Messages Do Diffuse Faster than Messengers: Reconciling Disparate Estimates of the Morphogen Bicoid Diffusion Coefficient

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The gradient of Bicoid (Bcd) is key for the establishment of the anterior-posterior axis in Drosophila embryos. The gradient properties are compatible with the SDD model in which Bcd is synthesized at the anterior pole and then diffuses into the embryo and is degraded with a characteristic time. Within this model, the Bcd diffusion coefficient is critical to set the timescale of gradient formation. This coefficient has been measured using two optical techniques, Fluorescence Recovery After Photobleaching (FRAP) and Fluorescence Correlation Spectroscopy (FCS), obtaining estimates in which the FCS value is an order of magnitude larger than the FRAP one. This discrepancy raises the following questions: which estimate is "correct''; what is the reason for the disparity; and can the SDD model explain Bcd gradient formation within the experimentally observed times? We use a simple biophysical model in which Bcd diffuses and interacts with binding sites to show that both theFRAP and the FCS estimates may be correct and compatible with the observed timescale of gradient formation. The discrepancy arises from the fact that FCS and FRAP report on different effective (concentration dependent) diffusion coefficients, one of which describes the spreading rate of the individual Bcd molecules (the messengers) and the other one that of their concentration (the message). The latter is the one that is more relevant for the gradient establishment and is compatible with its formation within the experimentally observed times.