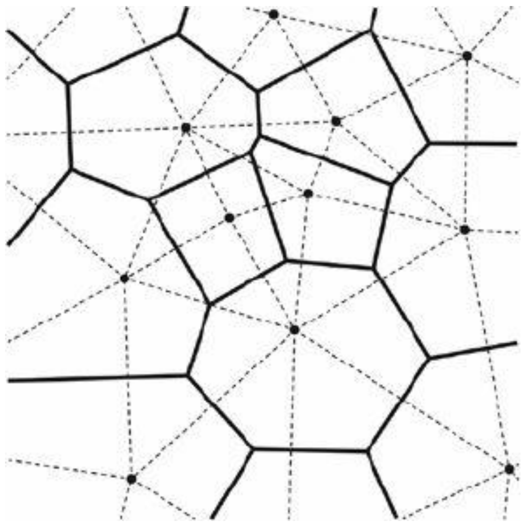
Following the Herd

Birds, fish, and many mammals, like antelope and buffalo, group together into "swarms" that we call flocks, shoals, or herds. Their self-organizing behavior is often uncannily precise. When huge flocks of starlings fly through the air at the end of the day we might ask how they organize themselves to create a group that seems to move as one great coordinated body. Sometimes the movement follows simple defensive rules. If you are in a shoal of fish that might be under attack from predatory sharks then it is a good idea to keep away from the periphery. This produces a continuous churning of the shoal as members try to avoid being on the vulnerable edge. Conversely, some flying insects want to be on the outside of the swarm in order to be the first to attract the attention of potential mates. Some birds and fish stay near their immediate neighbors; they move away from those who get too close, but are attracted back to the group if they stray too far from it. Others only pay attention to their seven or eight nearest neighbors and align themselves with their speed and direction of movement.

All these strategies can lead to large-scale orderly swarms and the impressive patterns of birds and fish that we see in Nature. Other more complicated strategies can be imagined for human interactions. For example, someone might move around at a large cocktail party aiming to get as close to one person as they can while getting as far away as possible from someone else. If lots of people are doing that at the same party then the result is not easy to predict!

Another, mathematically interesting strategy is that adopted by a herd of vulnerable wildebeest or antelope when a single predator, like a lion, appears on their horizon. Each animal will move so as to ensure that there is at least one other animal along the line of sight between itself and the predator. When the predator is stationary this will result in the herd adopting a particular pattern that mathematicians call a "Voronoi tessellation." To construct it for a collection of points just draw straight lines between all the pairs of points and then construct new straight lines at right angles to them passing through their midpoints. Continue each of these new bisecting lines until they encounter another one, and then stop them. The result is a network of Voronoi polygons.[1] Each has one point at its center and the polygon around it maps out the part of space that is closer to it than to any other point.



This polygon defines a region of danger for the animal at its central point. If this animal's region of danger is entered by a predator, it will find itself the nearest potential prey. Each animal wants to make its polygon of danger as small as possible and to be as far as possible from the predator. This type of collective behavior is called that of the "selfish herd" because each member acts in its own self-interest. Predators like lions move around quickly, making the changing Voronoi polygons difficult to determine in real situations, even though a computer program can easily come up with predictions. You need a slow-moving predator–prey scenario.

Interesting studies have been done by filming the dynamics of large groups of fiddler crabs when they feel threatened.[2] Crabs are slow enough and small enough in number to enable careful studies of their movement before and after a predator threatens. They appear to follow the selfish-herd behavior very closely, forming a pattern with large Voronoi polygons around each of them when the threat first arises. Next, they enter a panic mode in which they become much closer to each other with a smaller Voronoi pattern, each trying to keep someone else between itself and the predator. The threatened crabs do not necessarily scuttle away from the predator. They tend to move toward the center of their group (or “cast”) so as to put others between them and the predator:

Sometimes this means actually running toward the predator. Remember, an individual’s level of risk is proportional to the area of the Voronoi polygon defining its region of danger. These areas all become smaller when the crabs panic and get closer together and everyone feels safer. Evolutionary biologists teach us that those crabs that are less inclined to follow this behavior will be more likely to get picked off by a predatory sea bird, while those that instinctively respond quickest will be most likely to survive to produce offspring that share that trait.