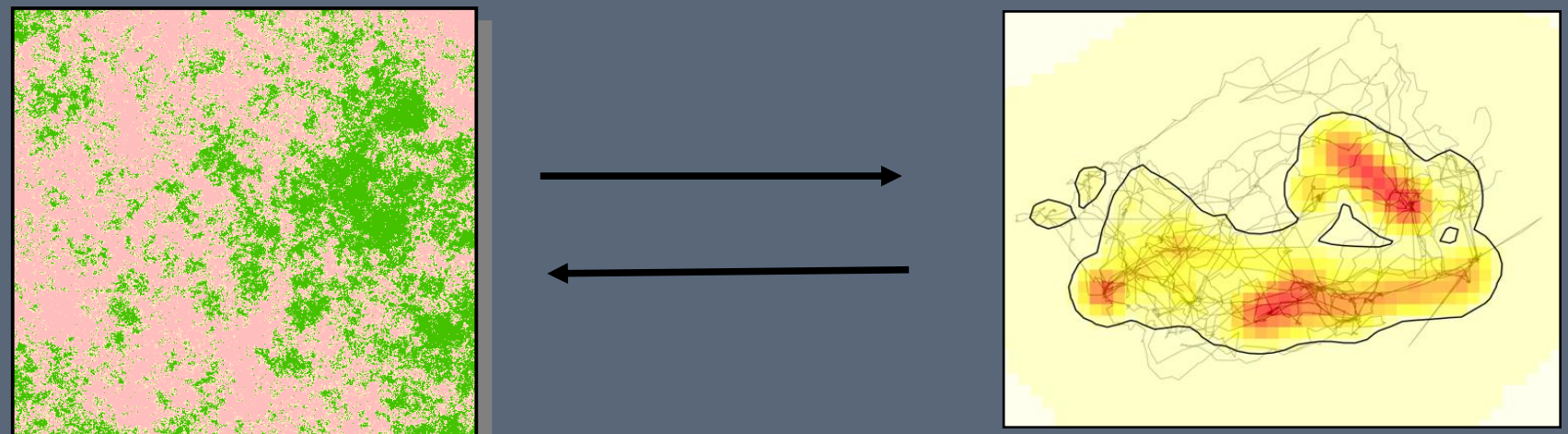
An introduction to movement (ecology) analyses



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NINA
Norwegian Institute for Nature Research

Animal Movement PhD-course, SLU
Ekenäs Herrgård
4-8 September, 2023

How to represent movement?

- How to represent movement in a meaningful way?

Reality

Model 1

Model 2

Model 3

How to represent movement?

- How to represent movement in a meaningful way?
- **What is your question?**
- What is your study system?
- Which organism(s)?
- Which process(es)?
- Which tools we use to measure movement?
- What type of data if produces?

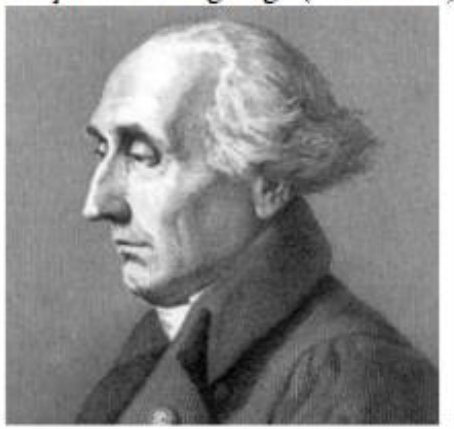
Eulerian

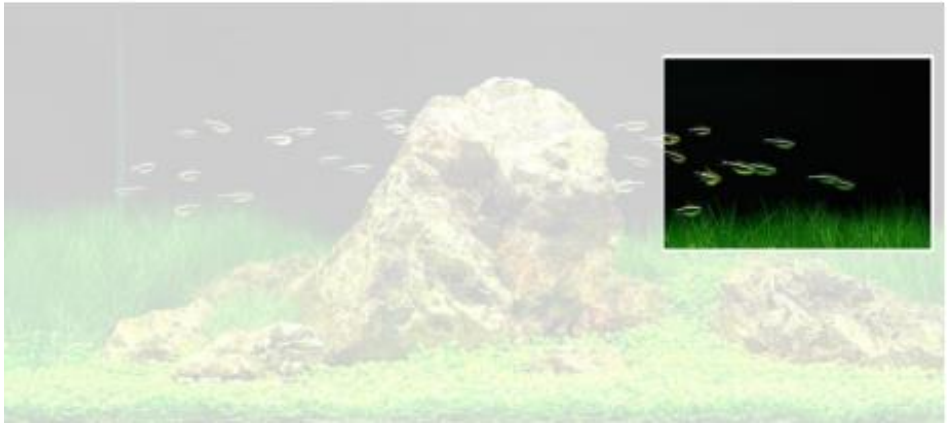
Leonhard Euler (1707-1783)

VS.

