Equations 1.35 - 1.39 removed due to copyright restrictions.
Diffusion-reaction in developing early embryos to measure length
Drosophila melanogaster (fruit fly) developmental cycle

9 days
Screenshot of Edward B. Lewis, Christiane Nüsslein-Volhard, Eric F. Wieschaus, The Nobel Prize in Physiology or Medicine 1995 winners removed due to copyright restrictions.
make a super simple fruit fly trap that works!

Materials:

- small glass bowl
- wine or juice
- dish soap
- plastic wrap
- bamboo skewer
mRNA molecules

position in oocyte

Figure of *Drosophila* early embryo protein gradients removed due to copyright restrictions.

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In the simplest model (14), Bcd protein diffuses through the embryo and decays with a lifetime $\tau$. The spatiotemporal dynamics of the concentration profile are determined by

$$\frac{\partial c(\vec{r}, t)}{\partial t} = D \nabla^2 c(\vec{r}, t) - \frac{1}{\tau} c(\vec{r}, t),$$

where $D$ is the diffusion constant. The steady state therefore is determined by

$$D \nabla^2 c_\infty(\vec{r}) = \frac{1}{\tau} c_\infty(\vec{r}).$$

If there is a source (translation of maternal RNA) at $x = 0$ and no variations along the dorsal-ventral direction, then the solution, projected along the anteroposterior axis, is $c_\infty(x) = A \exp(-x/\lambda)$, where $\lambda = \sqrt{D\tau}$, and the constant $A$ is set to match the diffusive flux to the translation rate at $x = 0$; this solution is valid if $L/\lambda \gg 1$, as observed. Identifying staining intensity as proportional to concentration, and allowing for background fluorescence $B$, the raw data of Bcd immunofluorescence intensities were fitted by $I = A \exp(-x/\lambda) + B$ for abscissae $x \in 15-85\%$ egg length. A nonlinear Nelder-Mead fitting procedure was used to estimate the parameters $A$, $B$, and $\lambda$ for each embryo (13).
Fluorescence Recovery After Photobleaching (FRAP) to measure diffusion and reaction in situ
diffusion-dominated recovery:

\[ \frac{\partial f}{\partial t} = D_f \nabla^2 f \]

\[ frap(t) = f(t) = e^{-\frac{\tau_D}{2t}} \left[ I_0 \left( \frac{\tau_D}{2t} \right) + I_1 \left( \frac{\tau_D}{2t} \right) \right] \]
reaction-dominated (off-rate) recovery:

\[ \text{frap}(t) = 1 - C_{eq} e^{-k_{off}t} \]
Effective diffusion recovery:

\[ \frac{df}{dt} = D_f \nabla^2 f - k_{on}^* f + k_{off} c \]

\[ D_{eff} = \frac{D_f}{1 + (k_{on}^*/k_{off})} \]