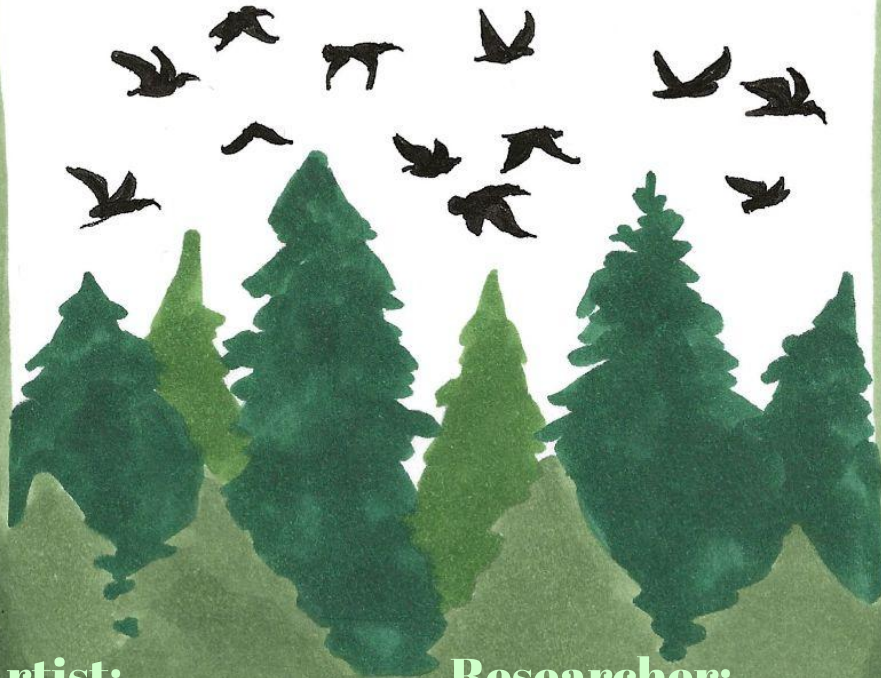


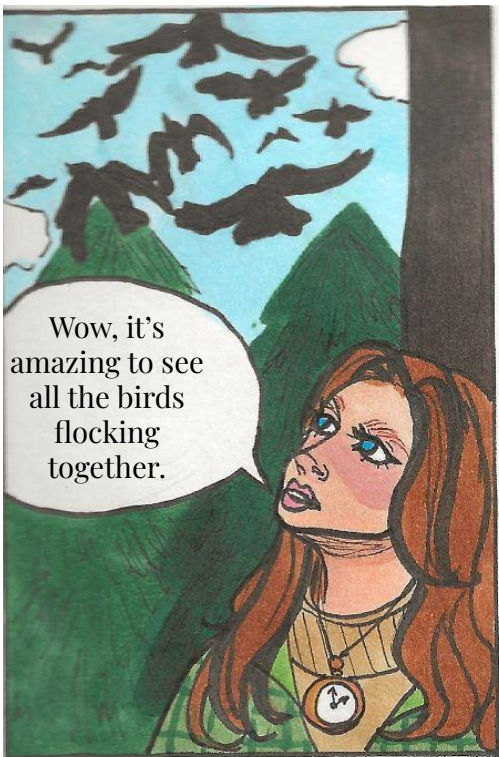
Flocking Birds and Active Matter



**Artist:
Madison Ellis**

**Researcher:
Professor John Toner**

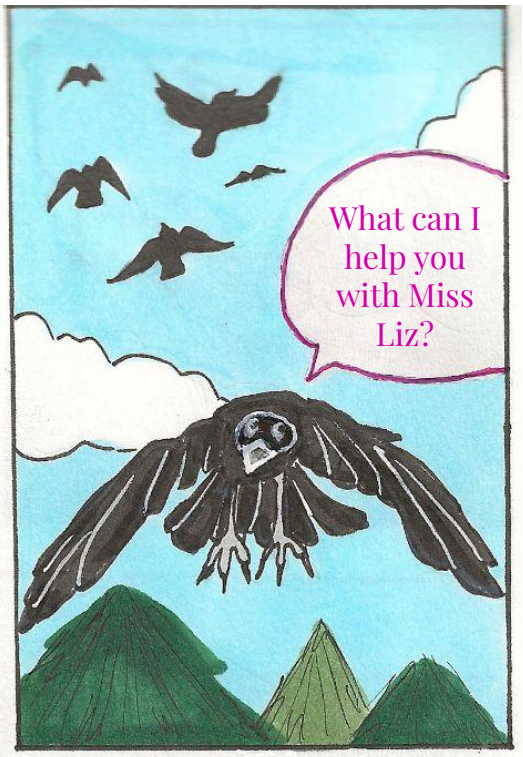
Created through the University of Oregon Science and Comics Fellowship program



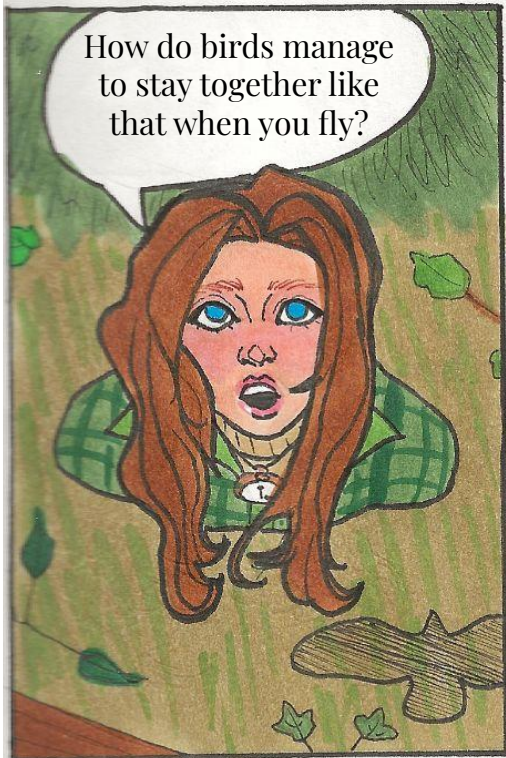
Wow, it's amazing to see all the birds flocking together.



