SPECIAL ARTICLES

THE PROTOZOA OF WILD MONKEYS[1]

RECENTLY, the writer[2] published the results of original observations and a review of literature on the protozoa of monkeys. In this paper it was pointed out that twenty-five different species of protozoa were recognized by protozoologists at the present time as inhabitants of man. Sixteen of these twenty-five species had been reported from monkeys; these sixteen species were morphologically indistinguishable from the corresponding species that occur in man. Certain experimental evidence was also cited as evidence that some of the species that live in monkeys and man are the same. Since then additions have been made to the number of species that have representatives in both monkeys and man. Kofoid[3] reports that the mouths of all of a number of captive specimens of *Macacus rhesus* and *M. cynomolgous* were infected with amebae indistinguishable from *Endamoeba gingivalis* that lives in the mouth of man. He states that all of nine monkeys examined were free from the trichomonas of the mouth, *Trichomonas buccalis*. This species, however, has been noted in a number of Philippine monkeys examined by the writer during the past three months. Dobell[4] has listed from monkeys a flagellate resembling *Tricercomonas intestinalis* which had not been reported previously. When these three species are added to those already recorded, the number of species of protozoa that occur in both monkeys and man is increased from sixteen to nineteen. As pointed out in a previous paper[2] other species of lower animals, such as the rat, may be infected with protozoa belonging to the same genera as those living in man, but to species that are morphologically so different as to be easily identified. The conclusion reached on the assumption that close relationships of parasites indicate a common ancestry of their hosts was that "the facts available regarding the protozoan parasites of monkeys and man furnish evidence of importance in favor of the hypothesis that monkeys and man are of common descent."

It was realized that one difficulty in reaching a definite conclusion was the fact that apparently the monkeys that had been studied were captive animals that had been associated more or less closely with man for a sufficient length of time to become infected with human parasites. The protozoa that were reported from monkeys may, therefore, not have been normal inhabitants of these animals, but human protozoa that had become established as a result of contamination from man. On this account, the writer at the first opportunity undertook a study of the protozoa of wild monkeys. The animals used belonged to the species common on the Island of Luzon, one of the Philippine Islands, the scientific name of which is usually given as *Macacus philippinensis*. Wild monkeys were either captured and brought to Manila for study or were shot and examined in the field within three hours. A comparative study is being made of the organisms found, but enough evidence was soon obtained to prove that wild monkeys are infected with most, if not all, of the species of protozoa that have been found in captive specimens. Amebae and trichomonad flagellates have been found in the mouths of many of them. Several monkeys were infected with the flagellate of the duodenum, *Giardia*. Trichomonad flagellates were found in the vagina of one specimen. The large intestine in man is the habitat of five species of amebae, four species of flagellates and one ciliate. Only one of these, the ameba, *Dintamoeba fragilis*, has not been recorded from monkeys. Most of these species were definitely recognized in the wild monkeys examined by the writer. Further study will probably reveal the rest. The large ciliate, *Balantidium coli*, was present in a considerable proportion of the monkeys, especially in the cecum. *Trichomonas* occurred in the colon of almost 100 per cent. of the monkeys. *Chilomastix* did not have quite such a high incidence. Small flagellates were noted which will probably turn out to be *Embadomonas* and *Tricercomonas* on further study.

Every animal harbored one or more species of ameba in the cecum or colon; these belonged to species resembling *Endamoeba histolytica, E. coli, Endolimax nana* and *Iodamoeba williamsi*. No trypanosomes or malarial parasites were discovered in the blood of the wild monkeys available for study.

These findings make it evident that, so far as intestinal protozoa are concerned, wild monkeys are apparently as heavily infected as captive monkeys. A pertinent question that arises is, are these wild monkeys closely enough associated with the rural inhabitants of the Philippines to become infected with human species of protozoa by contamination? It is not possible to answer this question definitely. Wild monkeys, however, spend much of their time in the trees away from soil which has been polluted by man and they particularly shun human excrement. It seems, therefore, that while transmission from man to wild monkeys is possible, it is not probable, and that the protozoan parasites now living in monkeys

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[2] Robert Hegner, "The Evolutionary Significance of the Protozoan Parasites of Monkeys and Man," *Quart. Rev. Biol.*, 3: 225–244, 1928.

