How do you follow a scent?

Readings for today

- Baker, K. L., Dickinson, M., Findley, T. M., Gire, D. H., Louis, M., Suver, M. P., ... & Smear, M. C. (2018). Algorithms for olfactory search across species. Journal of Neuroscience, 38(44), 9383-9389.

- Porter, J., Craven, B., Khan, R. M., Chang, S. J., Kang, I., Judkewitz, B., ... & Sobel, N. (2007). Mechanisms of scent-tracking in humans. Nature neuroscience, 10(1), 27-29.

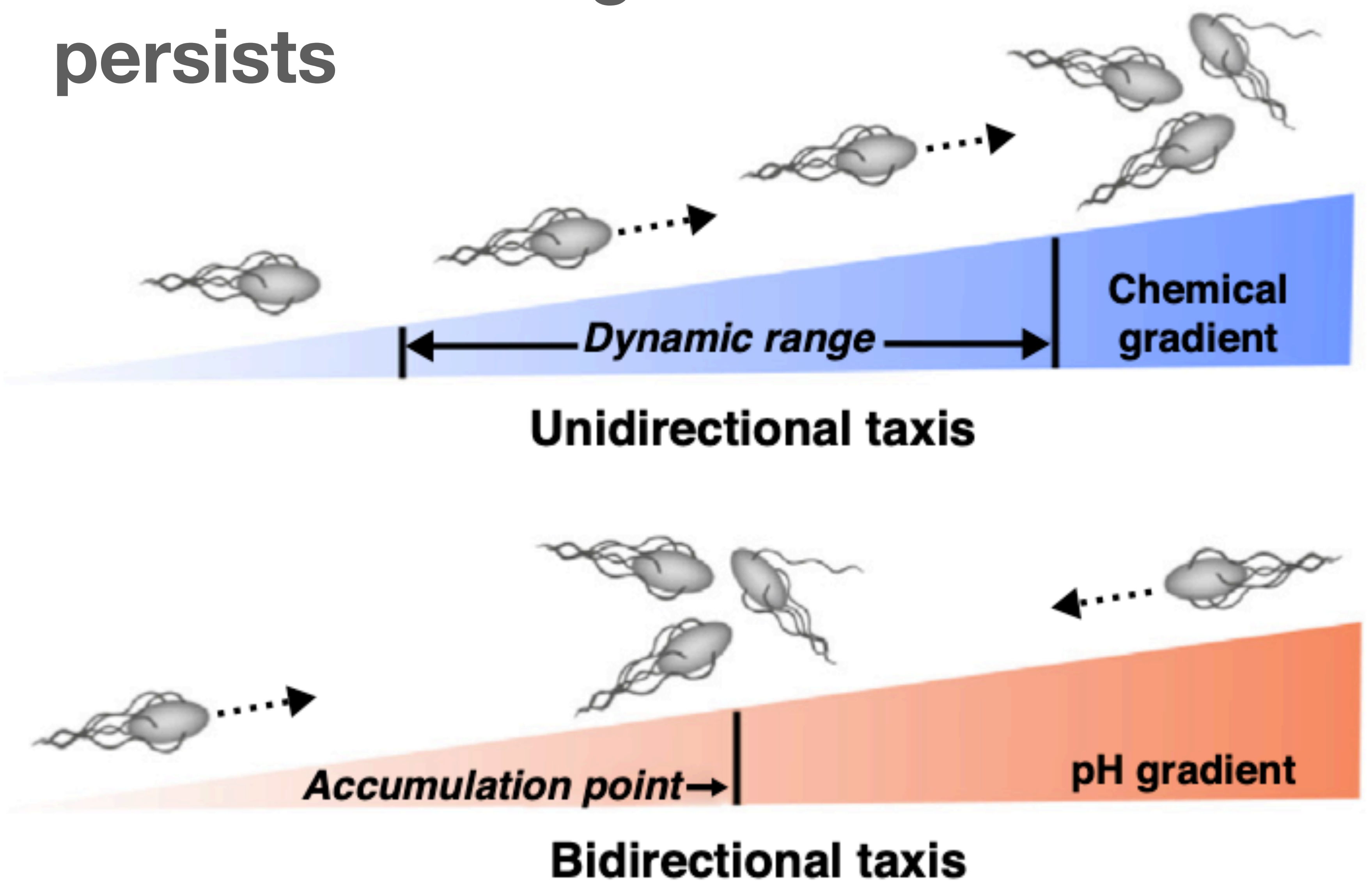
Topics