Hey Cordelia!



What can I help you with Miss Liz?



How do birds manage to stay together like that when you fly?

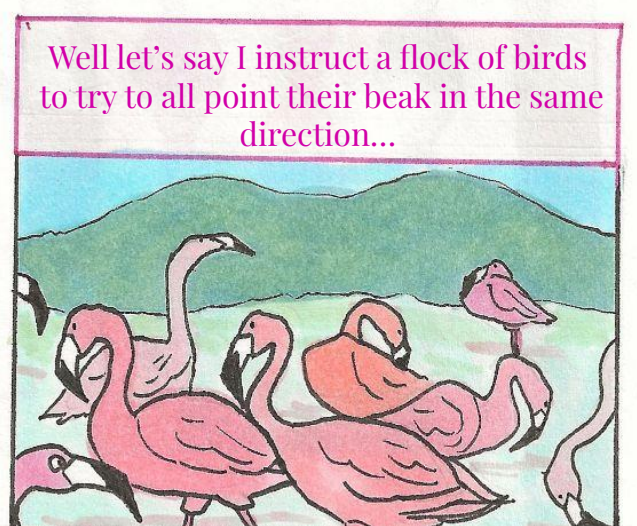
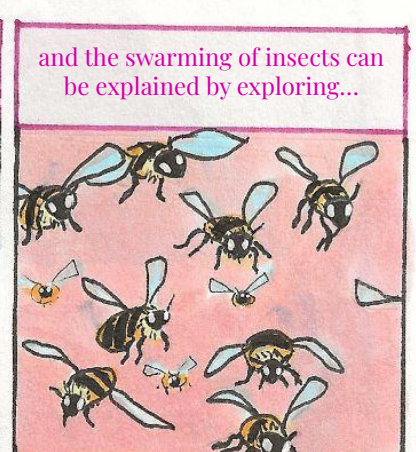
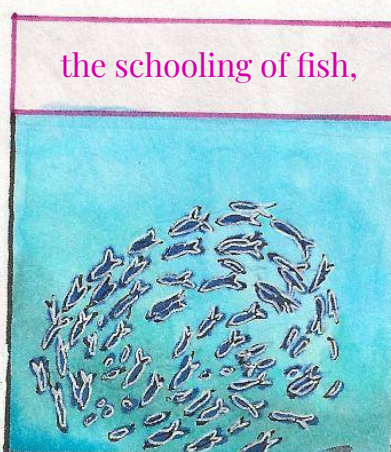
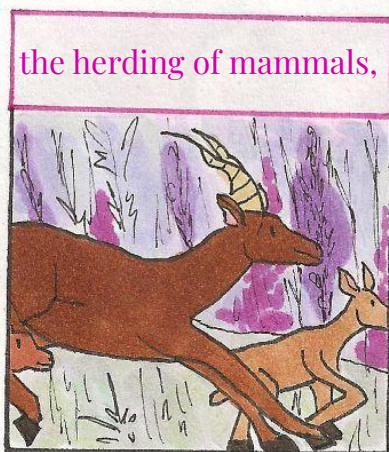
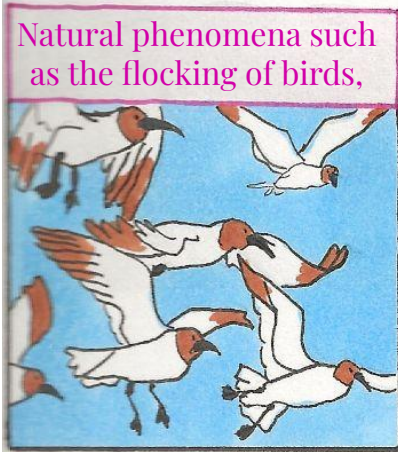
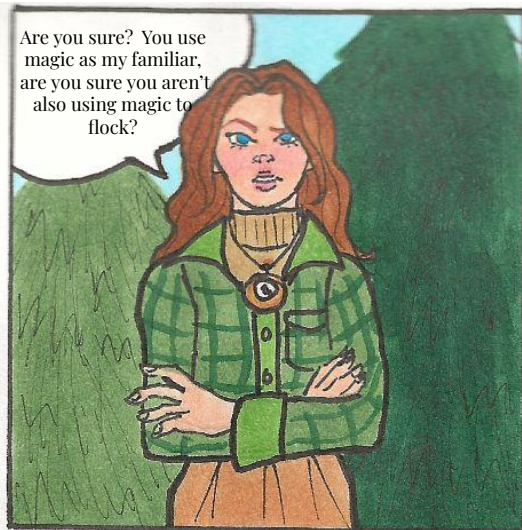
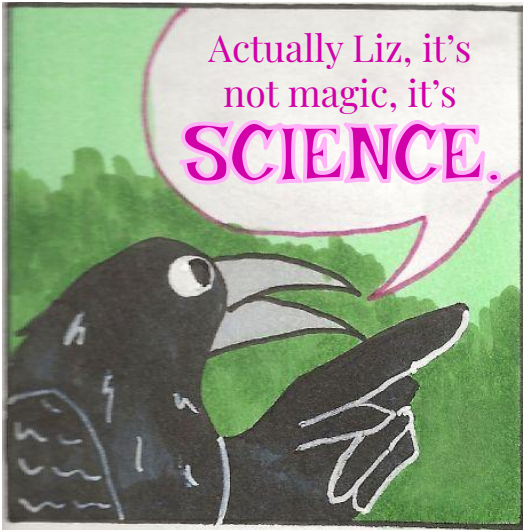


