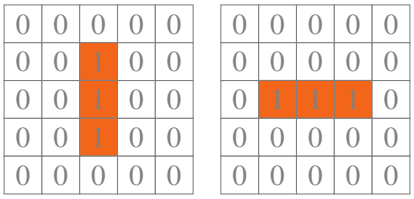
4. 2D Arrays

4.1 The Game of Life

The Game of Life was developed by British mathematician John Horton Conway. In Life, a board represents the world and each cell a single location. A cell may be either empty or inhabited. The game has three simple rules, which relate to the cell's eight nearest neigbours :

1. **Survival** An inhabited cell remains inhabited if exactly 2 or 3 of its neighbouring cells are inhabited.
2. **Death** An inhabited cell becomes uninhabited if fewer than 2, or more than 3 of its neighbours are inhabited.
3. **Birth** An uninhabited cell becomes inhabited if exactly 3 of its neighbours are inhabited.

The next board is derived solely from the current one. The current board remains unchanged while computing the next board. In the simple case shown here, the boards alternate infinitely between these two states.



The 1.06 format

A general purpose way of encoding the input board is called the Life 1.06 format :

www `http://conwaylife.com/wiki/Life_1.06`

This format has comments indicated by a hash in the first column, and the first line is always:

```
#Life 1.06
```

Every line specifies an x and y coordinate of a live cell; such files can be quite long. The coordinates specified are relative to the middle of the board, so 01 means the middle row, one cell to the right of the centre.

There are hundreds of interesting patterns stored like this on the above site.

Exercise 4.1 Write a program which is run using the `argc` and `argv` parameters to `main`. The usage is as follows :

```
% life file1.lif 10
```

where `file1.lif` is a file specifying the inital state of the board, and `10` specifys that ten iterations are required.

Display the output to screen every iteration using plain text, you may assume that the board is 150 cells wide and 90 cells tall. ■

Alternative Rules for The Game of Life

The rules for life could also be phrased in a different manner, that is, give birth if there are two neighbours around an empty cell (B2) and allow an 'alive' cell to survive only if surrounded by 2 or 3 cells (S23). Other rules which are *life-like* exist, for instance *34 Life* (B34/S34), *Life Without Death* (B3/S012345678) and HighLife (B36/S23).

`http://en.wikipedia.org/wiki/Life-like_cellular_automaton`

Exercise 4.2 Write a program that allows the user to input life-like rules e.g. :

```
life B34/S34 lifeboard.lif
```

or

```
life B2/S lifeboard.lif
```

and display generations of boards, beginning with the inital board in the input file. ■

4.2 Life Wars

Inspired by the classic game, *Core Wars*

`http://en.wikipedia.org/wiki/Core_War`

here we look at a two player version of Conway's Game of Life.

In our game, each of two 'players' submit a Life 1.06 file and cells from these inserted into an empty board. The cells are coded based on which player created them (say '+' and '@'). The game is then run, and the player having most cells left after a fixed number of iterations, over many games, is deemed the winner.

The rules are :

1. The board is 150 cells wide, and 90 cells tall.
2. The board is toroidal; that is, it wraps around from the left edge to the right, and the top to the bottom.
3. Each player can submit a Life 1.06 file that is maximum of 100 lines long, **including** the header line.
4. Since each of the Life 1.06 files describe absolute positions for cells, each player is assigned a random origin for their cells. If there is any collision when attempting to add the cells initially (i.e. both players happen to specify a cell in the same square), then new origins are chosen randomly and the process begun from scratch.

5. The ‘standard’ B3/S23 rules are used.
6. The colour of cells is never taken into account (i.e. cells are still either ‘alive’ or ‘dead’). The sole exception to this is that when a cell is born, it takes the colour of the majority its neighbours.
7. There are 5000 generations played every game.
8. A running count of how many cells each player has left at the end of each game is kept. The board is cleared and the next game randomly restarted.
9. There are 50 games run in total.
10. The player with the highest number of cells over all 50 games is the winner.