[3] C. A. Kofoid, "The Protozoa of the Human Mouth," *Journ. Parasit.*, 15: 151–174, 1929.

[4] C. Dobell, "Amebae of Monkeys," Rept. Med. Res. Council, 1924–25: 31–33, 1926.

are descendants of those that inhabited the common ancestors of man and monkeys.

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VELOCITY OF CHEMICAL REACTIONS[1]

It is well known that different chemical reactions progress with greatly different velocities. For examples, the oxidation and drying of linseed oil extends over a period of days, while the explosion of gasoline vapors is completed in a small fraction of a second. In most cases where velocities of reactions are recorded they are expressed as the total mass transformed per unit of time, $\frac{dc}{dt}$, and the absolute time required for the transformation of individual molecules is ignored or can not be estimated because there are very few methods for studying intramolecular mechanics and dynamics. In the case of explosions, however, data are available for the estimation of the time required for the reaction to proceed from molecule to molecule, as the following calculations will show.

When nitroglycerine explodes according to the reaction:

$$4\ C_3H_5(NO_3)_3 \rightarrow 12\ CO_2 + 10\ H_2O + 6\ N_2 + O_2$$

the explosive wave travels at the rate of five miles per second through the mass.[1] It might be argued that the explosive wave precedes the course of the chemical reaction, but since the exact nature of the former is unknown, it seems reasonable to conclude that it merely measures the progress of the chemical reaction from molecule to molecule. With this assumption the following calculations can be made.

The molecular weight of nitroglycerine is 227.1 and its density is 1.6, giving a molecular volume of 141.9 cc. Assuming this volume of nitroglycerine to be in the form of a cube, each edge will be $\sqrt[3]{141.9}$ cms and will contain $\sqrt[3]{(6.06)(10)^{23}}$ molecules, or $(1.622)(10)^7$ molecules per linear centimeter. In five miles there are $(8.047)(10)^5$ cms, so that a chain of nitroglycerine molecules five miles long, spaced as they are in the liquid, contains $(1.305)(10)^{13}$ molecules. Since the reaction proceeds from the first of these to the last one in one second, the time required for the explosion to go from molecule to molecule is $\frac{1}{(1.305)(10)^{13}}$ or $(7.661)(10)^{-14}$ seconds.

To conceive of this infinitesimal time, let us compare it to one second, which is the time of explosion of the entire mass and also approximately the lowest perceptible time unit. Making this comparison, since one year contains $(3.1536)(10)^7$ seconds, we find that 414,000 years bear the same relation to one second that one second bears to the time between successive explosions. In other words, if a being could take the time of a molecular explosion for his smallest perceptible time unit, then one of our seconds would bear the same relation to his time value that a geologic age does to our second.

In the above reasoning the assumption is made that a molecule of nitroglycerine explodes, sending out a wave of energy which upon striking the next molecule causes its explosion, whereupon the process is repeated; the disruption of the original molecule is assumed to be completed by the time its explosive wave has initiated the explosion of the next molecule; finally, the explosion of each molecule is assumed to be dependent upon energy received from the molecule immediately preceding. Under these conditions the time which we have calculated, namely $(7.661)(10)^{-14}$ seconds, represents the time required for a molecule both to complete its own explosion and to initiate the explosion of its neighbor through an energy transfer. It is impossible to estimate the relative times required for these two processes; however, it is at least true that the time of the individual molecular reaction is less than the number calculated.

While at present it is impossible to follow the breaking down of such individual molecules, and although thermodynamics as yet can not treat such reaction rates, still it can be concluded that with some chemical reactions their infinitesimal times bear a ratio to the times of human experience that the latter do to geologic and astronomical times.

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[1] Comey, Seventh Int. Cong., 1909, III b, 30.

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