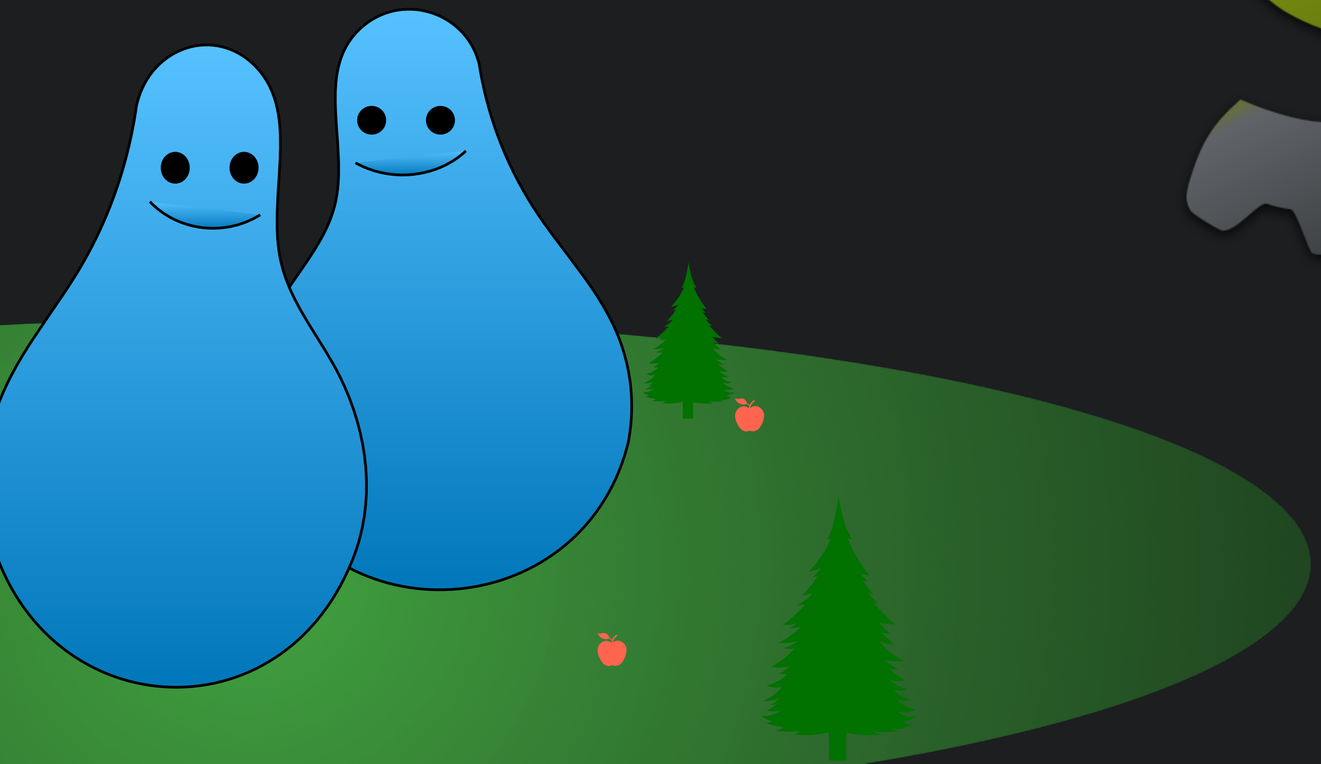
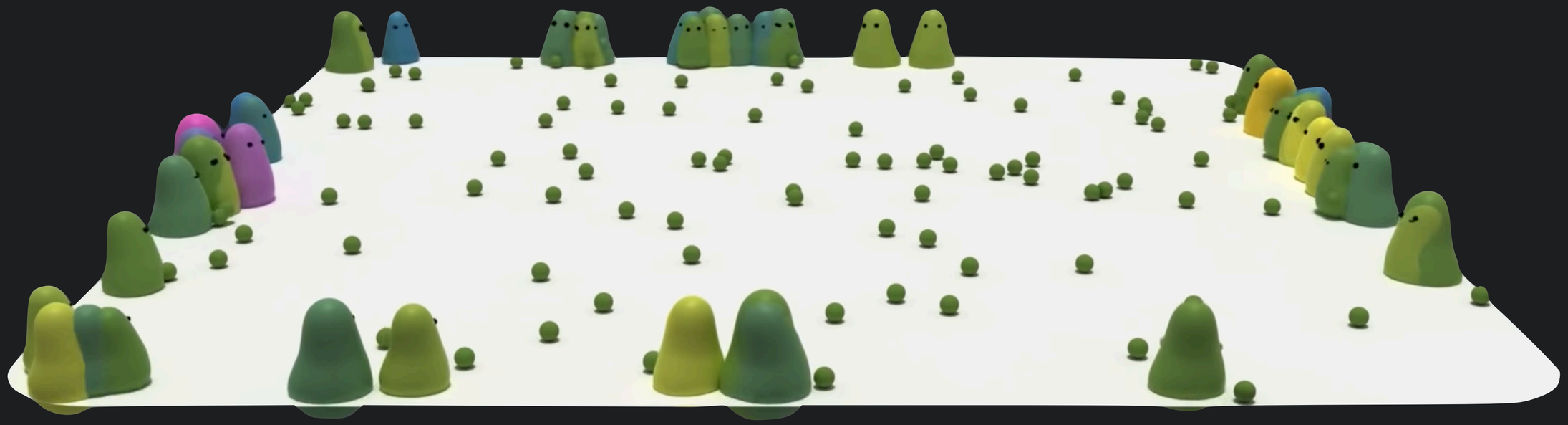
A Biological Simulation in *Python* using SimPy