- Active chemotaxic search

Active chemotaxic search

"Simple" chemotaxis machinery

Keep moving in the same direction if the gradients persists



Calculate gradient

olfactory scent magnitude

$$\nabla o = o_t - o_{t-1}$$

Calculate state

$$\eta_t \sim U(0,1)$$

random number from 0 to 1

Make decision

random turn

state change probability

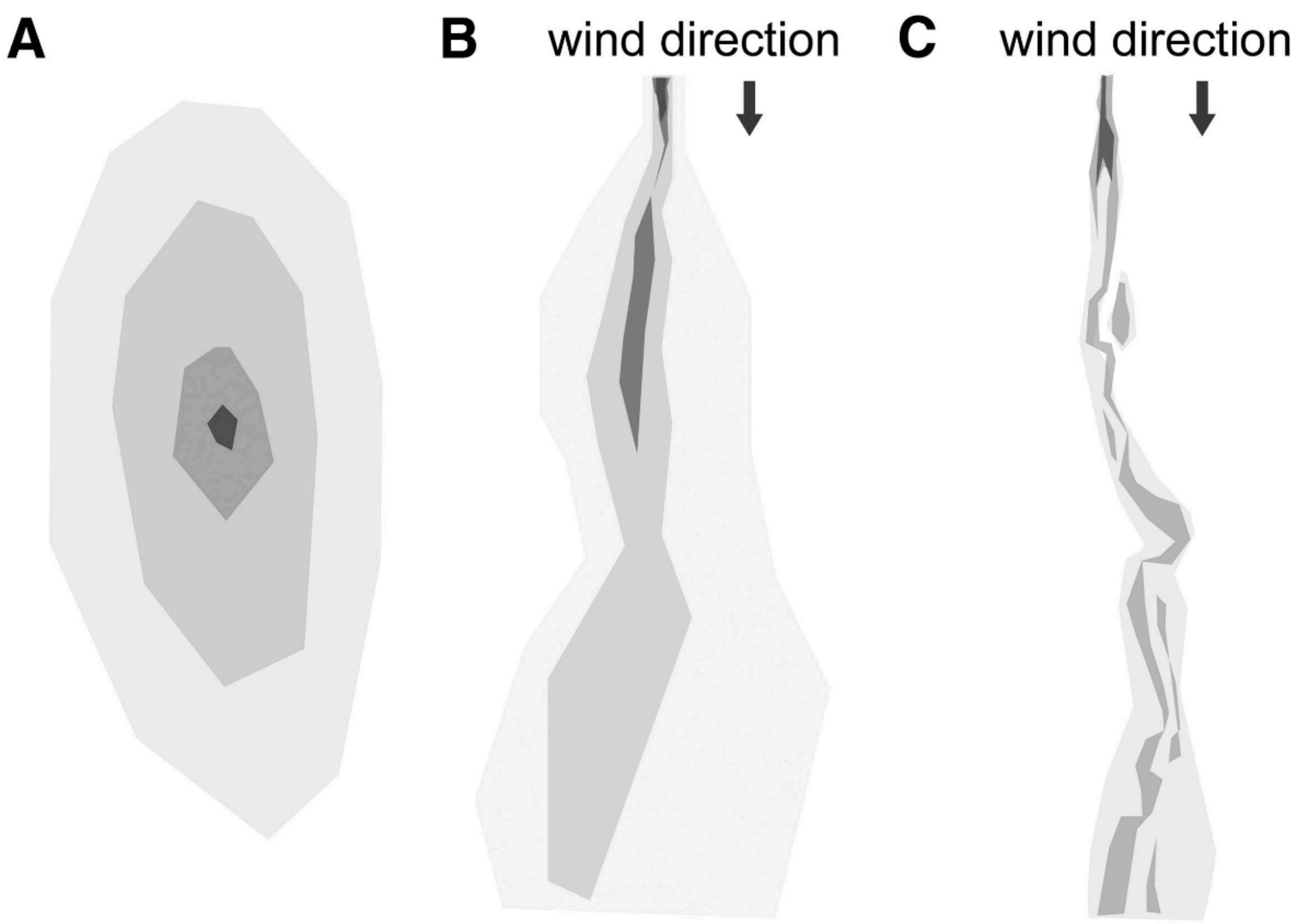
movement angle

$$\theta_t = \begin{cases} U(-\pi, \pi), & \text{if } \Delta o > 0 \ \& \ \eta_t > \rho_+ \\ U(-\pi, \pi), & \text{if } \Delta o \leq 0 \ \& \ \eta_t \leq \rho_- \\ \theta_{t-1}, & \text{otherwise} \end{cases}$$

keep going

(Bi & Source, 2018)

The problem with simple chemotaxic search



Prior assumption

Passive diffusion of chemo signals in the environment as basic Brownian motion.

Reality

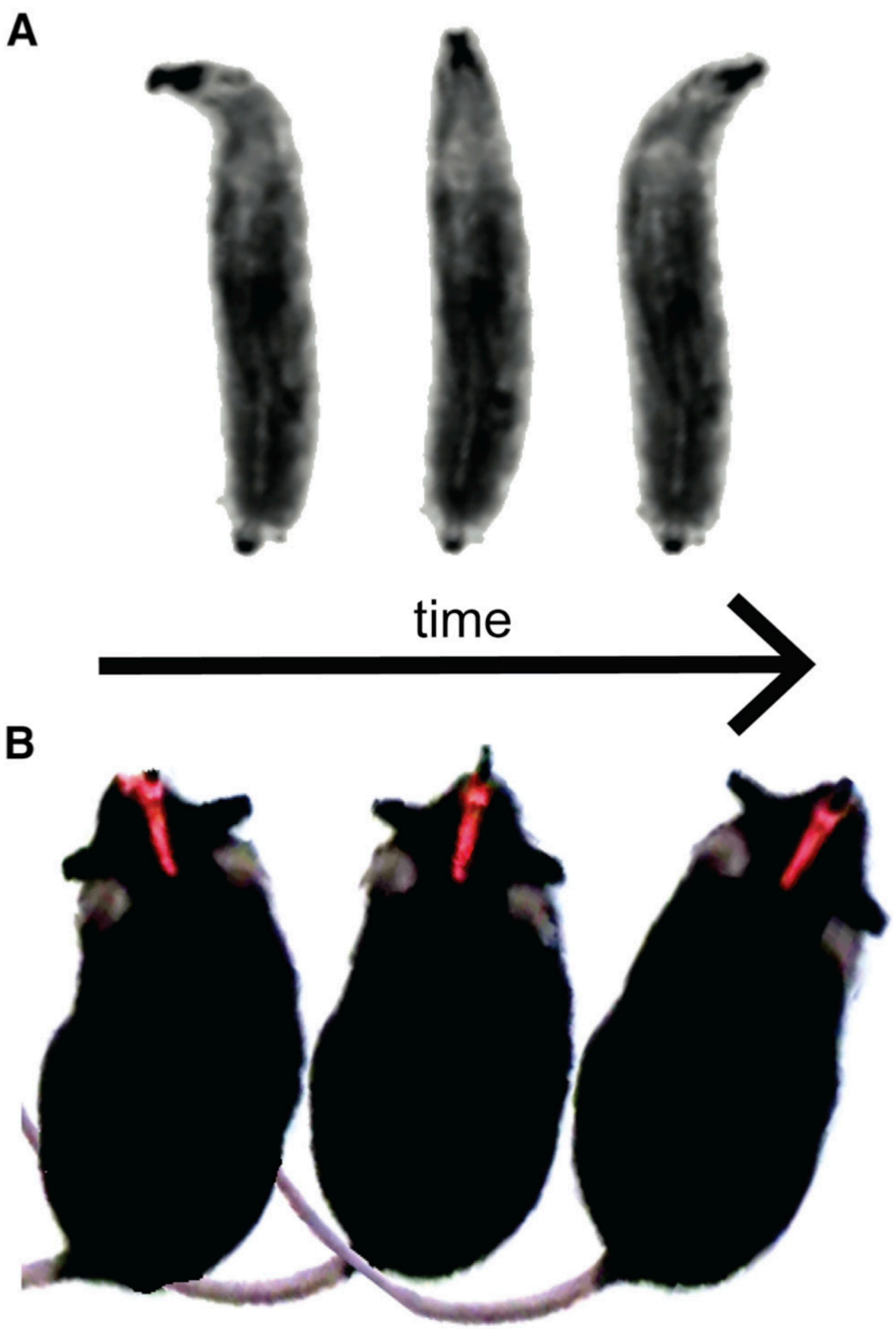
This assumption does not hold in most environments where more complex fluid dynamics distort the distribution of chemical signals used for localization.