Lagrangian

Joseph-Louis Lagrange (1736-1813)





Focus on a given location in space
Multiple individuals
Movement rates

Focus on a specific individuals
Individual trajectories

Slide adapted from Gastón Giné

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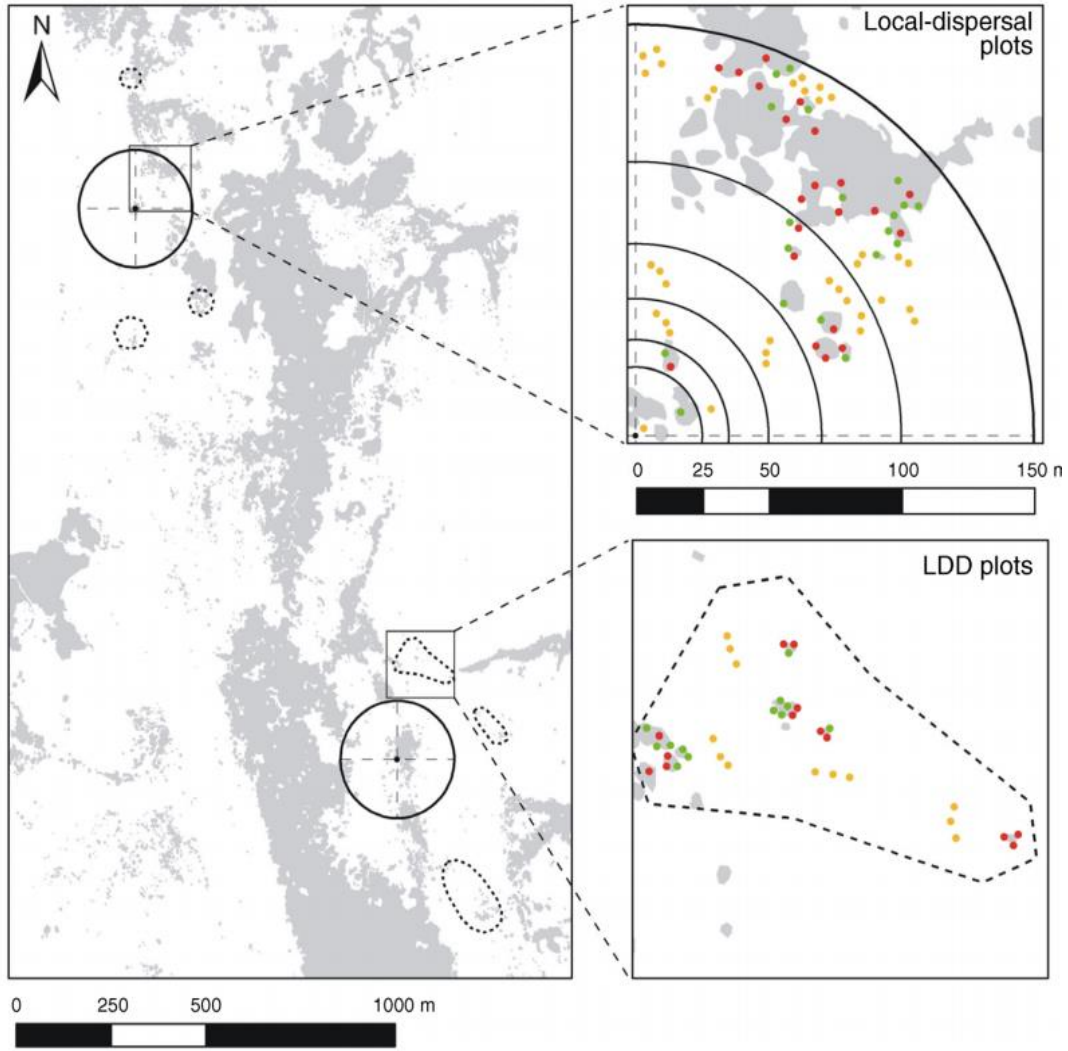
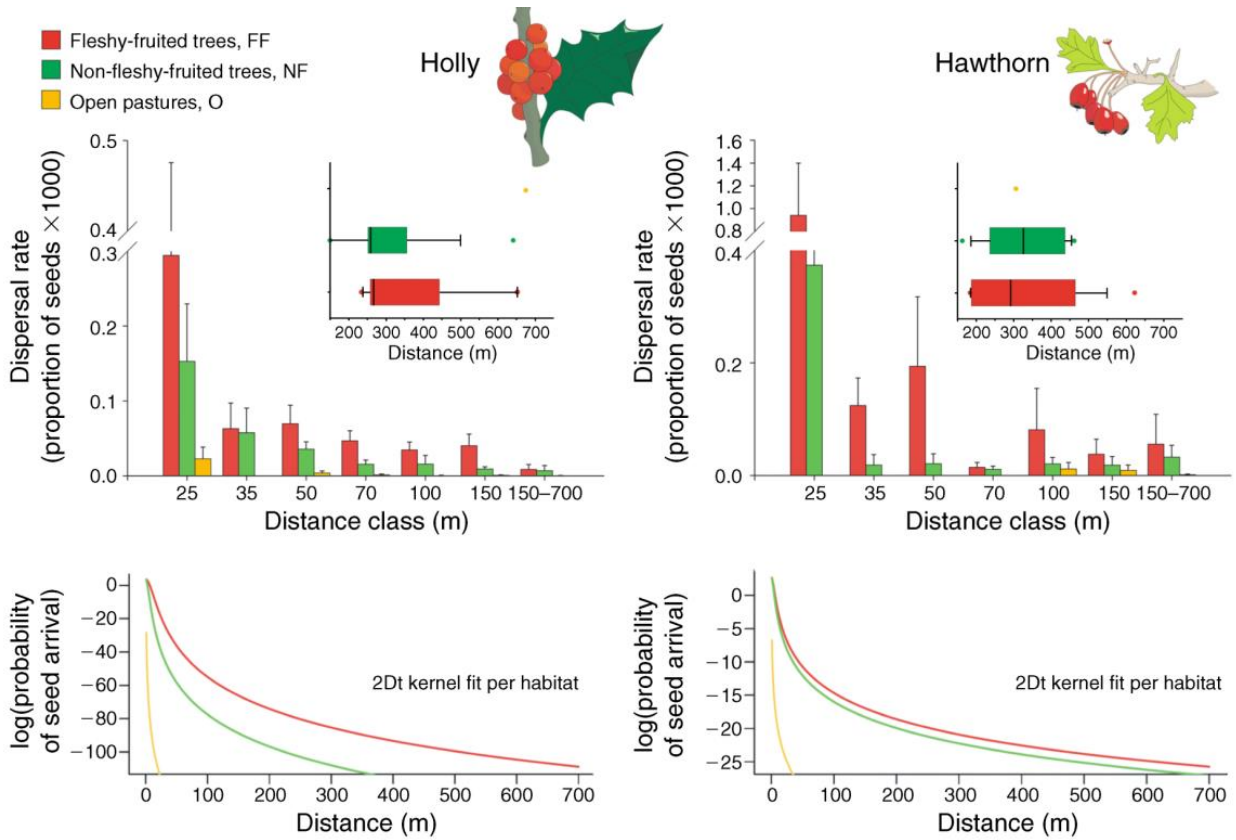
How to represent movement?

