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The relationship between various stimuli and the speed of migration of Physarum

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Abstract
Despite not having a brain, the unicellular organism called "Physarum" has the property of remembering stimuli and of spreading out and connecting its prey to one another over the shortest possible distance. For this reason, their usefulness has been attracting attention in recent years. However, Physarum moves too slowly to conduct efficient experiments. Therefore, we studied a method to increase the migration speed of Physarum. First, we compared starvation and normal conditions, and found that the hungry one resulted in faster movement speeds. We hypothesized that they may have increased their migration speed to obtain food. Next, experiments were conducted using calcium chloride with different calcium ion concentrations in the medium, and it was found that there was a concentration in the range of 0.1 mol or less at which the migration speed increased. Therefore, it is considered that this is the best calcium ion concentration for speeding up the migration rate.

1. Introduction

Currently, Japan is facing many issues such as delivery and shift scheduling for part-time jobs. To solve these issues, it requires solving a mathematical problem called a “combinatorial optimization problem”. However, conventional computers are not good at solving this problem. Because it requires too many calculations even for conventional computers. Therefore, developing a solution to this current situation was a challenge.

In the past five years, however, the invention of the electronic amoeba has attracted much attention. This is a digital version of the characteristics of a single-celled organism called "Physarum". The electronic amoeba makes it easy to solve combinatorial optimization problems. However, electronic amoeba research is still in the developmental stage, and more detailed studies on physarum are needed to develop more efficient electronic amoebas.

A previous study showed the efficiency of Physarum. When oatmeal was placed at two locations, the entrance and exit of an agar maze, with Physarum spread over the entire maze, the body moved over time to only follow the shortest path between the foods. In an agar medium that imitated the topography of the Kanto region, Physarum was placed at the location corresponding to Tokyo, and oatmeal was placed at the locations corresponding to each major city. After the experiment, the shape of the Physarum closely resembled the shape of the main transportation network of the Kanto region. However, it has the disadvantage of moving very slowly. They move only 1 cm per hour. This prevents scientists from experimenting efficiently. Therefore, the objective of our research was to increase the migration speed of the Physarum.

2. Definition of migration speed

The Physarum moves on the agar medium as they grow in a flat plane, thereby changing the area they occupy on the agar medium. We defined migration rate as the ratio of the size of the Physarum after the experiment to the size of it before the experiment . A large migration rate is considered to be a fast migration speed. The size of Physarum was defined by analyzing the yellow color system, which is the color of Physarum, using the image analysis appl8ication "色とりどり". (migration rate = area after 24 hours / original area)

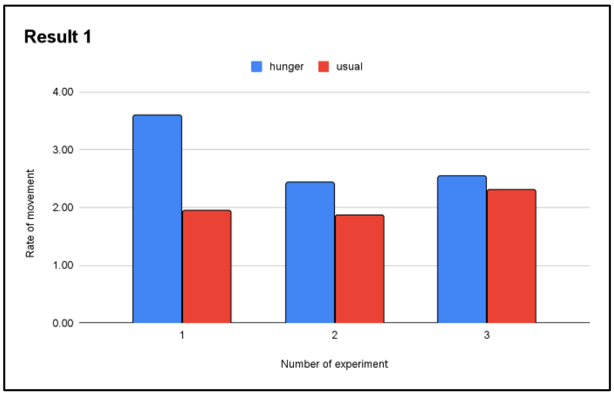
3. Culture environment

Spread paper towels on the bottom of a plastic Tupperware container and spray water with a mist to make the paper towels culture medium. Put Physarum on the medium and place the food/ oatmeal on the medium once a day. Change the medium every 3 days and cover tightly to prevent drying. Incubate in a cold incubator in a dark room set at 23.5°C.

In our experiments, a paper towel medium is prepared in a petri dish. Then, put Physarum in the medium and leave it for 24 hours, and measure the migration rate. No food is fed during the experiment.

3. Experiment 1

We conducted an experiment to see how the migration speed changed between starvation and non-starvation conditions. We expected that the starvation condition would result in faster migration. We cut out pieces of the same size physarum from one individual slime and placed one piece with food and the other without food for 3 days to be used as experimental physarums.



Result

In Result 1, we take the original physarum size as 1. We can see that in all three of our experiments, the starvation condition moved larger. A fourth experiment produced similar results. Results suggest that starved physarum will move faster to reach their food despite starvation conditions.