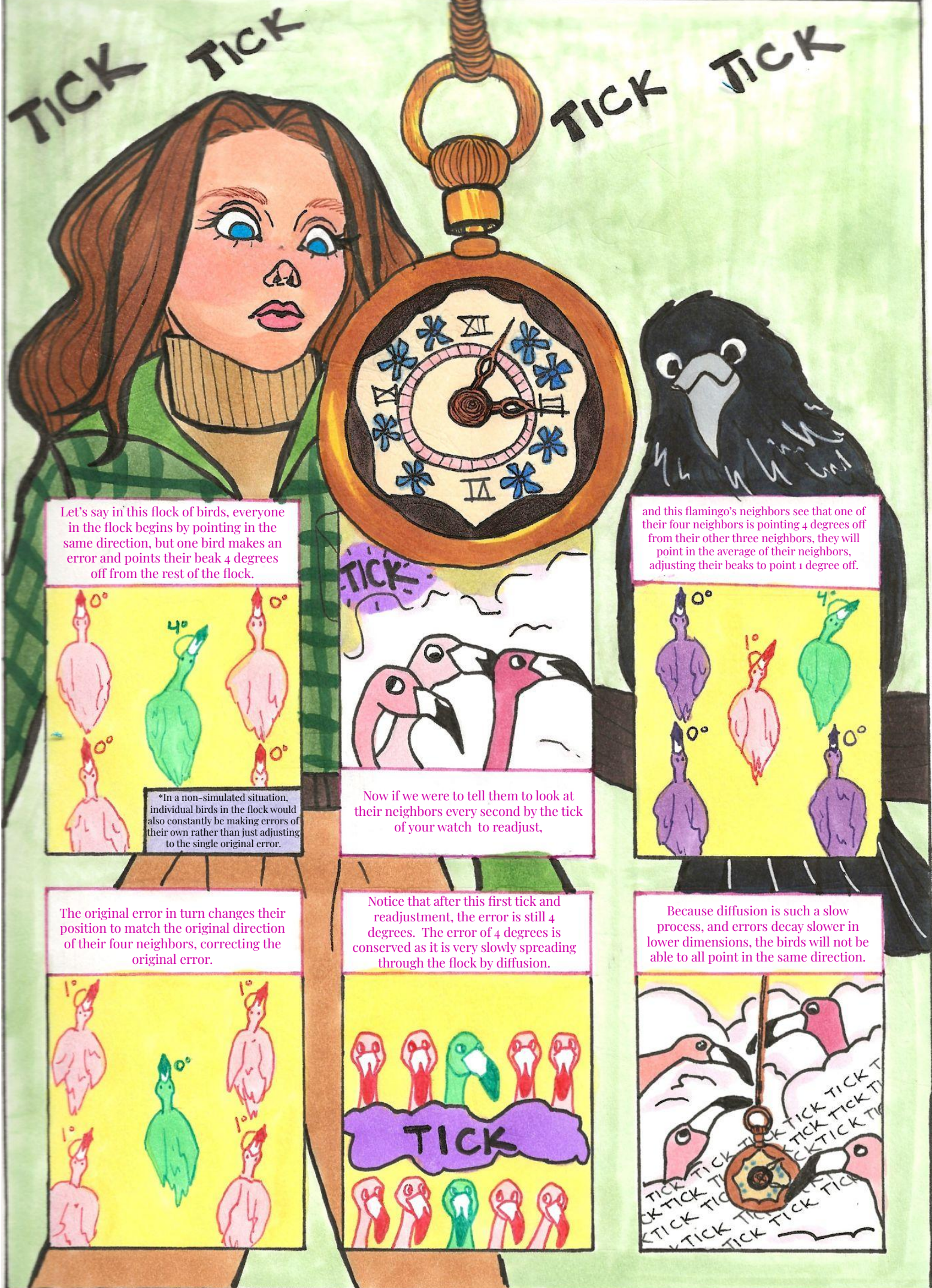
Excellent question! We...



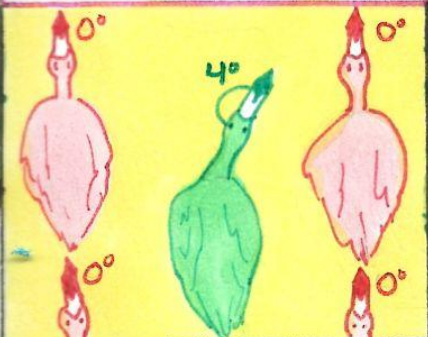
Is it **MAGIC**?







Let's say in this flock of birds, everyone in the flock begins by pointing in the same direction, but one bird makes an error and points their beak 4 degrees off from the rest of the flock.

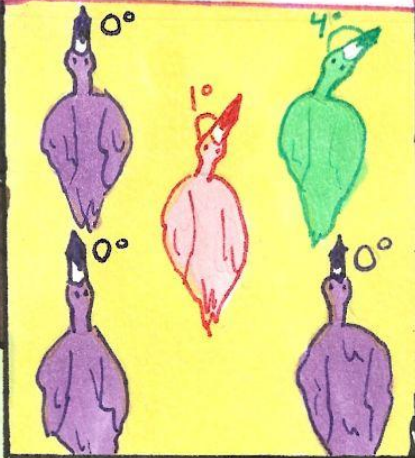


*In a non-simulated situation, individual birds in the flock would also constantly be making errors of their own rather than just adjusting to the single original error.