- **What is your question?**
  - **How do seeds move and where do they go?**

Where do seeds go when they go far? Distance and directionality of avian seed dispersal in heterogeneous landscapes

Tomás A. Carlo,[1,4] Daniel García,[2] Daniel Martínez,[2] Jason M. Gleditsch,[1] and Juan M. Morales[3]





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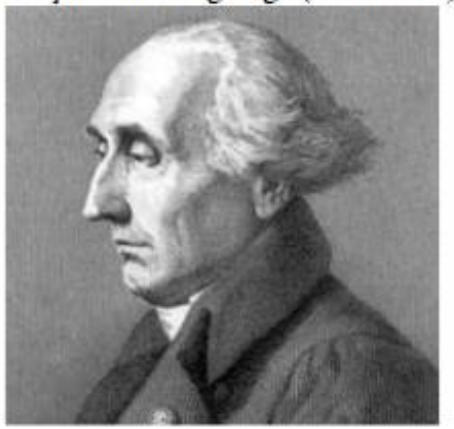

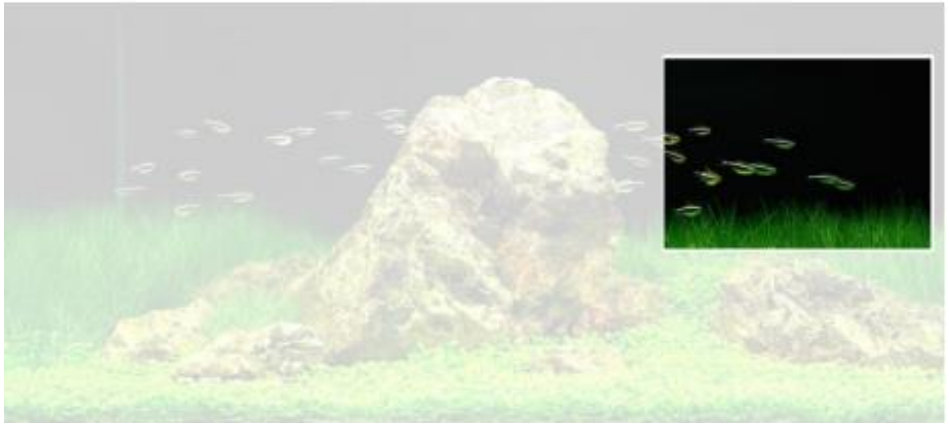

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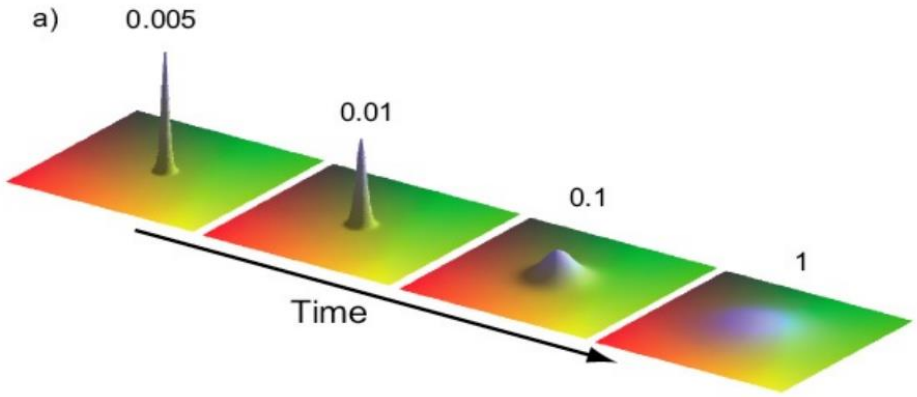
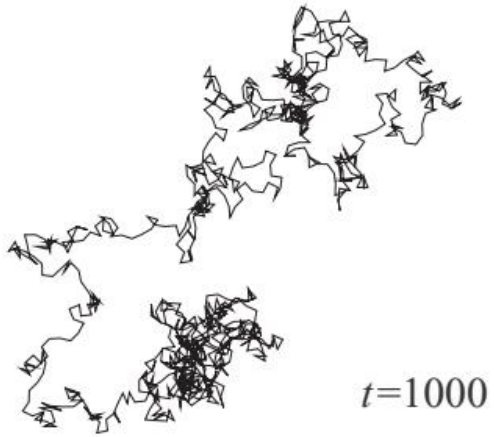
How to represent movement?

