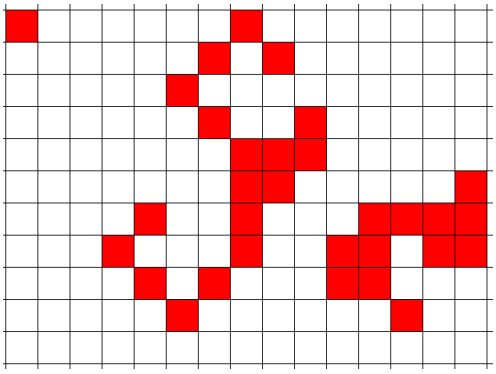
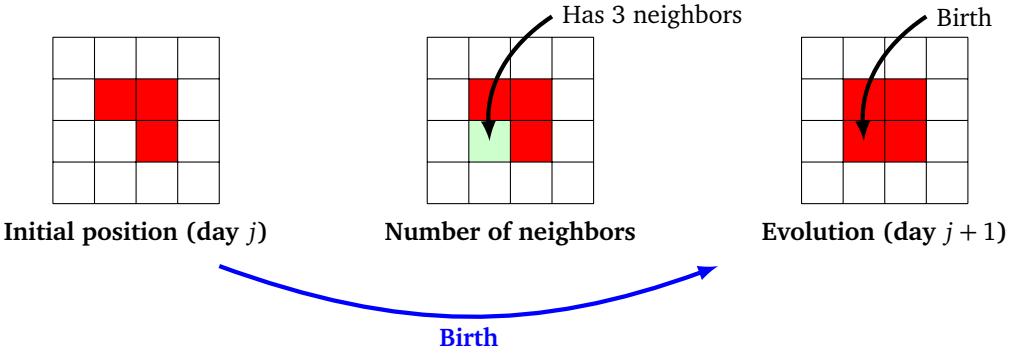
Game of life

The game of life *is a simple model of the evolution of a population of cells that born and die over time. The "game" consists in finding initial configurations that give interesting evolution: some groups of cells disappear, others stabilize, some move...*

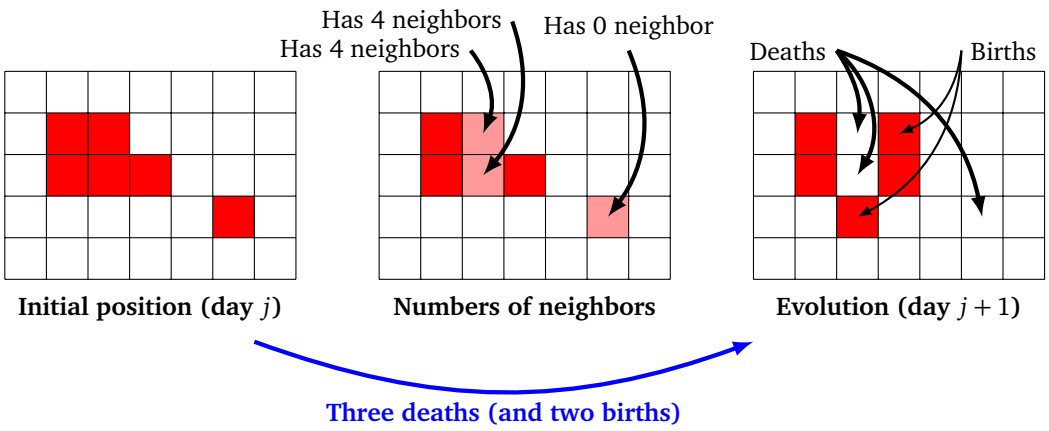


Lesson 1 (Rules of the game of life)**.**
The *game of life* takes place on a grid. Each square can contain one cell. Starting from an initial configuration, each day cells will be born and others will die depending on the number of its neighbors.
Here are the rules:

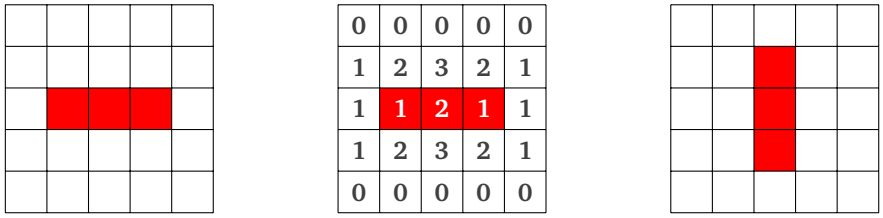
- For an empty square on the day j and having exactly 3 neighboring cells: a cell is born on the day $j+1$.