(Baker et al., 2018)

Olfactory search

Fly larvae

Mice

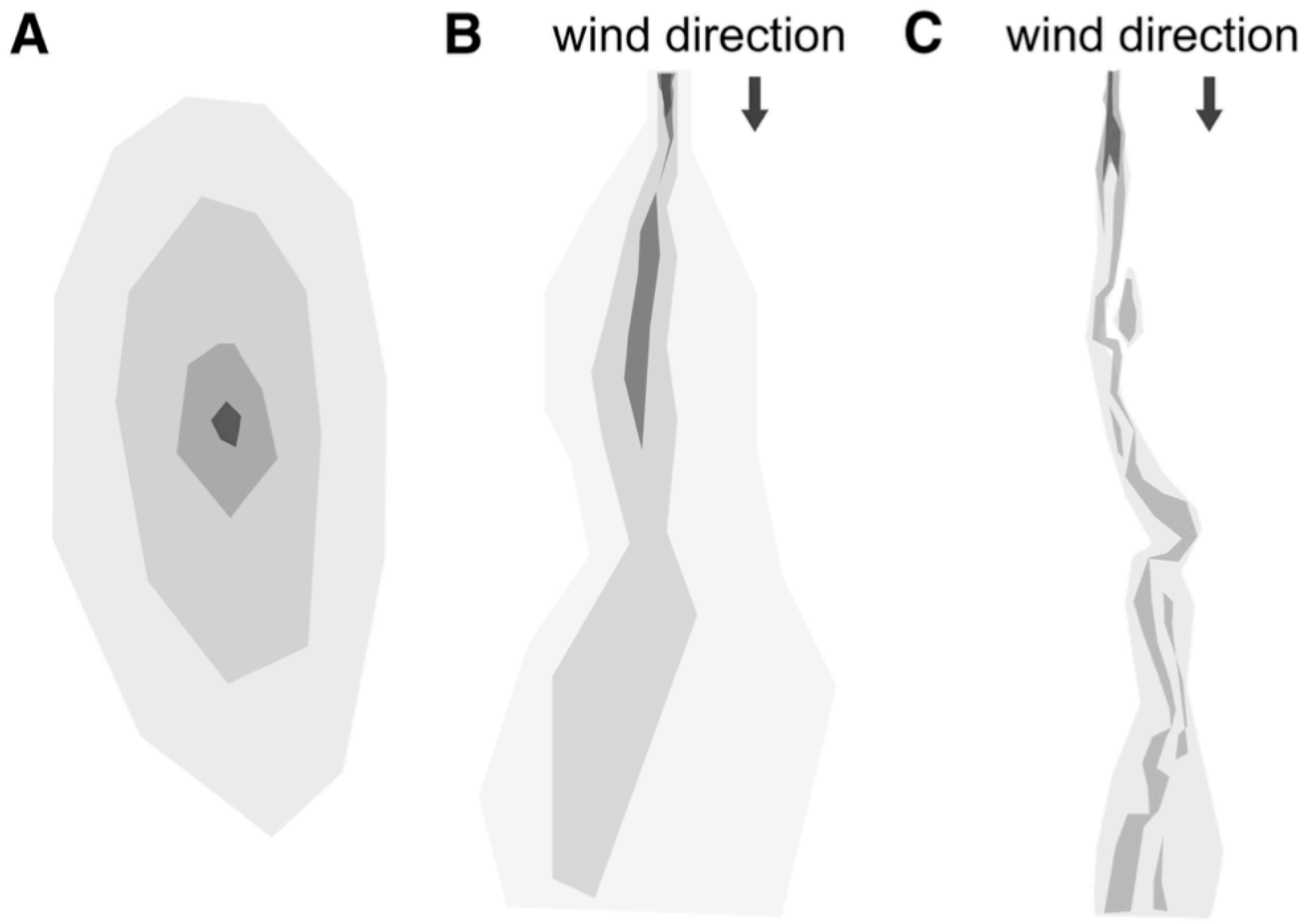


Animals across phyla engage