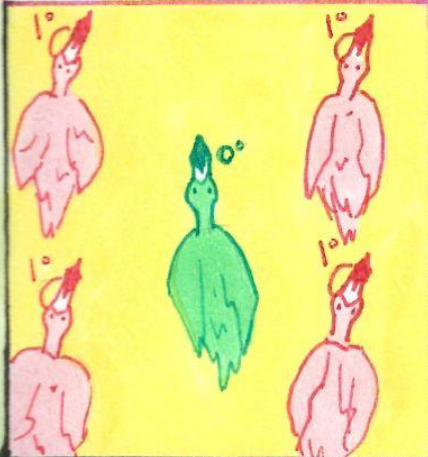


Now if we were to tell them to look at their neighbors every second by the tick of your watch to readjust,

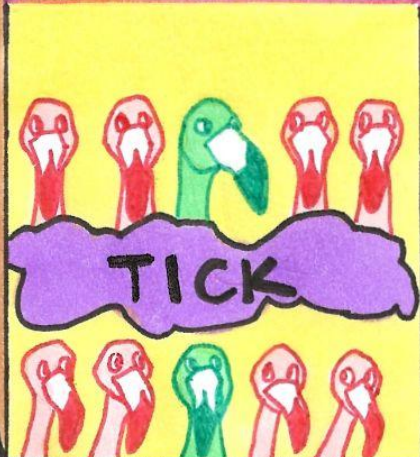
and this flamingo's neighbors see that one of their four neighbors is pointing 4 degrees off from their other three neighbors, they will point in the average of their neighbors, adjusting their beaks to point 1 degree off.



The original error in turn changes their position to match the original direction of their four neighbors, correcting the original error.



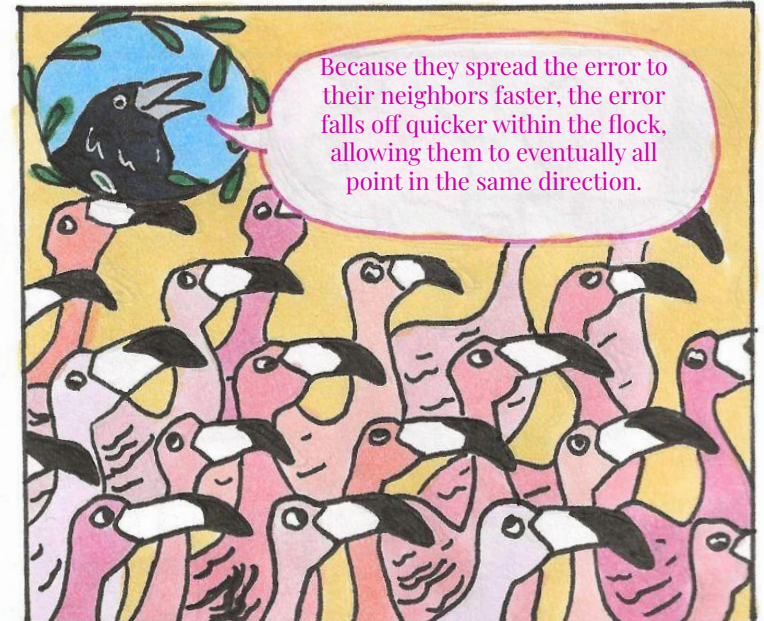
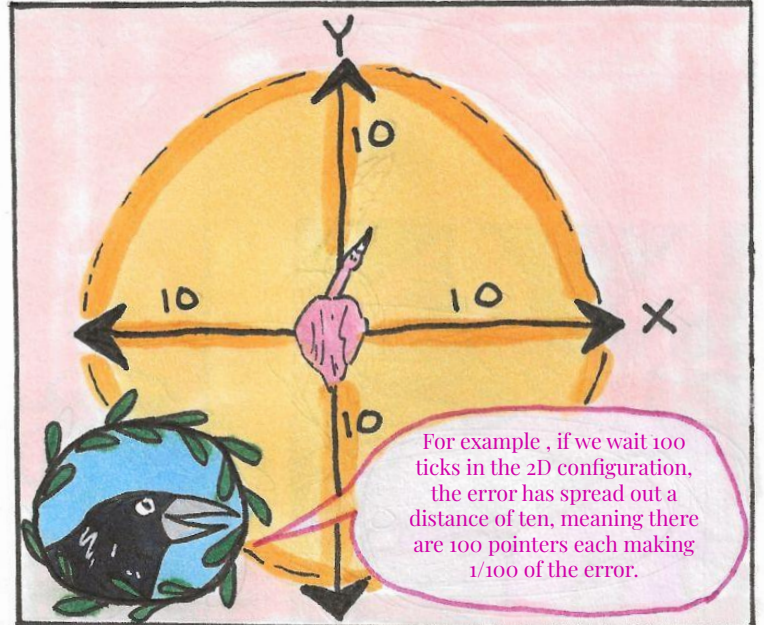
Notice that after this first tick and readjustment, the error is still 4 degrees. The error of 4 degrees is conserved as it is very slowly spreading through the flock by diffusion.

