Foraging Behaviors and Potential Computational Ability of Problem-Solving in an Amoeba

Toshiyuki Nakagaki[1,2]

[1] Research Institute For Electronic Science,
Hokkaido University, N12 W6, Sapporo 001-0021, Japan
[2] JST, CREST, 5, Sanbancho, Chiyoda-ku, Tokyo, 102-0075, Japan
nakagaki@es.hokudai.ac.jp

Abstract. We study cell behaviors in the complex situations: multiple locations of food were simultaneously given. An amoeba-like organism of true slime mold gathered at the multiple food locations while body shape made of tubular network was totally changed. Then only a few tubes connected all of food locations through a network shape. By taking the network shape of body, the plasmodium could meet its own physiological requirements: as fast absorption of nutrient as possible and sufficient circulation of chemical signals and nutrients through a whole body. Optimality of network shape was evaluated in relation to a combinatorial optimization problem. Here we reviewed the potential computational ability of problem-solving in the amoeba, which was much higher than we'd though. The main message of this article is that we had better to change our stupid opinion that an amoeba is stupid.

Keywords: *Physarum*, sub-cellular computing, primitive intelligence, problem-solving, ethology.

1 Introduction

An amoeba of true slime mold, the plasmodium of *Physarum polycephalum*, has the ability to solve a maze although it consists of only a single cell. Cells are units, which have common nature over all of organisms. People are likely to look at human and other higher animals when considering what makes *intelligence* appear. From an evolutionary point of view, however, any tiny organisms can show *bud* of intelligence in some sense. Otherwise, it may be difficult to succeed to survive for such a long time as a little less than a billion of years. The thought that single celled-organisms may be more intelligent than people normally expected has been claimed repeatedly since one-hundred years ago[1]. It is quite interesting to study how intelligent cells are and what the mechanism of intelligence is in terms of dynamics and in terms of computational algorithm.

To test intelligence in animals other than human, appetite for food in animals plays an important role. Foods are given to animals but it is difficult for them to get the foods, then they try to demonstrate their potential ability of finding a way to get the foods. A typical example is that chimpanzee in the room

F. Peper et al. (Eds.): IWNC 2009, PICT 2, pp. 42–54, 2010.

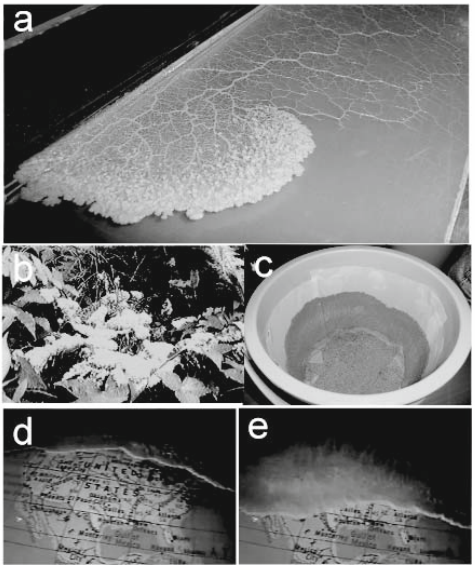

Fig. 1. Beauty and wonder of the plasmodium of *Physarum polycephalum*. a) a large plasmodium, which is single-celled but multinuclear. It is coming downward in the picture. The frontal part is sheet-like and the complicated network of tubular channel develops toward the rear. The frontal part with the semi-circle shape is approximately 3cm in the diameter. b) the plasmodium of *Fuligo*, a different species from *Physarum*, in the wild nature. c) a plasmodium that crawls up along the wall of bucket. d-e) a plasmodium that takes over the globe. Locomotion speed is a few centimeters per hour.

uses a tool to get a banana, which is hung from the ceiling and impossible to reach directly by a hand. A similar method is used in the test for unicellular organisms.

Here we describe a nice model organism of unicellular organism, a giant amoeba of true slime mold (see Fig.1). The plasmodium of true slime mold *Physarum polycephalum* is an amoeba-like organism in which network structure of tubular element developed. Through the network, nutrient and signal are carried through the organism. When multiple small food sources (FSs) were presented to a starved plasmodium that spread over an entire culture dish, it concentrated at each FS. Almost the entire plasmodium accumulated at the FSs and covered each of them in order to absorb nutrient. Only a few thick tubes remained connecting the quasi-separated components of the plasmodium[2,3,4,5]. By forming such a pattern, the organism derives the maximum nutrition in the minimum time. Hence this strategy is rather smart; it implies that the plasmodium can solve a complex problem[6,7,8].

We review here how high the computational ability of problem-sovling is in the amoeba and what the mechanism is in some sense of computational algorithm.[9,10,11,12,13,14,15].