in **active** olfactory **search**.

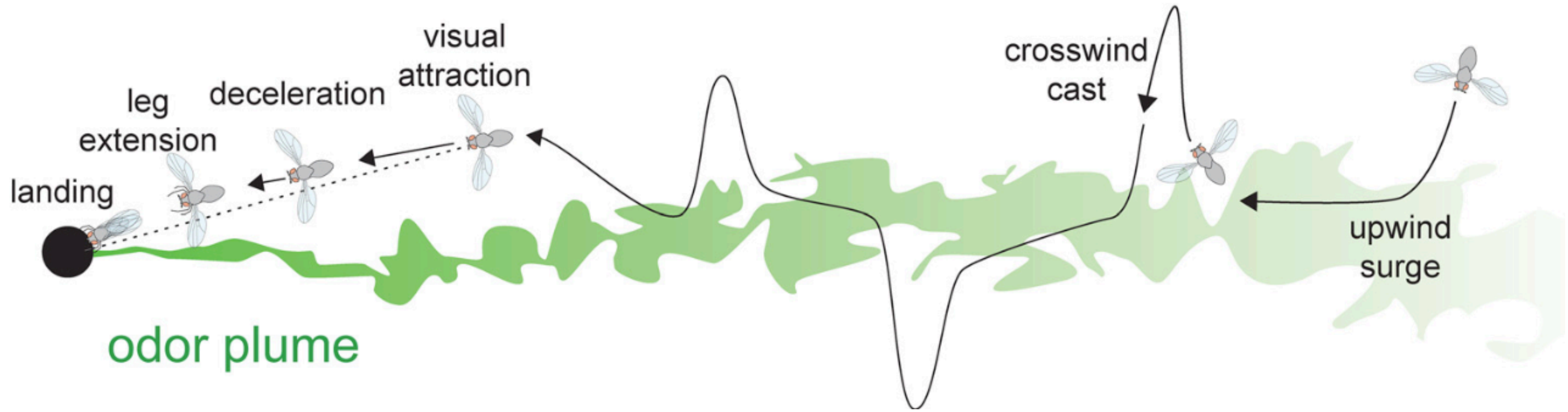
Using strategic movements to follow a scent trail.