Stefano Mangini, Unipv, July 2020

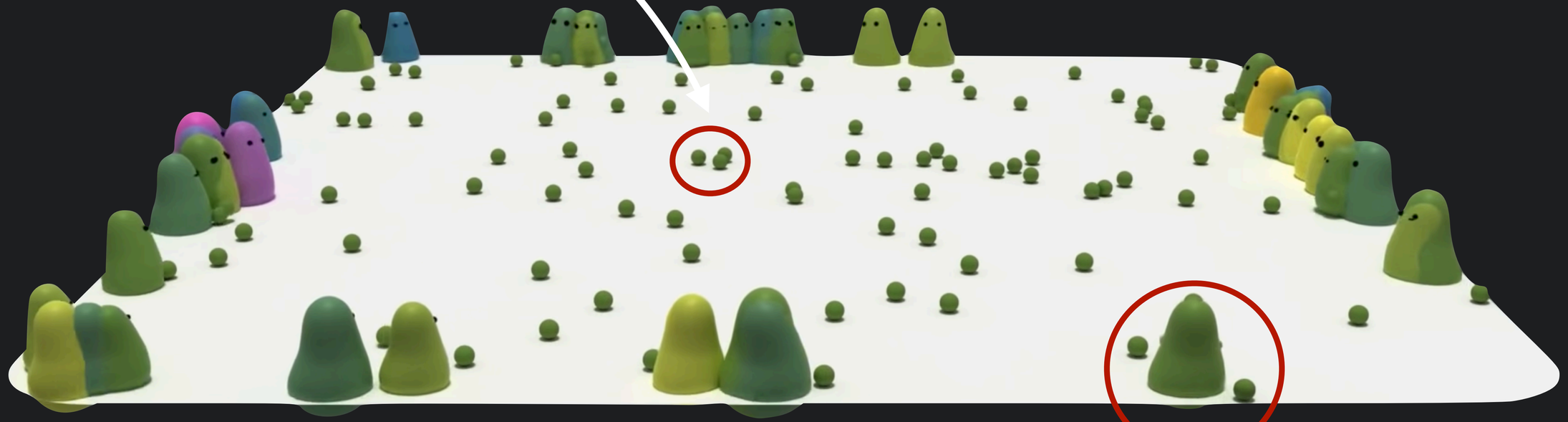
PRIMER



Link Youtube: Primer

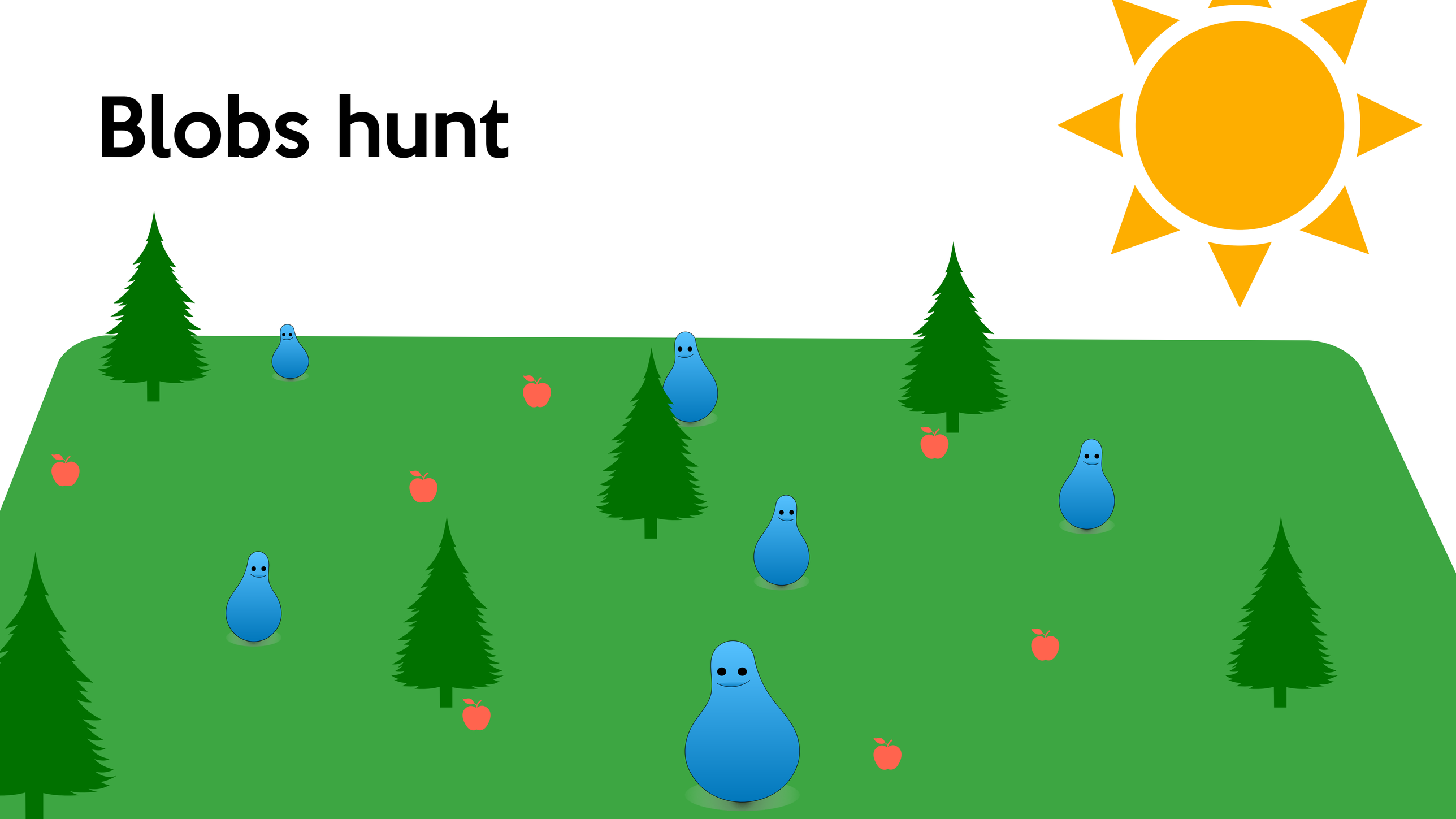
Forest

Food



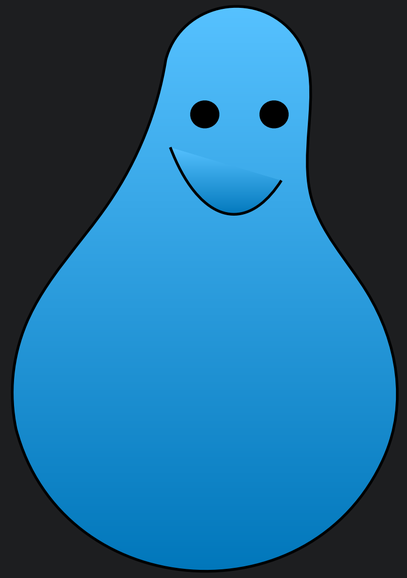
Blob

