The Interaction of Particulate Material and Dissolved Foodstuffs in Food Uptake by *Tetrahymena pyriformis*

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Received June 24, 1971

Summary. 1. The uptake of dissolved nutrients (peptone) per average digestive vacuole in starved *Tetrahymena pyriformis* is much increased by the concurrent uptake of indigestible inert particulate matter. When 0.5 and 1.1 μm diameter polystyrene, and 2.02 μm polyvinyltoluene, latex particles together with peptone were individually fed to starved cells of *Tetrahymena* the mean digestive vacuolar diameters were 4.6, 6.5 and 7.3 μm respectively. Feeding of peptone without the particles resulted in a mean vacuolar diameter of 3.4 μm. The volumes of peptone solution taken in by cells fed peptone and latex particles (0.5, 1.1 and 2.02 μm diameters) were calculated to be 86% 306% and about 320% respectively of the volume taken in upon presentation of peptone by itself.

2. Starved cells of *Tetrahymena* took in digestive vacuoles at similar rates when presented either with peptone or peptone and latex particles (1.1 and 2.02 μm diameters), the latter rates being slightly raised.

Ricketts (1971) has shown that fed *Tetrahymena pyriformis* rapidly endocytized a variety of both digestible and indigestible solutes or particles whereas starved cells only took in the digestible materials. Rasmussen and Kludt (1970) have shown that the addition of insoluble inorganic particles to cultures of this organism, grown in peptone medium, caused a marked increase in the rate of cell multiplication; which did not occur when various digestible solutes were added to the medium. The present work illustrates an aspect of the response to particle uptake.

Materials and Methods

An axenic culture of *Tetrahymena pyriformis* (Ehrenberg) Lwoff (Cambridge Culture Collection No L1630/1 GL, Lwoff, 1922) was used. This had been grown at 20 °C in PY-medium (1% w/v proteose peptone [Oxoid] and 0.25% w/v yeast extract [Oxoid]). The culture was harvested by centrifugation and the deposit re-suspended in mineral salts medium (KCl, 6 mg; CaHPO₄, 4 mg; MgSO₄·7H₂O, 2 mg; per litre of water) and resedimented. The final cell deposit was re-suspended in mineral salts medium and left at 20 °C to starve until required. The starved cells show no microscopic digestive vacuoles. Aliquots of the starved culture were treated with
peptone and latex particle suspension (Dow Chemical Co.) as indicated in Table 1 and shaken for 1 hr at 100 oscillations per min before microscopic examination. Samples of the cells were harvested after each treatment by gentle centrifugation and were then treated with a little formalin. The diameters of 50 digestive vacuoles (no more than two from any one cell) were then measured microscopically (using a micrometer eyepiece) for each treatment. The cells lacking latex particles were examined under phase contrast. Standard deviations for vacuolar diameters are given in Table 1. Smaller numbers of living cells were also examined under phase contrast. Their vacuolar diameters were similar to those of the formalin treated cells.

Estimates of the approximate numbers of latex particles present per average digestive vacuole were determined (assuming that the latex particles were not distorted in shape in the digestive vacuoles) by placing solid spheres of uniform diameter into a rubber balloon until the ratio of the diameter of the balloon plus contents (spherical shape) to the diameter of each enclosed sphere were the same as the ratio's of the average digestive vacuolar diameter to the latex particle diameter. In the case of the 0.5 and 1.1 μm diameter latex particles the numbers of particles per digestive vacuole could be determined with accuracy, but the estimate for the digestive vacuoles formed from 2.02 μm diameter latex particles were more inaccurate since a rather irregular knobbly sphere was formed in the balloon, which had contents ranging in number from 30—35, depending upon where on the surface of the balloon the measurements of diameter had been made. A value of 32.5 particles per digestive vacuole was used in Table 1.

Results

The mean diameters of digestive vacuoles formed in cells taken 1 hr after feeding Tetrahymena pyriformis (which had been starved in mineral-salts medium for 28 hr) with peptone and various diameters of latex particle suspensions are shown in Fig. 1. Various calculations from these values and those of the empirically determined latex particle concentrations per average digestive vacuole are also shown in Table 1. Starved cells treated only with 0.5μm diameter latex particles showed only a very slight uptake. The starved cells would not take in 7.6 μm diameter styrene-DVB copolymer latex particles after peptone and particle treatment. Microscopically the latex particles showed no observable distortion in shape in the digestive vacuoles, at least in their external aspects. This suggests that the packing of the inert indigestible latex particles is a simple geometric matter.

Aliquots (5 ml) of cells which had been starved for 26 hr and then treated for 2 hr with 0.5 ml 5% w/v proteose peptone solution, pH 7, showed 69% of cells with more than 8 digestive vacuoles/cell, 24% with 4—8 vacuoles/cell, 5% with less than 4 vacuoles/cell and 2% with no digestive vacuoles. Equivalent values for cells which had been treated additionally with 0.02 ml of 1.1 μm diameter latex particle suspension were 79, 20, 1 and 0% respectively. A hundred randomly selected cells were examined in each case. These results showed that digestive vacuolar uptake was probably somewhat stimulated by the addition of particles.