It’s easy to extend these rules, of course, to allow for three or more players, but it’s unclear for three players what would happen in the majority vote if there was a draw (i.e. a new cell is born based on three cells around it, one belonging to each player. Other rule variants are also possible (e.g. *Highlife* (B36/S23), but once again, the birth rule for 3 or 6 neighbours would cause majority voting issues for two and three players.

Exercise 4.3 Write a program that accepts two Life 1.06 files and reports which of them is the winner. The first few games might look like:

```
% /lifewars blinkerpuffer2.lif bigglider.lif

        0    50    12  Player 1
        1   370   141  Player 1
        2   437   281  Player 1
        3   450   602  Player 2
        4   540   623  Player 2
        5   991   629  Player 1
        6  1063   674  Player 1
        7  1211   707  Player 1
        8  1263   735  Player 1
        9  1358   758  Player 1
  .
  .
  .
    Player 1 wins by 7857 cells to 2373 cells
```

■

4.3 Wireworld

Wireworld is a cellular automaton due to Brian Silverman, formed from a 2D grid of cells, designed to simulate digital electronics. Each cell can be in one of four states, either ‘empty’, ‘electron head’, ‘electron tail’ or ‘copper’ (or ‘conductor’).

The next generation of the cells follows the rules, where n is the number of electron heads found in the 8-surrounding cells:

- empty $->$ empty
- electron head $->$ electron tail
- electron tail $->$ copper
- copper $->$ electron head if $n == 1$ or $n == 2$
- copper $->$ copper otherwise

See also:

www https://en.wikipedia.org/wiki/Wireworld

www http://www.heise.ws/fourticklogic.html

Exercise 4.4 Write a program which is run using the `argc` and `argv` parameters to `main`. The usage is as follows :

```
$ wireworld wirefile.txt
```

where `wirefile.txt` is a file specifying the initial state of the board. This file codes empty cells as ' ', heads as 'H', tails as 't' and copper as 'c'. Display the board for 1000 generations using plain text. You may assume that the grid is always 40 cells by 40

■

Make sure all your code is fully ANSI compliant, and fully follows the house-style guidelines. Show that your code has been developed using short, well-tested functions via the use of `assert()` testing.

4.4 ncurses

C has no inherent functionality to allow printing in colour etc. Therefore, a programming library know a `ncurses` was created in 1993 to allow terminals to interpret certain control-codes as colours and other effects.

The library itself is somewhat complex, allowing keyboard and mouse events to be captured and a whole range of simple graphics functionality. On the web page is my 'wrapper' for the library, along with a program demonstrating its use. This will only work in unix-style terminals. Note that after you begin ncurses mode (using `Neill_NCURS_Init()`) that you can't print to stdout or stderr, until you switch it off (using `Neill_NCURS_Done()`).

To compile the code you'll have to use both my code `neillncurses.c` and also link in the ncurses library. A typical compile might look like

```
gcc yourcode.c neillncurses.c -Wall -Wfloat-equal -Wextra -O2
    -pedantic -ansi -lncurses -lm
```

If you're running a virtual box you may also need to install the `ncurses` developer files, including `ncurses.h`, using:

```
sudo apt install libncurses-dev
```

Some terminals do not support ncurses, so make sure you are using an 'xterm' or equaivalent.

Exercise 4.5 Adapt the wireworld code in Exercise 4.4 so that the output is displayed using this library, with tails being red, heads being blue, copper being yellow and background being black. The main loop will update the board, display it, and repeat until a quit event occurs (e.g. a mouse click or the ESC key is pressed).

■

Exercise 4.6 Adapt the life code in Exercise 4.1 so that the output is displayed using this library, with sensible choices made for cell colours. The main loop will update the board,

display it, and repeat until a quit event occurs (e.g. a mouse click or the ESC key is pressed).