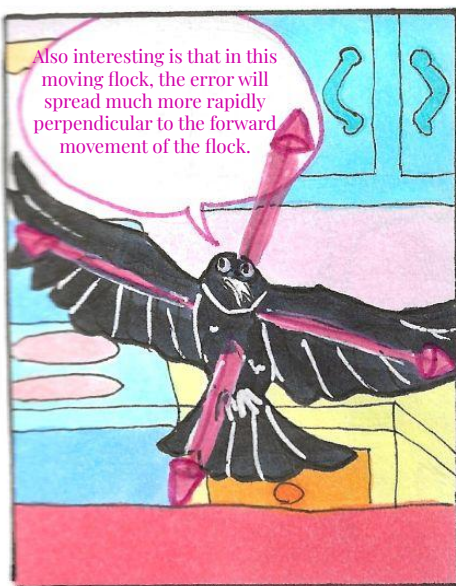
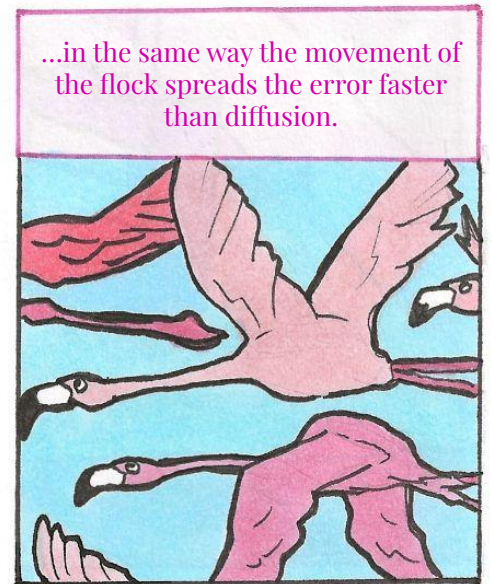
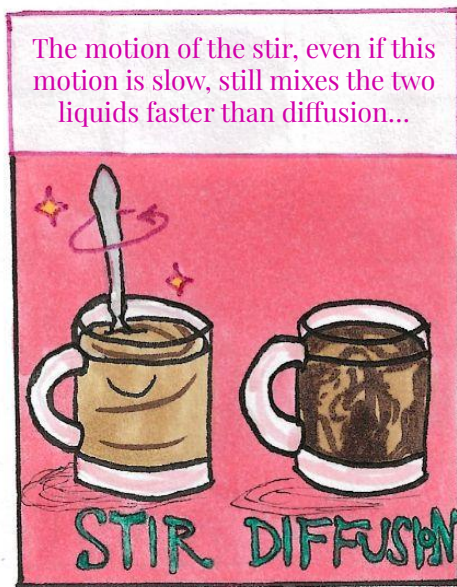
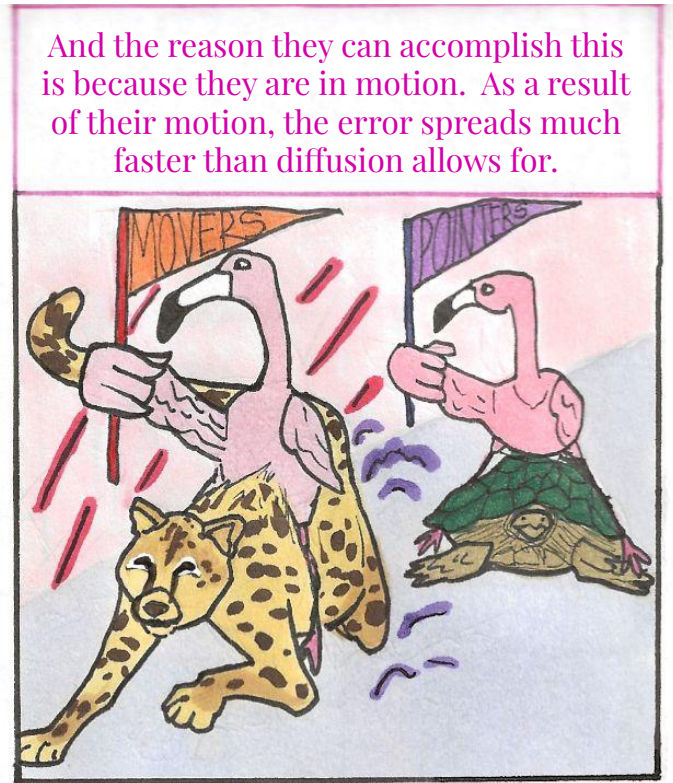
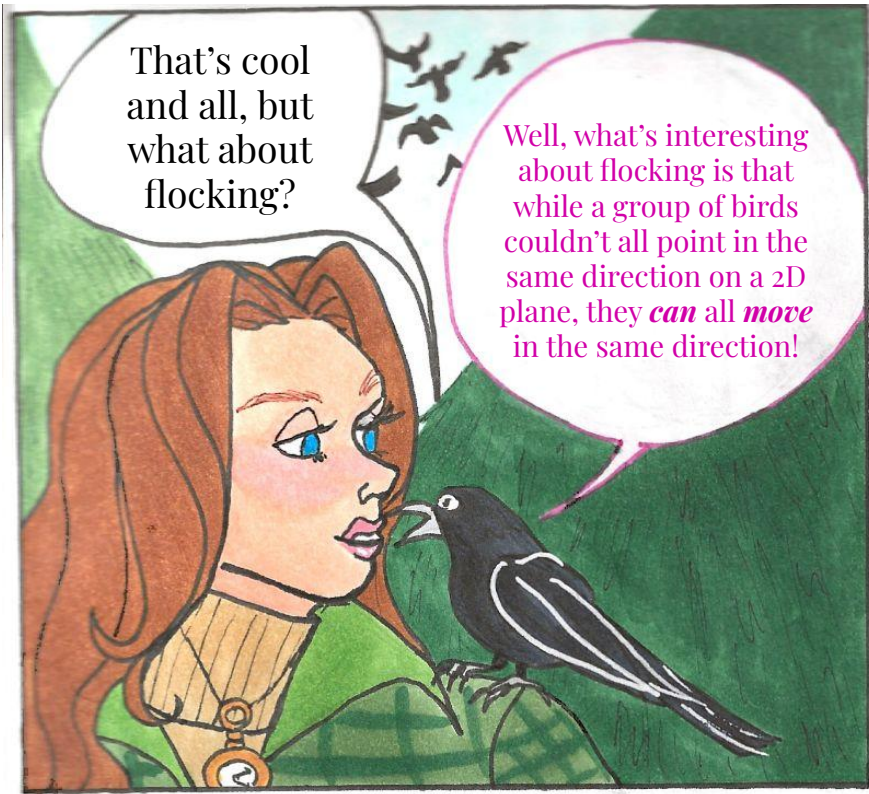