Continuous-time stochastic process



Discrete-time stochastic process



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Continuous-time stochastic processes

Muskrat

- The muskrat, an species native of North-america, was introduced in Europe.
- In 1905, five individuals were introduced in Prague.
- Today, there are millions in Europe
- In what follow, we see the expansion of the muskrat's range around Prague over 17 years..

1921

Slide adapted from
Roberto Kraenkel

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Continuous-time stochastic processes

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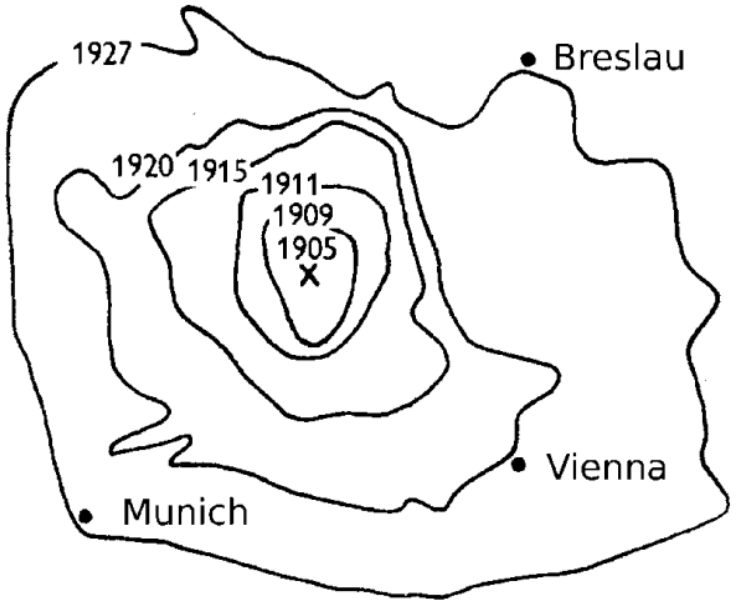

Viswanathan et al 2011, adapted from Skellam 1951

Slide adapted from
Roberto Kraenkel

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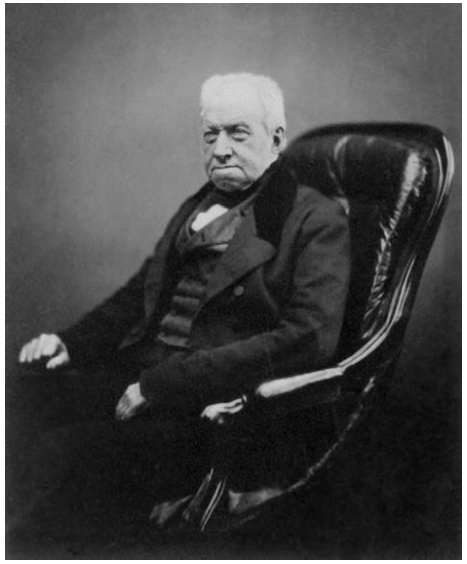
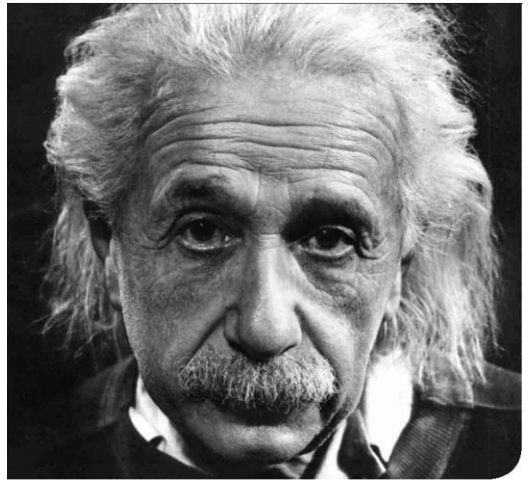
Continuous-time stochastic processes

- Our main hypothesis is that individuals move **randomly.**
- In some sense, they behave as molecules in a gas.
- If we look at such population from a space scale much larger than the typical scale of the movement of the individuals we will see the macroscopic phenomenon called **diffusion**.



Robert Brown
(1773-1858)

Brownian motion



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In two dimensions we would have:

$$\frac{\partial \rho}{\partial t} = D\nabla^2\rho$$

where $\nabla^2\rho \equiv \frac{\partial^2\rho}{\partial x^2} + \frac{\partial^2\rho}{\partial y^2}$

Variation in population size along time = Diffusion rate x Variation in population size across space

Slide adapted from Roberto Kraenkel

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Dispersal function or kernel

$$\rho(x,t) = \frac{Q}{2(\pi Dt)^{1/2}} e^{-x^2/(4Dt)}$$

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Continuous-time stochastic processes