(Baker et al, 2018)

Move to track across complex trails

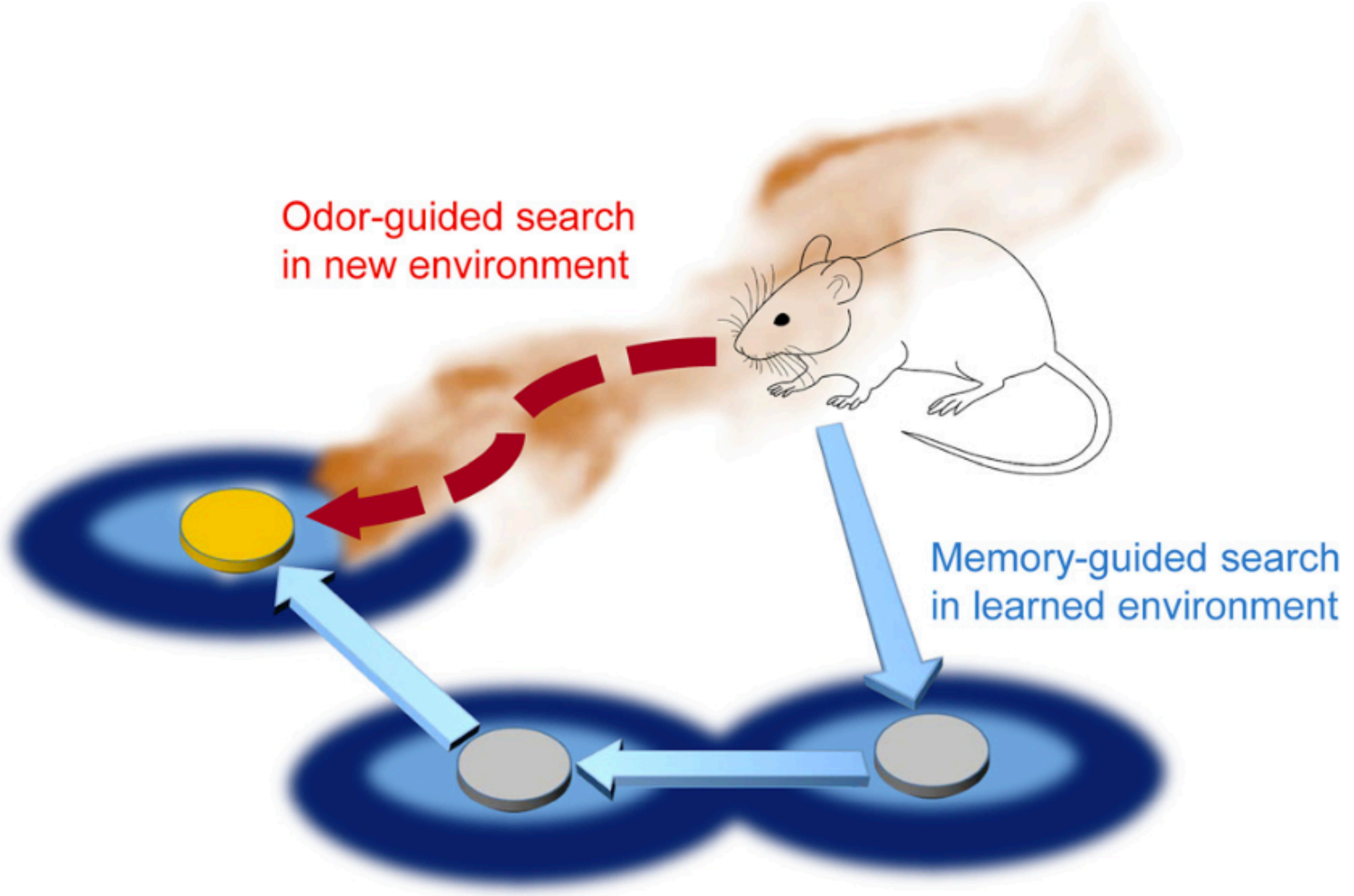


Currents create complex plume patterns that can be tracked using sequential sampling.