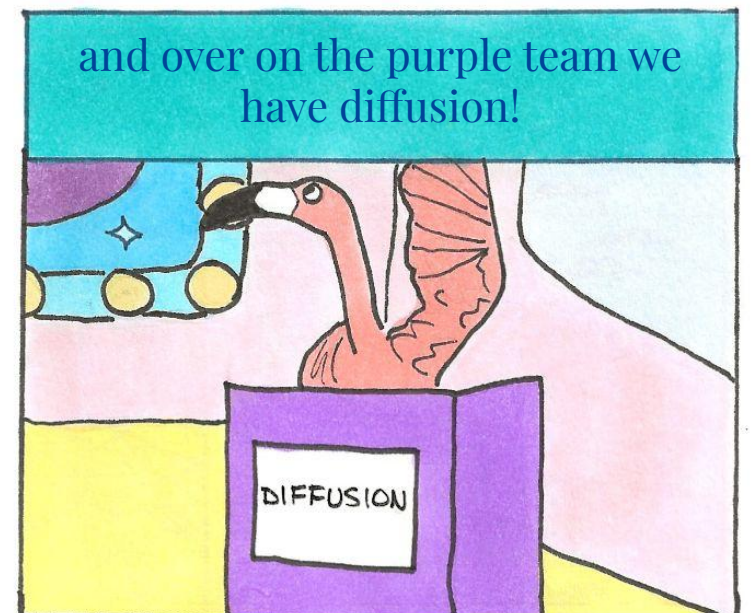
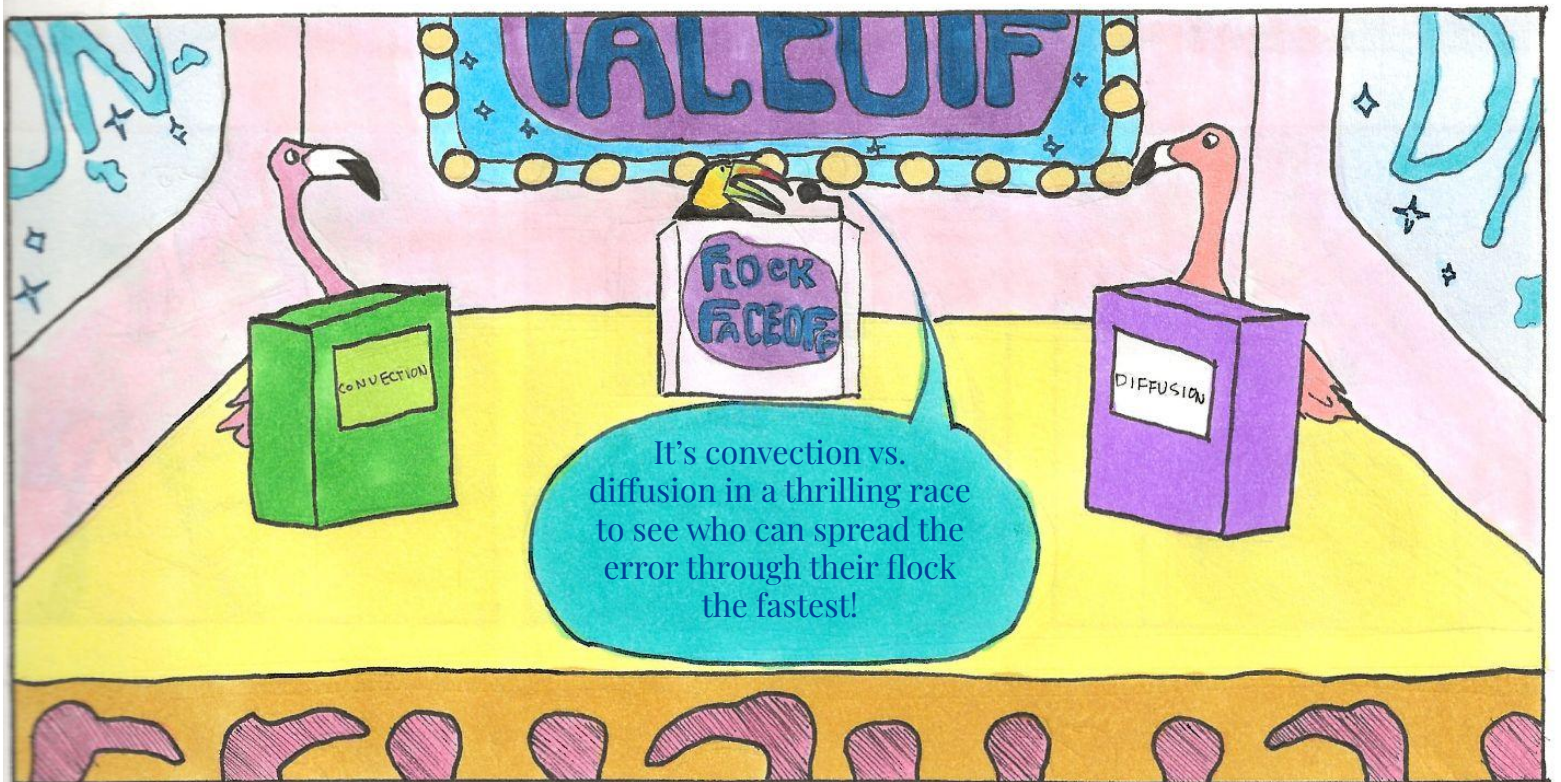
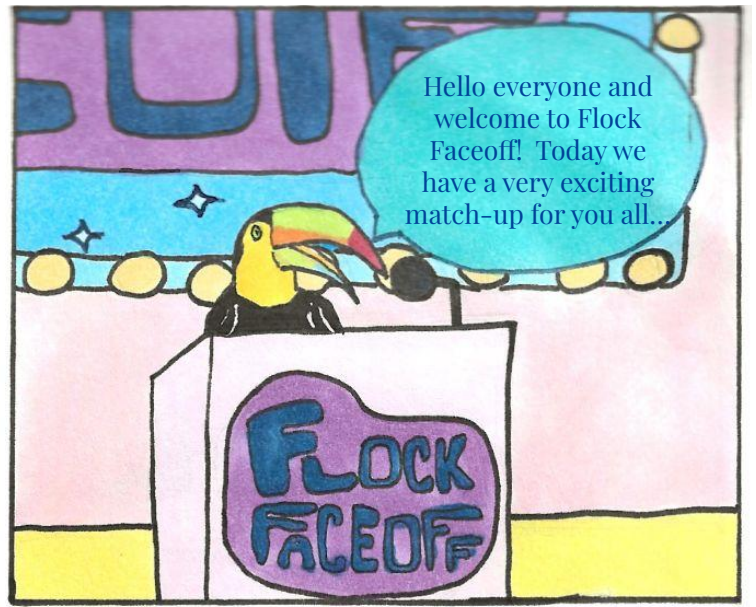
Because diffusion is such a slow process, and errors decay slower in lower dimensions, the birds will not be able to all point in the same direction.

