brief communications

early (soon after puberty) and very late (approaching menopause) pregnancies are common in humans.

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Intelligence

Maze-solving by an amoeboid organism

The plasmodium of the slime mould *Physarum polycephalum* is a large amoeba-like cell consisting of a dendritic network of tube-like structures (pseudopodia). It changes its shape as it crawls over a plain agar gel and, if food is placed at two different points, it will put out pseudopodia that connect the two food sources. Here we show that this simple organism has the ability to find the miniChicago Press, Chicago, 1988).

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mum-length solution between two points in a labyrinth.

We took a growing tip of an appropriate size from a large plasmodium in a 25×35 cm culture trough and divided it into small pieces. We then positioned these in a maze created by cutting a plastic film and placing it on an agar surface. The plasmodial pieces spread and coalesced to form a single organism that filled the maze (Fig. 1a), avoiding the dry surface of the plastic film. At the start and end points of the maze, we placed $0.5 \times 1 \times 2$ cm agar blocks containing nutrient (0.1 mg g⁻¹ of ground oat flakes). There were four possible routes (α 1,





 $\alpha 2$, $\beta 1$, $\beta 2$) between the start and end points (Fig. 1a).

The plasmodium pseudopodia reaching dead ends in the labyrinth shrank (Fig. 1b), resulting in the formation of a single thick pseudopodium spanning the minimum length between the nutrient-containing agar blocks (Fig. 1c). The exact position and length of the pseudopodium was different in each experiment, but the path through $\alpha 2$ — which was about 22% shorter than that through $\alpha 1$ — was always selected (Fig. 1d). About the same number of tubes formed through $\beta 1$ and $\beta 2$ as the difference (about 2%) in their path lengths is lost in the meandering of the tube trajectory and is within experimental error.

The addition of food leads to a local increase in the plasmodium's contraction frequency, initiating waves propagating towards regions of lower frequency^{1–5}, in accordance with the theory of phase dynamics⁶. The plasmodial tube is reinforced or decays when it lies parallel or perpendicular, respectively, to the direction of local periodic contraction⁷; the final tube, following the wave propagation, will therefore link food sites by the shortest path.

To maximize its foraging efficiency, and therefore its chances of survival, the plasmodium changes its shape in the maze to form one thick tube covering the shortest distance between the food sources. This remarkable process of cellular computation implies that cellular materials can show a primitive intelligence⁸⁻¹⁰.

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