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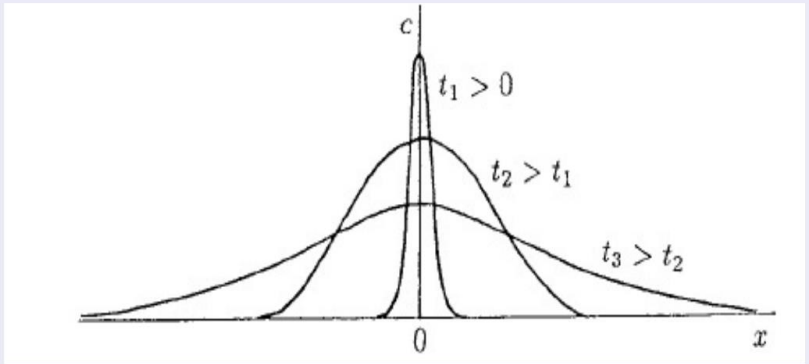
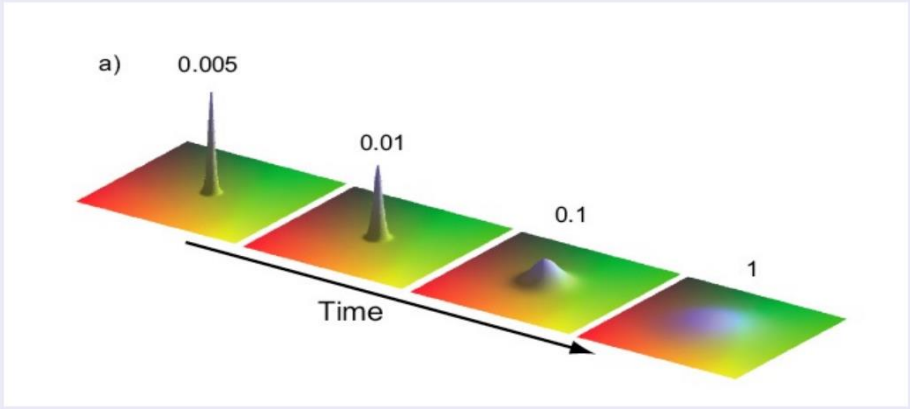
Solution to the 1D diffusion equation



Solution to the 2D diffusion equation



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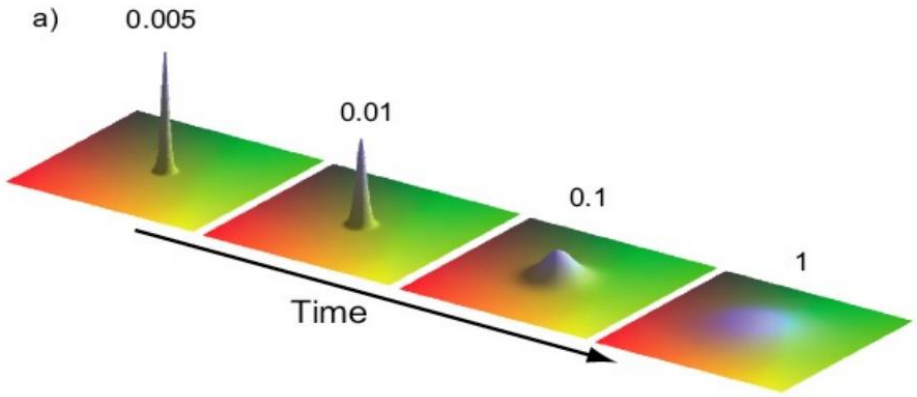

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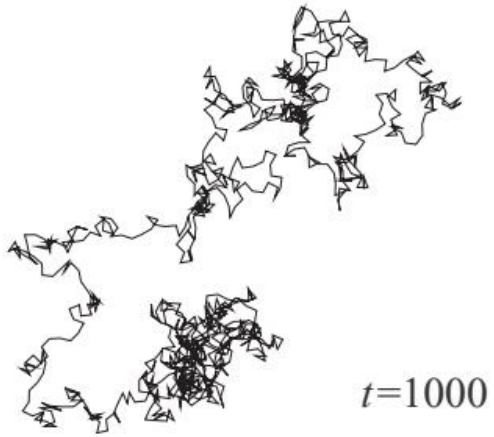

