## Project for week 2 and 3:

# Comparing the effect of spatial structure in the prisoner's dilemma and hawk-dove game

## Background

The prisoner's dilemma (PD) is probably the most famous two-player game known from game theory. In a single-round PD with only pure strategies ("cooperate" and "defect"), defection is the only evolutionarily stable strategy (ESS), yet in reality cooperation is common among humans and many other animals. One solution to this paradox lies in the realization that populations are often spatially structured, causing each individual to mainly interact with its neighbours. If neighbours are more likely to share the same strategy (e.g., because of limited dispersal), clusters of cooperators may be able to persist despite the presence of defectors in the population. However, not all social conflicts are adequately described by a PD. Whereas in a PD cooperation is only beneficial if the other player also cooperates, in some situations the benefit of cooperation may still outweigh the cost even if the other player does not cooperate. Such situations can be described by the hawk-dove (HD) game (also called "snowdrift" or "chicken").

To illustrate the difference between the PD and HD games, here is the general notation of a two-player game:

| | **C** | **D** |
|---|---|---|
| **C** | R | S |
| **D** | T | P |

(R: Reward; T: Temptation; S: Sucker's reward; P: Punishment)

In a prisoner's dilemma, the relationship between payoffs is $T > R > P > S$, whereas in a HD game the positions of P and S are reversed: $T > R > S > P$.

# Programming tasks

## Task 1

Change the code of Friday's NetLogo exercise (PD_spatial.nlogo) so that either a PD or a HD game can be simulated and each game can either be spatial (only neighbours play against each other) or non-spatial (any individual can play against any other). One possible way of implementing the two games is to use the following payoff matrices:

**PD**

| | **C** | **D** |
|---|---|---|
| **C** | b-c | -c |
| **D** | b | 0 |

**HD**

| | **C** | **D** |
|---|---|---|
| **C** | b-c/2 | b-c |
| **D** | b | 0 |

Here, b and c are the benefit and cost of cooperation, respectively. To keep things simple, you can keep the value of b at 1 in all simulations, and only vary c ($0 < c < 1$). For comparability with the paper by Hauert and Doebeli (2004, *Nature*) the baseline fitness should be set to zero. When a HD game is played, the denominator of `change-prob` in the procedure `reproduce` needs to be set to b (instead of b+c for a PD game).

Using the BehaviorSpace in NetLogo, perform one or more experiments to compare the effect of spatial structure on the persistence of cooperators in the PD and HD games. The paper of Hauert and Doebeli contains examples of how to test this, but you are free to perform completely different experiments as long as they are relevant for the question.

## Task 2

Change the size of the neighbourhood in the spatial PD and HD games. In addition to the neighbourhood of eight patches (i.e., a 3x3 square with the focal patch at the centre), repeat the experiments of task 1 with a neighbourhood of four patches around the focal patch (excluding the corner cells of the 3x3 square) and a neighbourhood with a radius of <=3 patches.

## Task 3

Implement mixed strategies in the HD game. Instead of a fixed (pure) strategy (either “C” or “D”), each player has a certain probability *p* to play “C” in the next game. This probability is heritable and subject to a mutation rate. In other words, each individual inherits its parent's value of *p*, but this value is slightly changed with a low probability. Compare the effect of spatial structure in the mixed-strategy HD game with that in the pure-strategy game.

# Report and Grading

## Report writing

Regardless of whether you completed all three tasks or only parts of them, write a report in the format of a scientific paper about your findings (see material on ILIAS for further instructions on paper writing).

## Grading

Points for the grading will be awarded

- 1/3 for fulfilling the three tasks above, each task will be equally weighted, i.e. the completion of each task counts 1/9 to the grade
- 1/3 for the quality of the presentation of your method and results (writing, figures, etc.)
- 1/3 for how well you interpret your findings and place them in the context of relevant research and applications.

## Bonus tasks

If after completing all three tasks and writing the report you still have time left, you may tackle one of the following problems:

1. Effect of partner choice in the iterated prisoner's dilemma

   Try to find out if the ability to choose one's partner in the (non-spatial) iterated PD makes the evolution of cooperative behaviour more or less likely. See Enquist & Leimar (1993, *Animal Behavior*) for further information.

2. Effect of costly punishment in the iterated prisoner's dilemma

   Test the effect of being able to punish non-cooperating individuals in the iterated PD. An example of how this can be done is the paper by Boyd & Richardson (1992, *Ethology & Sociobiology*).