Blobs hunt

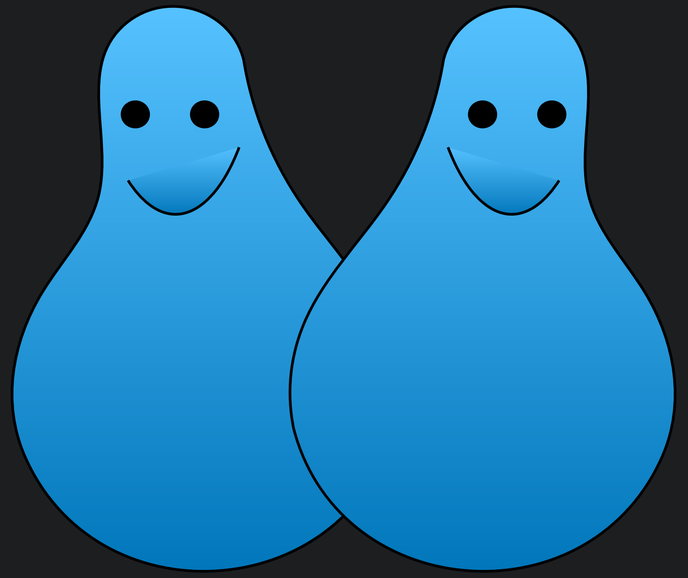



Blobs sleep
Food regrows back

If food_eaten **< 1**



If food_eaten **>3**

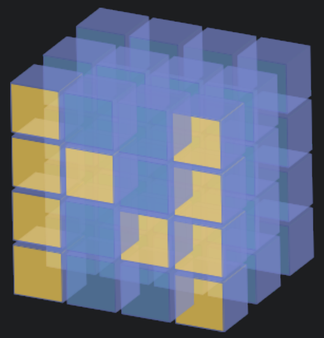



SimPy?


SimPy!

Required packages:

