First-passage times of diffusion processes and Geometry-controlled kinetics

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(Dated: June 7, 2010)

It has long been appreciated that transport properties can control reaction kinetics. This effect can be characterized by the time it takes a diffusing molecule to reach a target – the first-passage time (FPT). We will present a new method of determination of the statistics of the FPT in confined geometries, and show that transport processes as various as regular diffusion, anomalous diffusion, diffusion in disordered media and in fractals fall into the same universality classes. Beyond this theoretical aspect, this result could have potential impact on standard reaction kinetics. More precisely, we argue that geometry can become a key parameter so far ignored in this context, and introduce the concept of "geometry-controlled kinetics" (see figure 1). These findings could help understand the crucial role of spatial organization of genes in transcription kinetics, and more generally the impact of geometry on diffusion-limited reactions.

PACS numbers:

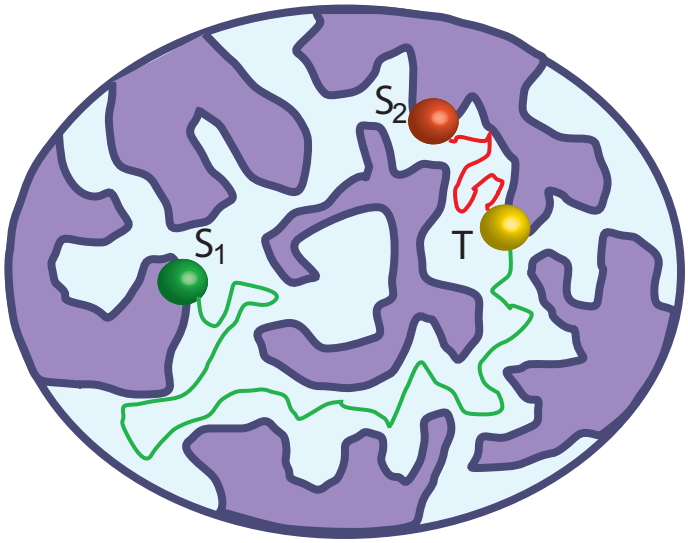

FIG. 1: **First-passage times and geometry controlled kinetics**. Is (or is not) the initial position of the particle an important parameter of the kinetics ? We show quantitatively that in the case of compact exploration (eg for dilute solutions), the kinetics turns out to be widely independent of the starting point (S_1 or S_2), whereas in the non compact exploration case (eg for crowded environments), the position of the starting point strongly influences the search time of the target, leading to "geometry controlled kinetics". This result in particular implies that the kinetics of activation of a gene T by a transcription factor (TF) can be orders of magnitudes faster if the TF is released from a site $S \equiv S_2$ which is colocalized with (*i.e.* in the vicinity of) T, as compared to the case where the TF is released from a remote site $S \equiv S_1$.

References

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