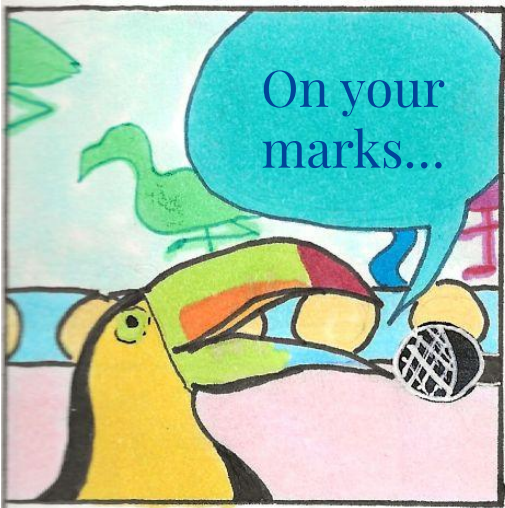
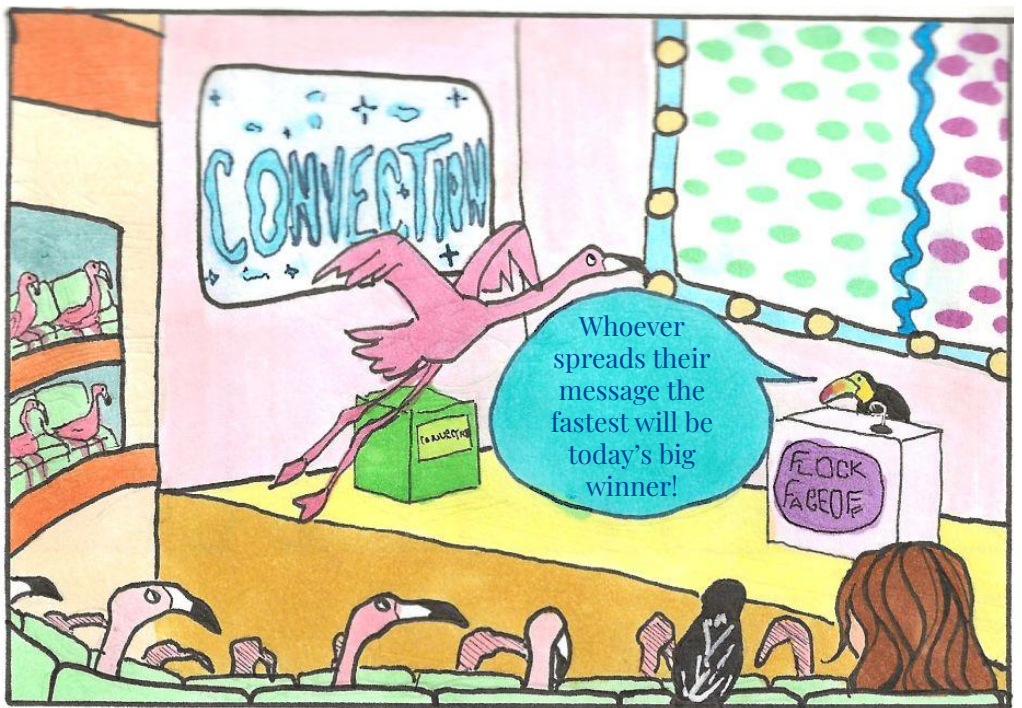
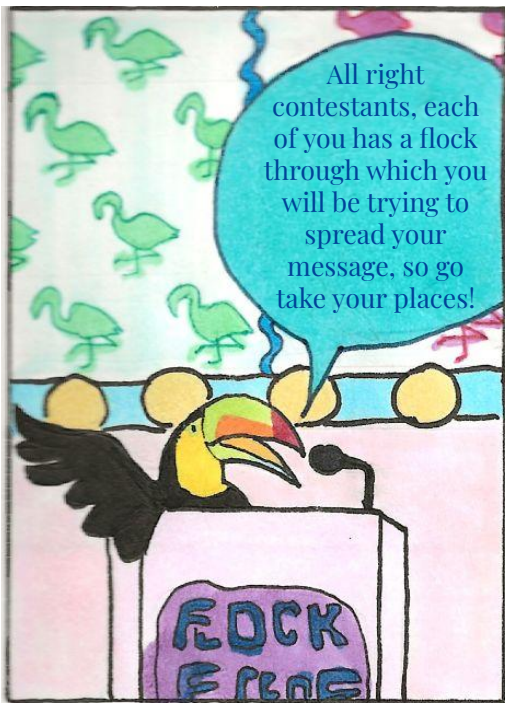


Now, if I were to recreate the previous experiment, same birds, same ticking clock, but instead the flock of birds were situated in the 3D environment of a tree... they would all be able to point their beaks in the same direction!