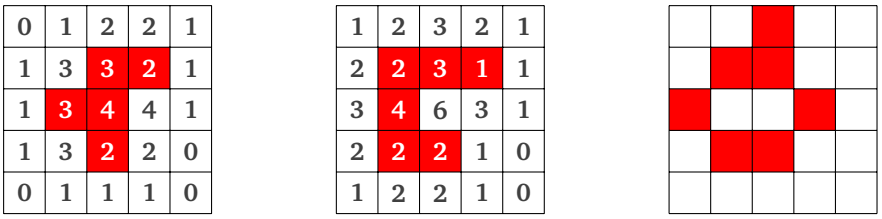
- For a square containing a cell at day j, having either 2 or 3 neighboring cells: then the cell continues to live. In other cases the cell dies (with 0 or 1, it dies of isolation, with more than 4 neighbors, it dies of overpopulation).



Here is a simple example, the “blinker”.



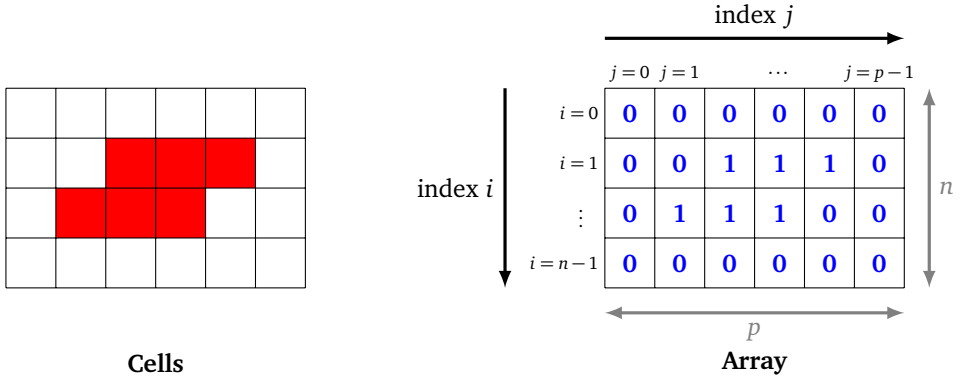
Here is another example (with directly the number of neighbors), the first evolution and the evolution of the evolution.



Activity 1 (Display)**.**

Goal: define and display arrays.

We model the living space of the cells by a double entry table, containing integers, 1 to indicate the presence of a cell, 0 otherwise. Here is an example of the configuration “toad” and its array:



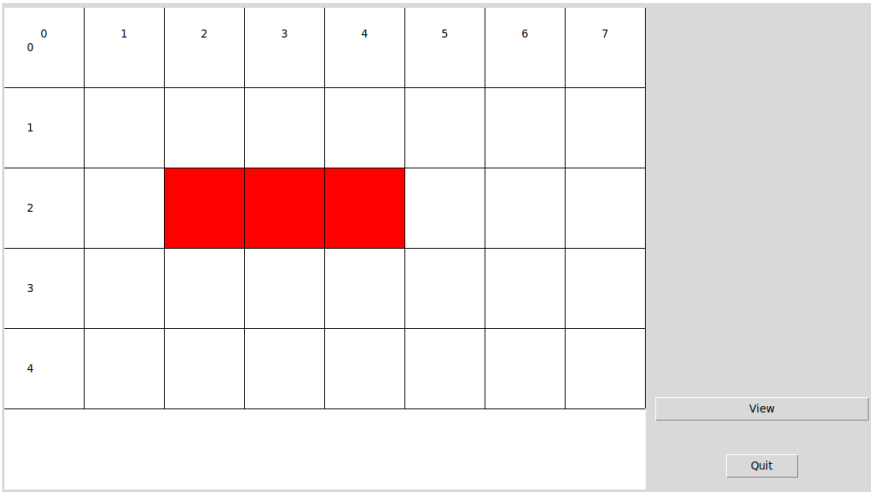
1. • Initialize two variables `n` (the height of the table) and `p` (the width) (for example at 5 and 8).
   • Define a two-dimensional table filled with zeros by the command:
   ```
   array = [[0 for j in range(p)] for i in range(n)]
   ```
   • By instructions of the type `array[i][j] = 1`, fill in the table to define the configuration of the blinker, the toad ...
2. Program the display of a given array on the screen. For example, the blinker is displayed as follows:

```
00000000
00000000
00111000
00000000
00000000
```

Hint. By default the command `print()` passes to the next line on each call (it adds the character `"\n"` which is the end of line character). It can be specified not to do so by the option `print("My text",end="")`.