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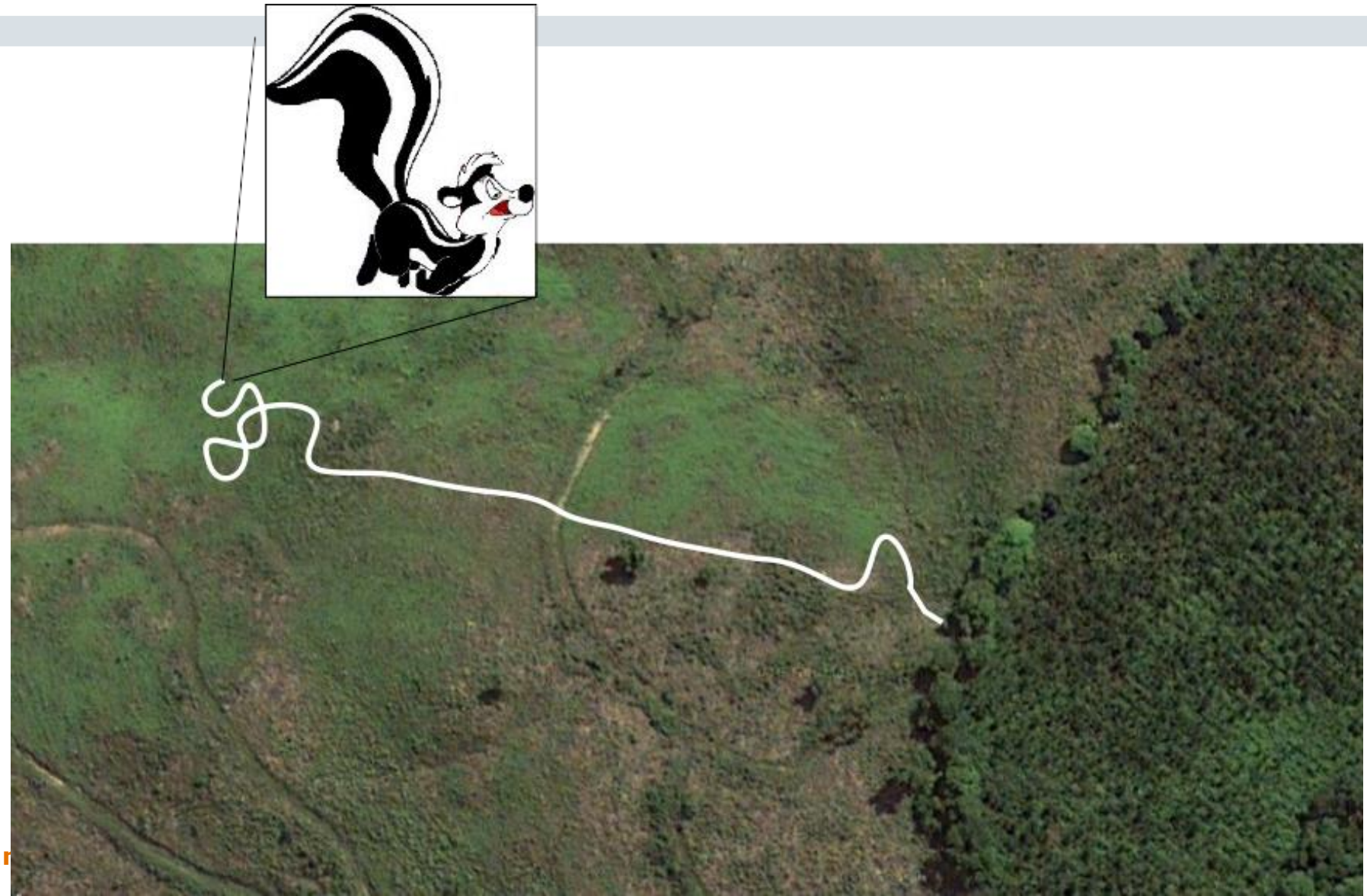
Discrete-time stochastic processes



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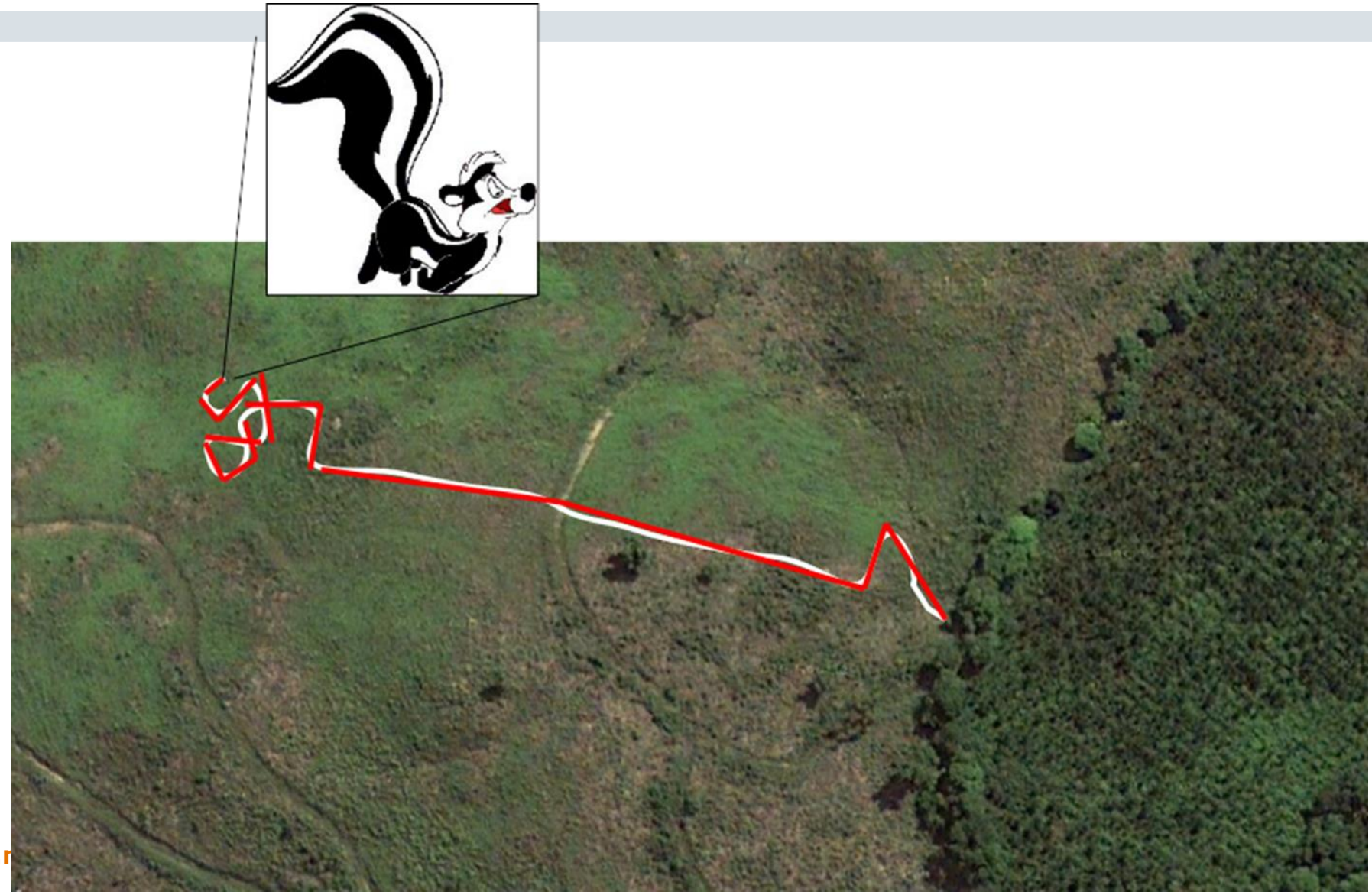

