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

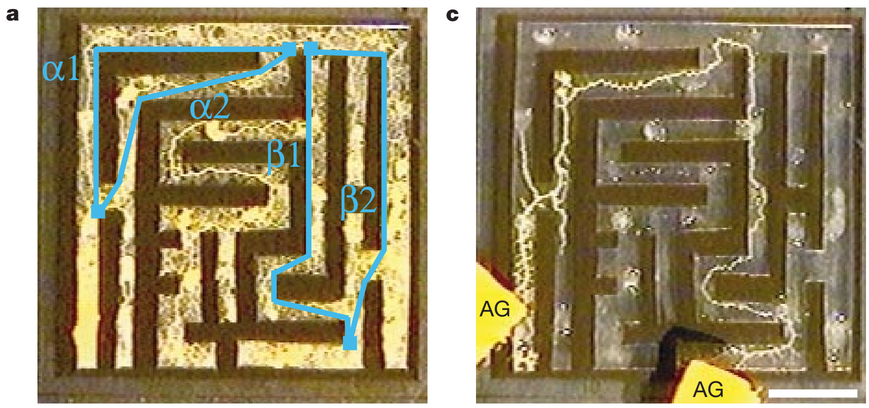
The plasmodium of the slime mould *Physarum polycephalum* is a large amoeba-like cell consisting of a dendritic network of tube-like structures (pseudopodia). It changes its shape as it crawls over a plain agar gel and, if food is placed at two different points, it will put out pseudopodia that connect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

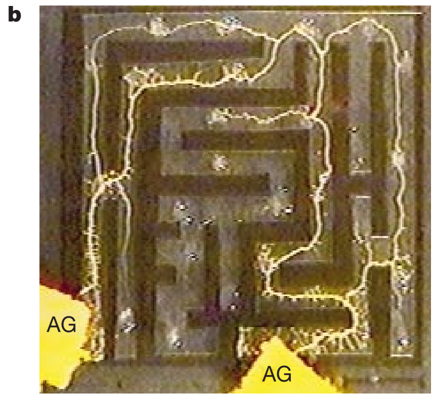
We took a growing tip of an appropriate size from a large plasmodium in a 25 × 35 cm culture trough and divided it into small pieces. We then positioned these in a maze created by cutting a plastic film and placing it on an agar surface. The plasmodial pieces spread and coalesced to form a single organism 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 × 1 × 2 cm agar blocks containing nutrient (0.1 mg g^{-1} of ground oat flakes). There were four possible routes (α1, α2, β1, β2) 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 α2 — which was about 22% shorter than that through α1 — was always selected (Fig. 1d). About the same number of tubes formed through β1 and β2 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 dynamics[6]. The plasmodial tube is reinforced or decays when it lies parallel or perpendicular, respectively, to the direction of local periodic contraction[7]; 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 intelligence[8–10].





d

	None	β1	β2	β1, β2
None	2	0	0	0
α1	0	0	0	0
α2	0	5	6	3
α1, α2	0	0	0	3

Figure 1 Maze-solving by *Physarum polycephalum*. **a,** Structure of the organism before finding the shortest path. Blue lines indicate the shortest paths between two agar blocks containing nutrients: α1 (41 ± 1 mm); α2 (33 ± 1 mm); β1 (44 ± 1 mm); and β2 (45 ± 1 mm). **b,** Four hours after the setting of the agar blocks (AG), the dead ends of the plasmodium shrink and the pseudopodia explore all possible connections. **c,** Four hours later, the shortest path has been selected. Plasmodium wet weight, 90 ± 10 mg. Yellow, plasmodium; black, 'walls' of the maze; scale bar, 1 cm. **d,** Path selection. Numbers indicate the frequency with which each pathway was selected. 'None', no pseudopodia (tubes) were put out. See Supplementary Information for an animated version of **a**–**c**.

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Supplementary information is available on *Nature*'s World-Wide Web site (http://www.nature.com).