SimPy



NumPy

Scipy

tqdm

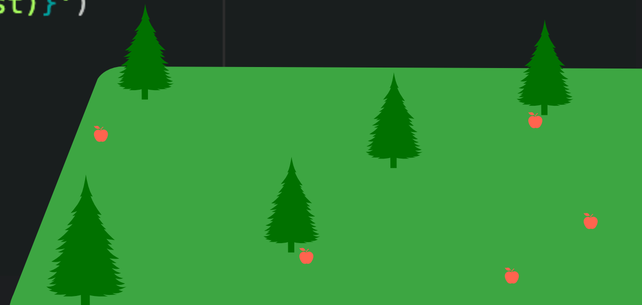
Forest

Simpy Container **and start of processes**

Time passes

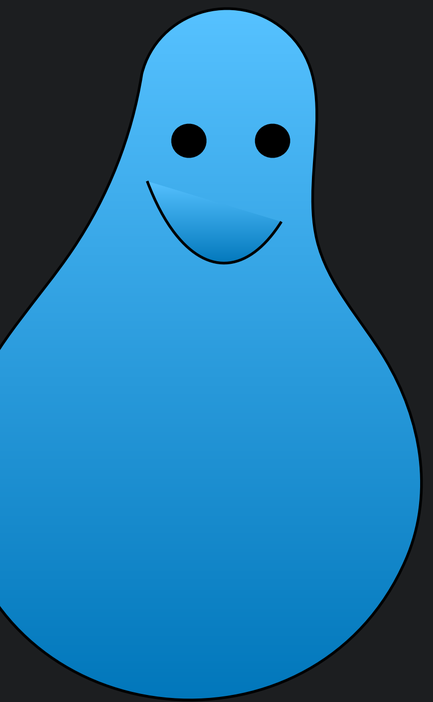
Food grows (with .put **method)**

```
class Forest:
    """
    The Forest is the natural environment where the Blobs live.
    The each day in the simulation is divided in two: Daylight and Nighttime.
    The Forest starts with a limited food supply that the Blobs eat during Daylight in order to survive.
    At nightime, the blobs goes to sleep and the Forest grows new food.

    """
    def __init__(self, env):
        self.food = simpy.Container(env, init=INITIAL_FOOD)
        self.time_proc = env.process(self.day_cycle(env))

    # Define the day to night cycle, and prints when they occur
    def day_cycle(self, env):
        while True:
            day = int(env.now/DAY)
            print(f'\nSTART OF DAY {day} (sim. time {env.now})')
            print(f' > Forest food level: {self.food.level}')
            print(f' > Living Blobs: {count_alive_blobs(Blob_list)}')
            living_blobs.append(count_alive_blobs(Blob_list))
            food_level_list.append(self.food.level)
            yield env.timeout(DAYLIGHT) # Wait for the sun to set.

            print(f'\nNIGHTTIME STARTS at {env.now}')
            # living_blobs.append(count_alive_blobs(Blob_list))
            yield env.process(self.food_growth(env)) # Food grows
            yield env.timeout(NIGHTTIME) # Wait for the sun to rise
            print(f' > Survived Blobs: {count_alive_blobs(Blob_list)}')

    # New food is added to the Forest
    def food_growth(self, env):
            print(f' > Forest food level: {self.food.level}')
            new_food = FOOD_RATE_PRODUCTION
            yield self.food.put(new_food)
```



Blob

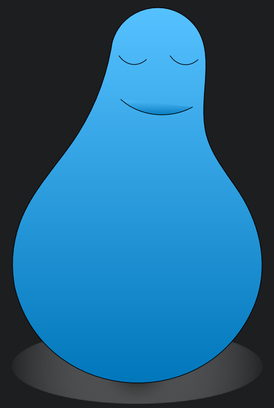
```
class Blob:
    """
    A Blob is a living creature poppulating the Forest.
    Each blob can be either alive or dead, depending on its ability to search for food.
    If a Blob eats enough food during a day, it survives to the next day. Otherwise, it dies.

    The Blob only search for food during Daylight. When the nighttime arrives, it goes to sleep.


    """
    def __init__(self, env, forest, name):
        self.env = env
        self.name = name # Name of the blob

        self.alive = True # Denotes the Blob's state: alive or dead
        self.isHunting = True # Denotes if the Blob is searching for food
        self.food_requirements = 1 # Minimum food to eat per day to survive
        self.food_eaten = 0 # Amount of food eaten during the current day
        self.can_reproduce = False

        self.sleep_proc = env.process(self.sleep(env, forest))
        self.hunt_proc = env.process(self.hunt(env, forest))
```



Various attributes serving as flags in `if` and `for` statements

Start the hunt and sleep process

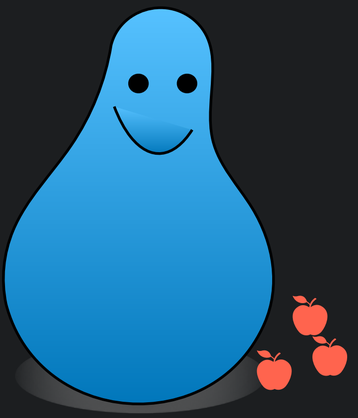
Blob



Prob. 0
why self.alive?