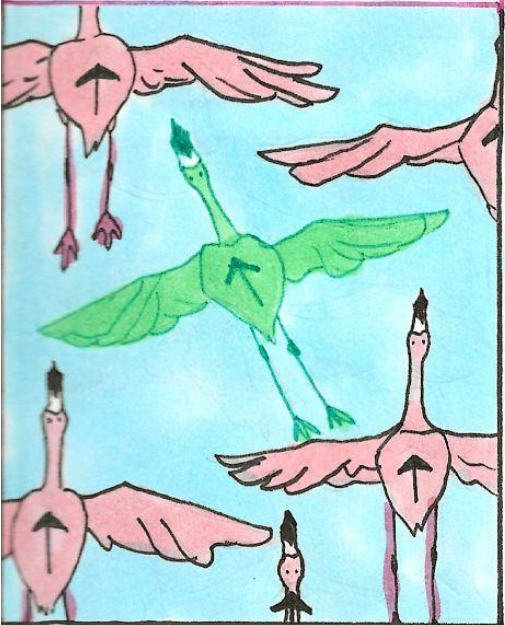








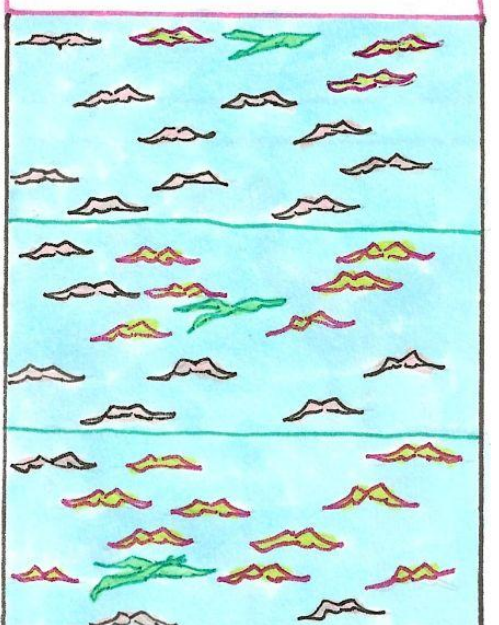
The green bird is moving slightly off from the forward motion of their flock,



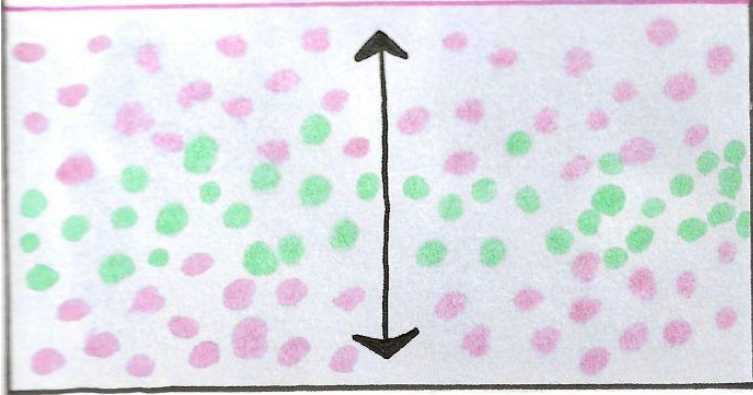
so they are constantly drifting past other birds,



thus spreading the error to those that they pass.



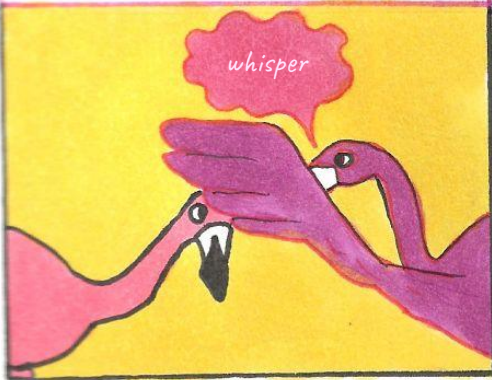
As a result, the cloud of information being spread grows perpendicular to the forward motion of the flock because the green bird is able to spread the error convectively to those on their right and left.



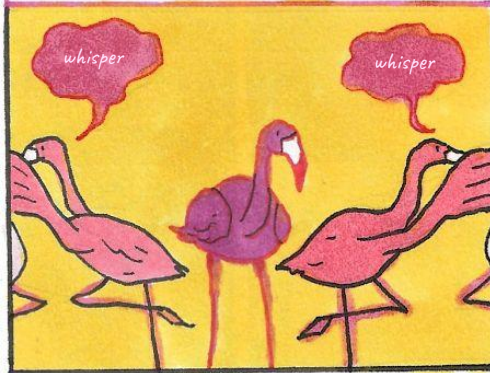
The green bird's forward and backwards motion is still about the same as everyone else's, so the message still spreads diffusively in those directions.



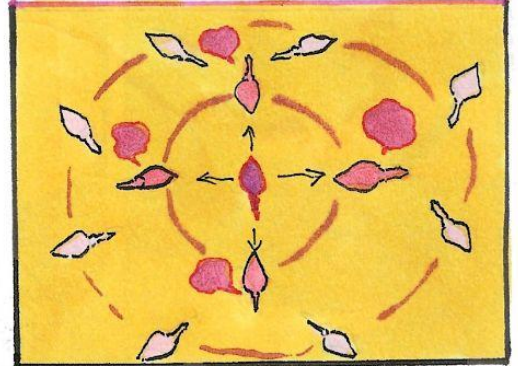
The purple bird, however, is left spreading the message by word of mouth.



They can share the message to their neighbors,



but since they are not passing other flock members, they are **only** able to share with their neighbors, so the spread of information is much slower.



Think of Paul Revere. He would have not been able to spread *his* message as quickly if he were spreading it by word of mouth rather than riding through town, right?