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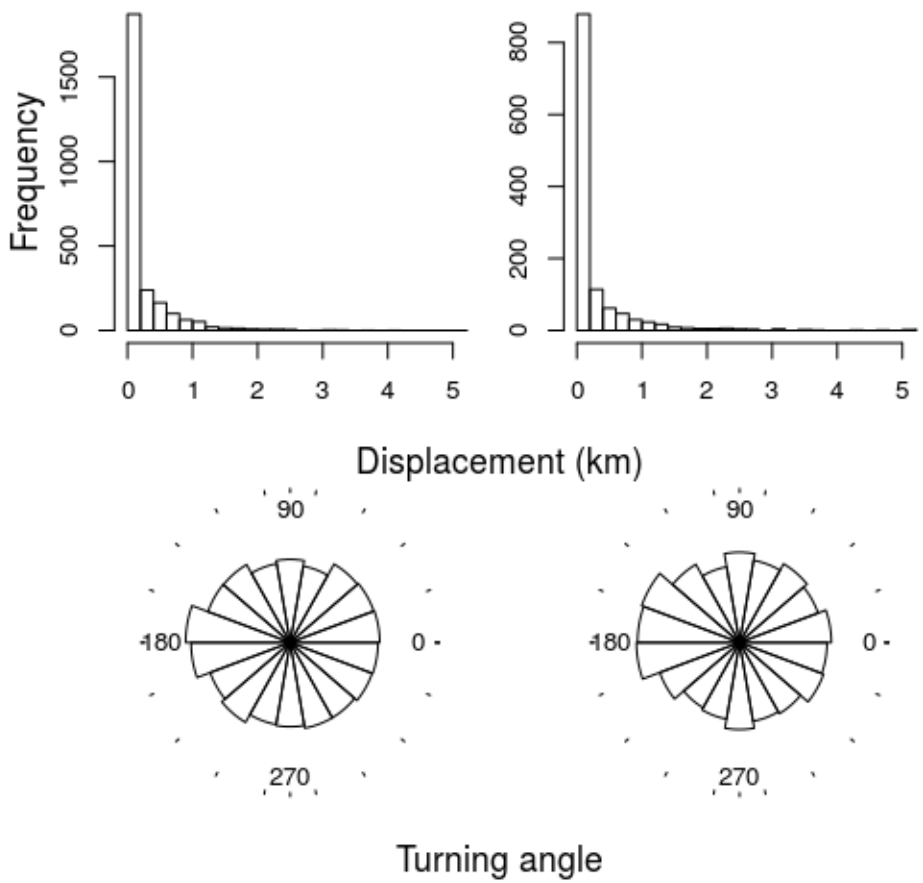
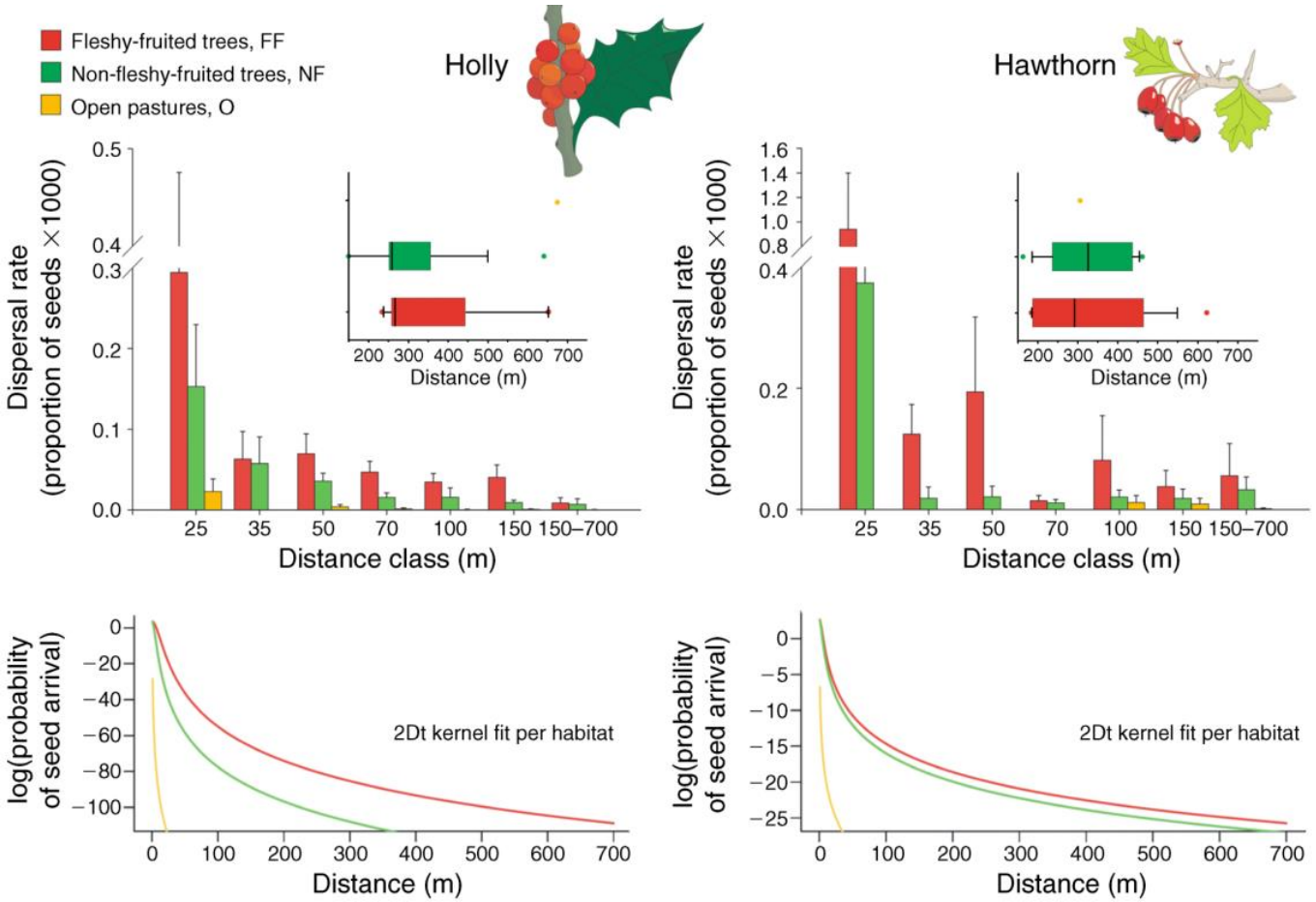