(Baker et al, 2018)

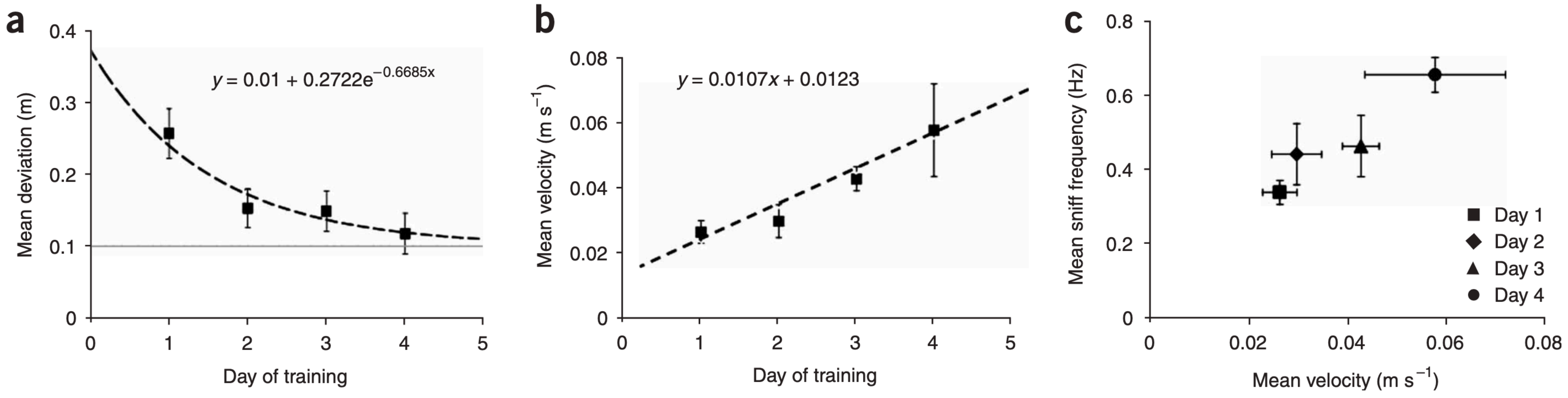
Having an internal map of the world helps



Having a spatial memory with a cognitive map aids in tracking scents in more complex environments.

(Baker et al, 2018)

