. The influence of a purely vegetable diet on the one hand and of a strict meat diet on the other, upon these anaerobes, is much in need of careful investigation.

C. A. HERTER.

[2] Many of the herbivora yielded mixed flora incapable of making gas on dextrose bouillon.

THE EXCEPTIONAL NATURE AND GENESIS OF THE MISSISSIPPI DELTA.

AT the December meeting of the Cordilleran Section of the American Geological Society, 1905, I read a paper under the above title, an abstract of which, printed on the program, is copied below:

This paper discusses the wholly exceptional materials and form of the lower delta of the Mississippi river, as observed by the writer in 1867 and 1869, and described and discussed in the *American Journal of Science* in 1871. Following out the suggestions of Lyell, and the disputed statement of Humphreys and Abbott that the alluvial deposits of the great river are only of slight depth, the writer investigated the extreme mouths of the Passes, the 'Neck' and the similar minor, bird-foot-like arms projecting beyond. It became apparent that the silty river deposit on these narrow dikes or banks is only superficial, and that their resistance to erosion during overflows is due to their being mainly composed of tough, inerodable 'mudlump clay.' That these mudlumps, observed and described by Lyell, are upheavals of the river bottom, and are formed of such clay as is deposited *outside* of the bar, where the turbid water of the river meets, and is clarified by, the saline sea water. Also, that the mudlump upheavals occur in the *main* outlets or passes of the river, as a direct result of their being the main outlets. No mudlumps then existed in the South Pass, but now that it has been artificially made the main channel, mudlump upheaval has taken, and is taking, place. Mudlump formation is thus