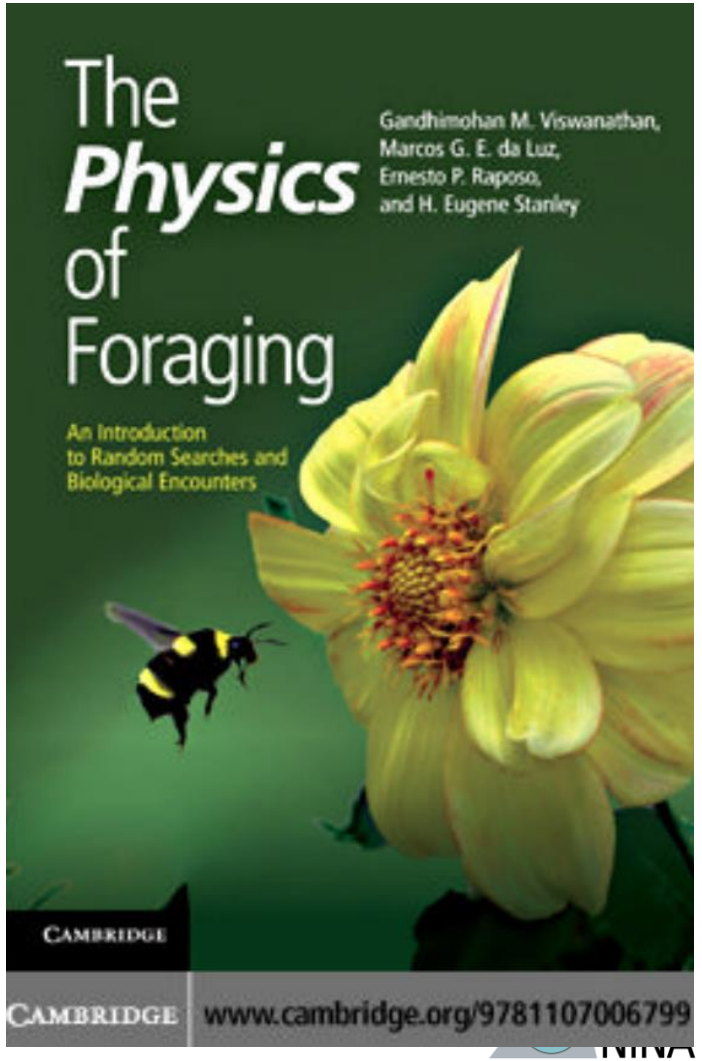
Take-home message

- How we represent and quantify movement depends on our question, our study system, our tools, and the data we can collect with it
- There are different ways of representing movement
- In discrete time, movement of organisms is most often classified in trajectories, which can be subdivided into steps
- Trajectories might be used to compute movement parameters: step length, speed, turning angles, …
- Inferring the distribution of movement parameters and their causes is one of the aims in movement ecology

Literature

- Carlo, T. A., García, D., Martínez, D., Gleditsch, J. M., & Morales, J. M. (2013). Where do seeds go when they go far? Distance and directionality of avian seed dispersal in heterogeneous landscapes. Ecology, 94(2), 301–307. https://doi.org/10.1890/12-0913.1

- Viswanathan, G. M., da Luz, Marcos G. E., Raposo, E. P., & Stanley, H. Eugene. (2011). *The Physics of Foraging*. Cambridge University Press.



Cooperation and expertise for a sustainable future

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