Mixing by Cilia
Node in Mouse Embryo

(Okada, et al., Cell, 2005; Hirokawa, et al., Cell, 2006)
Cilia Beating Creates Flow
Cilia and Symmetry Breaking

• Advection-Diffusion in rectangular coordinates

which side the morphogen ends up on depends on the advection rate

The inv mice have slower right-left advection, so diffusion rapidly delivers the morphogen to the receptors on the floor.

(Cartwright, et al., PNAS, 2004)
Changing Diffusivity

- Watching fluorescently-labeled proteins (no degradation)

\[ Pe = \frac{vL}{D} \]