4. Experiment 2

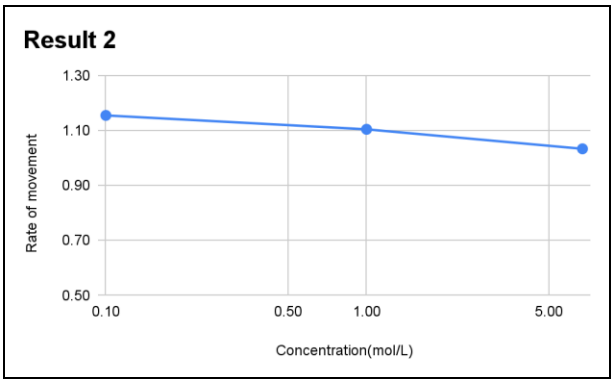
Previous studies have shown that Physarum has myosin filaments like animals. Physarum migrates by protoplasmic flow using their filaments and it closely resembles muscle contractions.

This migration involves the concentration of calcium ions. We have therefore conducted experiments using calcium chloride to change protoplasmic flow in the external fluid. To determine the appropriate concentration, we used the following concentrations:

0.00 mol/L (pure water), 1.00 mol/L, 1.00×10^{-1} mol/L, 6.73 mol/L (the solubility of calcium chloride at room temperature)

We expected the migration rate to increase the most under an appropriate concentration.

Result



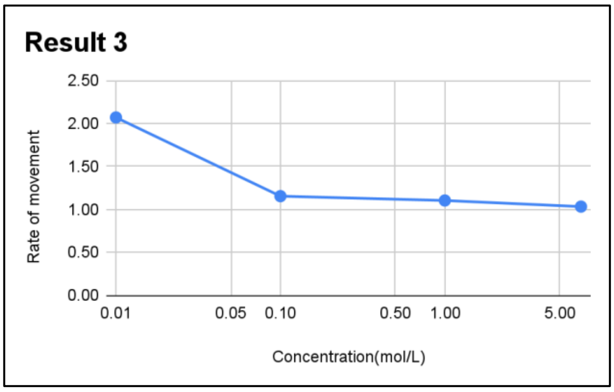
In this graph, the horizontal axis represents the concentration and is logarithmic and the vertical axis represents the rate of migration. In this experiment, the higher the concentration, the smaller the rate was, and there was little change at 1.00 mol/L and 6.73 mol/L. Although not reflected in the graph, at 0.00 mol/L the rate of migration was 1.19, almost the same as at 0.1 mol/L. We discussed and searched for the cause of the results of this experiment. Then, we found that high calcium intake inhibited the action of myosin, causing muscle weakness and other symptoms in people. Therefore, we predicted that the reason for the slowness at higher concentrations was, first, that the calcium ion concentration was too high and, second, that chloride ions may have inhibited the physarum's moving process.

5. Experiment 3

Based on the consideration that the concentration of the calcium chloride in Experiment 2 may have been too high. So, we conducted an experiment at a lower concentration. The experiment has now been completed only at 1.00×10^{-2} mol/L.

Result

As expected, the mobility rate increases with decreasing concentration. At 0.01mol/L, the migration rate was higher than that of pure water which is the control experiment. The fact that the migration rate increased indicates that the concentration of the calcium chloride solution was too high in experiment 2. The result exceeded that of the control experiment. This indicates calcium chloride may promote migration of physarum.



6. Experiment 4

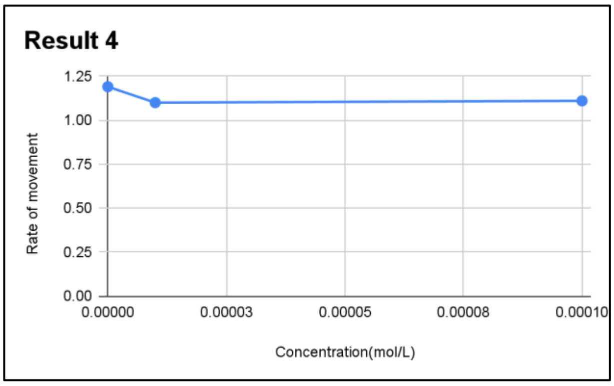
Based on the consideration that chloride ions may have inhibited the process, we used calcium carbonate to investigate the effect of chloride ions. We looked at the following concentrations.

1.00mmol/L(pure water),1.50×10^{-1}mmol/L

1.50×10^{-2} mmol/L (the solubility of calcium carbonate at room temperature)

Result

There was almost no difference between the concentrations, and neither moved more than in the control experiment. We attributed this result to the basicity of the calcium carbonate solution.



7.Conclusion

Starving physarum moves faster in order to reach food more quickly. High concentrations of calcium also inhibit Physarum migration.

8. References

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9. Key words

physarum, migration speed, calcium ion, protoplasmic streaming, myosin filament