Activity 2 (Graphic display).

Goal: create a graphical display of a cell configuration.



1. Program the creation of a `tkinter` window (see chapter "Statistics – Data visualization"). Write a function `draw_grid()`, without parameters, that displays a blank grid of coordinates. You will need a constant `scale` (for example `scale = 50`) to transform the indices i and j into graphic coordinates x and y, depending on the relationship: $x = s \times j$ and $y = s \times i$ (s being the scale).
   Bonus. You can also mark the values of the indices i and j at the top and the left to make it easier to read the grid.
2. Build a function `draw_array(array)` that graphically displays the cells from a table.
   Bonus. Add a button "View" and a button "Quit" (see chapter "Statistics – Data visualization").

Activity 3 (Evolution).

Goal: calculate the evolution of a configuration to the next day.

1. Program a function `number_neighbors(i,j,array)` that calculates the number of living neigh-

boring cells to the cell (i, j).
Hints.

- There is a maximum of 8 for possible neighbors. The easiest way is to test them one by one!
- For the counting, it is necessary to be very careful with the cells that are placed near one edge (and have less than 8 neighbors).

2. Program a function `evolution(array)` that receives a table at the input and returns a new array corresponding to the situation on the next day, according to the rules of the game of life described at the beginning. For example, if the table on the left corresponds to the input, then the output corresponds to the table on the right:

00000000		00000000
00000000		00010000
00111000	evolves in	00010000
00000000		00010000
00000000		00000000

Hints. To define a new table, use the command:

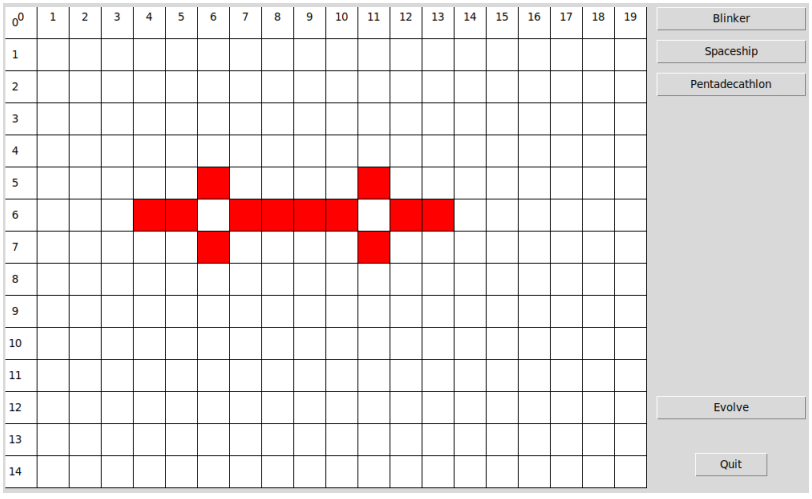
```
new_array = [[0 for j in range(p)] for i in range(n)]
```

and then modify the table as desired.

Activity 4 (Iterations).

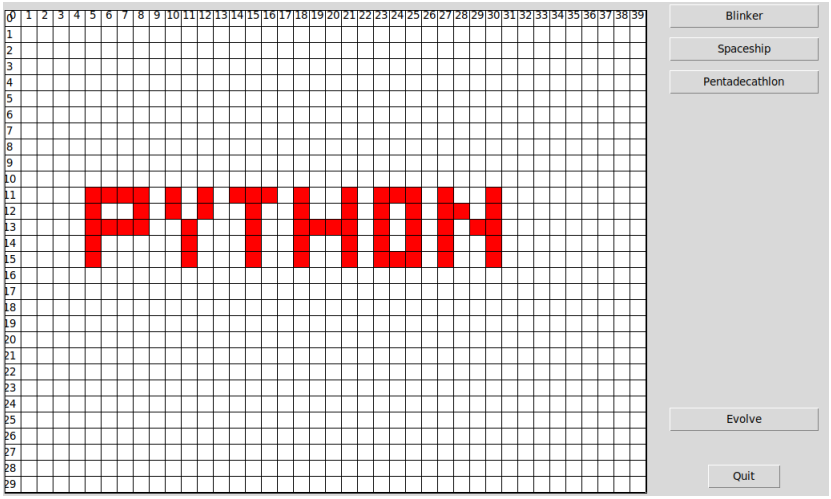
Goal: end the graphic program so that the user can define configurations and make them evolve with a simple click.