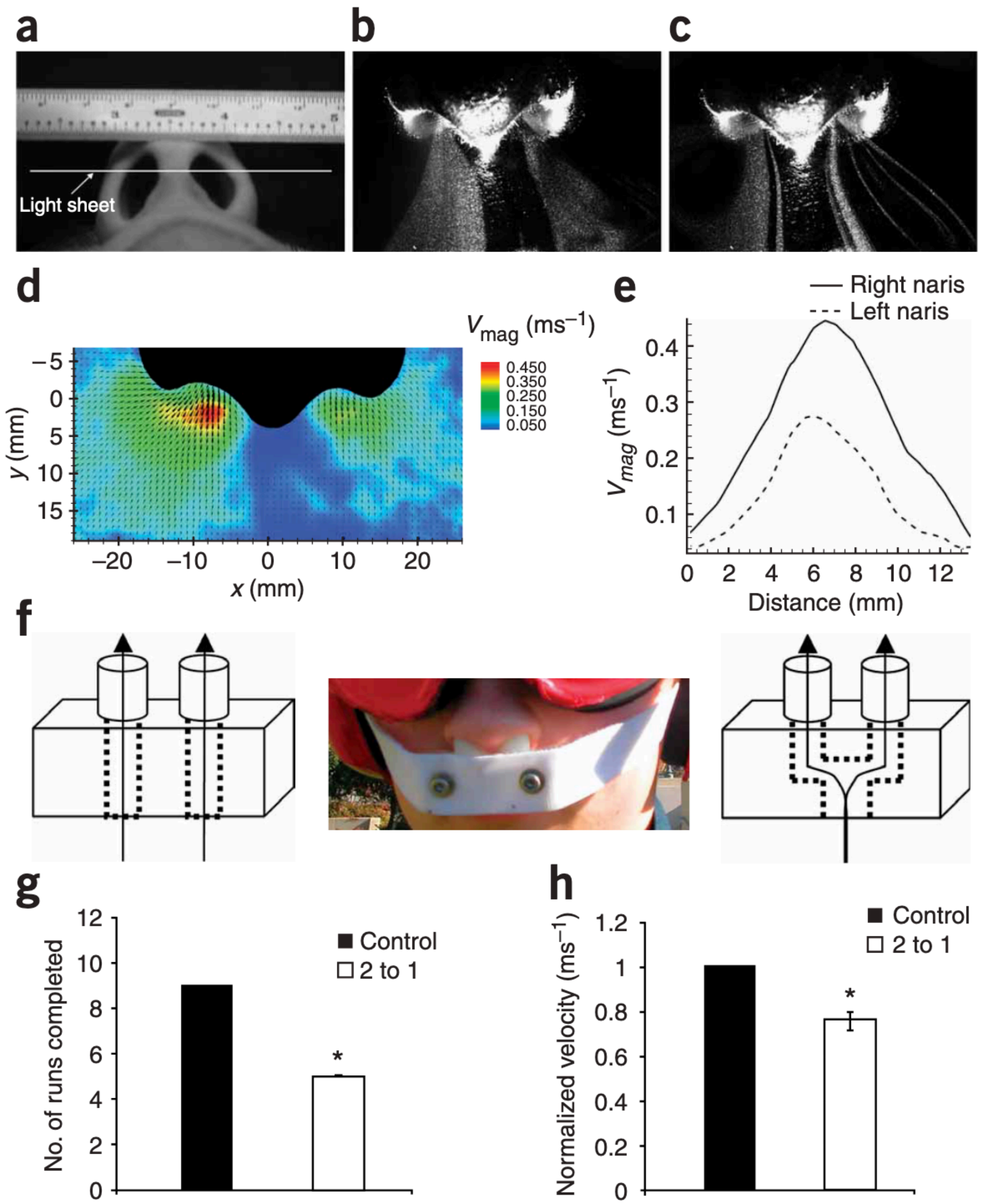
Human scent tracking



When denied the use of other senses, humans can learn to effectively track a scent using a similar active search pattern as canines.

(Porter et al., 2007)

The value of two (different) nostrils



The differential air flow through the two nostrils creates a form of olfactory parallax, that aids in the localization of a scent trail.

(Porter et al., 2007)

Take home message

- The simple chemotaxis implemented by e. coli bacteria reflects an inefficient approach to tracking scents.
- More complex organisms, including humans, use a variety of cognitive abilities to aid in scent localization via active search.

Discussion groups

Algorithm 1 Example algorithm structure

Set n_{max} number steps
Set other initial parameters
for $step = 1, \ldots, n_{max}$ **do**
    Do some things
    Do some other things
    if Some conditionals **then**
        Do some more things
    else if Some different conditionals **then**
        Do other things
    else
        Default thing to do
    end if
    Do some last things before taking next step?
end for

Algorithm

A step-by-step procedure or a set of rules designed to perform a specific task or solve a particular problem. It consists of a sequence of well-defined instructions that take some input, process it through a series of steps, and produce an output.

Task

Design a *simple* algorithm that implements the sort of sequential search that mammals (and other animals do) along scent trails.