1. Improve the graphic window to make the user's life easier:
   - A button "evolve" which displays a new evolution with each click.
   - Buttons to display predefined configurations (on the screenshot below is the configuration "pentadecathlon").



2. Perfect your program so that the user can draw the configuration he wants with mouse clicks. Clicking on an extinguished cell turns it on, clicking on an living cell turns it off. You can break this work down into three functions:
   - `on_off(i,j)`, which switches the cell (i, j) ;
   - `xy_to_ij(x,y)` that converts graphic coordinates (x, y) into integers coordinates (i, j) (use variable `scale` and the integer division).

- `action_click_mouse(event)` to retrieve the coordinates (x, y) with a mouse click (see course below) and switch the clicked box.



Lesson 2 (Mouse click).
Here is a small program that displays a graphic window. Each time the user clicks (with the left mouse button) the program displays a small square (on the window) and displays "Click at $x = \ldots$, $y = \ldots$" (on the console).

```
from tkinter import *

# Window
root = Tk()
canvas = Canvas(root, width=800, height=600, background="white")
canvas.pack(side=LEFT, padx=5, pady=5)

# Catch mouse click
def action_mouse_click(event):
    canvas.focus_set()
    x = event.x
    y = event.y
    canvas.create_rectangle(x,y,x+10,y+10,fill="red")
    print("Click at x =",x,", y =",y)
    return

# Association click/action
canvas.bind("<Button-1>", action_mouse_click)

# Launch
root.mainloop()
```

Here are some explanations:

- The creation of the window is usual. The program ends with the launch by the command `mainloop()`.
- The first key point is to associate a mouse click to an action, that's what the line does:

```
canvas.bind("<Button-1>", action_mouse_click)
```

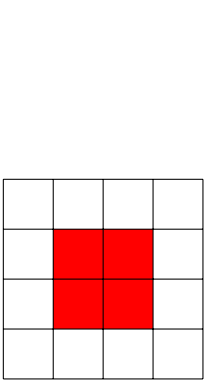
Each time the left mouse button is clicked, `Python` executes the function `action_mouse_click`. (Note that there are no brackets for the call to the function.)

- Second key point: the `action_mouse_click` function retrieves the click coordinates and then does two things here: it displays a small rectangle at the click location and displays the (x, y) coordinates in the terminal window.
- The coordinates x and y are expressed in pixels; $(0, 0)$ refers to the upper left corner of the window (the area delimited by `canvas`).

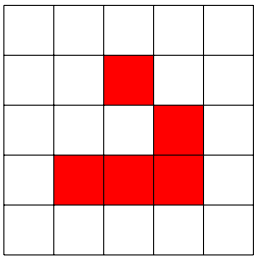
Here are some ideas to go further:

- Make sure that the grid automatically adapts to the screen width, i.e. calculate `scale` based on `n` and `p`.
- Add an intermediate step before evolving: color in green a cell that will be born and in black a cell that will die. For this purpose the elements of `array` can take values other than 0 and 1.

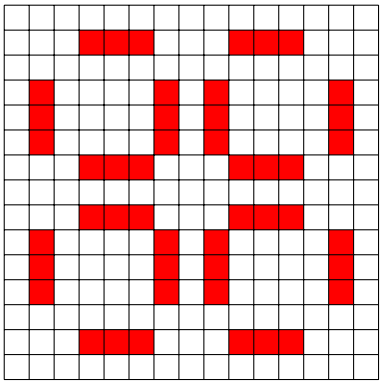
Here are some interesting configurations.



Square



Spaceship



Pulsar

You will find many more on the Internet but above all have fun discovering new ones!
In particular, find configurations:

- that remain fixed over time;
- which evolve, then become fixed;
- which are periodic (the same configurations come back in loops) with a period of 2, 3 or more;
- who travel;
- that propel cells;
- whose population is increasing indefinitely!