Prob. 1
why self.isHunting?

Prob. 2
why self.can_reproduce?



Prob. 3
the .get() **method**

Process interrupted and exception

Newborn Blob!

```
def sleep(self, env, forest):
    """
    This method defines when the Blob goes to sleep, that is during Nighttime.
    It waits for the Nighttime to come, and then set the Blob to sleep.
    If the Blob is hunting while Nighttime starts, the hunting process is interrupted and the Blob
    goes to sleep.

    """
    while self.alive: # Execute only if the Blob is still alive
        yield env.timeout(DAYLIGHT) # Wait for the night to pass
        if self.isHunting: # If the Blob is hunting, interrupt it and set to NOT hunting.
            self.hunt_proc.interrupt()
            self.isHunting = False
            if self.food_eaten < self.food_requirements: # If the Blob hasn't eaten enough, it dies.
                self.alive = False
            if self.food_eaten > 3: # If the Blob ate more than 3 foods, then it reproduces creating a new Blob
                self.can_reproduce = True
            self.food_eaten = 0 # Reset to zero the food eaten for the next day

def hunt(self, env, forest):
    """
    This method defines when the Blob goes searching fo food.

    """
    while self.alive: # Execute only if the Blob is still alive
        try:
            self.isHunting = True # Blob goes searching for food
            print(f'{self.name} starts hunting at time {env.now}')
            yield env.timeout(time_to_food()) # Some time is spent searching some food
            if forest.food.level > 0:
                yield forest.food.get(1) # A food item is gathered from the Forest
                self.food_eaten += 1 # The Blob has eaten a food
            else:
                # print('Forest is depleted')
                pass
        except simpy.Interrupt: # Nighttime has come
            self.isHunting = False
            yield env.timeout(NIGHTTIME) # Wait for the night to pass
            if self.can_reproduce:
                print("Newborn blob")
                Blob_list.append(Blob(env, forest, f'Newborn Blob {int(env.now/DAY)}'))
                self.can_reproduce = False
```

Main

Prob. 4
why `global` variables?

```
def main(start_blob = 50, start_food = 1000, food_rate = 100, num_days = 50):

    global FOOD_RATE_PRODUCTION
    global NUM_BLOB
    global INITIAL_FOOD
    global NUM_DAYS

    NUM_BLOB = start_blob
    INITIAL_FOOD = start_food
    FOOD_RATE_PRODUCTION = food_rate
    NUM_DAYS = num_days

    # Declaration of the Simpy Environment, Forest and Blobs
    env = simpy.Environment()
    forest = Forest(env)

    global Blob_list
    Blob_list = [Blob(env, forest, f'Blob {i}') for i in range(start_blob)]

    global living_blobs
    living_blobs = []

    global food_level_list
    food_level_list = []

    # Start the simulation
    env.run(until=NUM_DAYS*1440)
```

Declaration for Simpy environment

Initial population of the forest

Empty arrays for results

Simulation starts and lasts for `NUM_DAYS`

```
if __name__ == '__main__':
    main()
```

(**Snippet for executing as script**)

Run 0

```
SIMULATION RESULTS
Initial Blob:          50
Blob survived:         56
Initial food:        1000
Food growth:          100
Number of days:        50

Living Blobs [50, 52, 56, 58, 60, 62, 67, 71, 73, 74, 79, 80, 83, 87, 90, 93, 94, 100, 101, 107, 113, 119, 125, 130, 82, 70, 64, 66, 63, 62, 65, 62
, 60, 56, 55, 57, 60, 63, 66, 68, 64, 65, 68, 64, 61, 62, 64, 62, 63, 61]

Food Level [1000, 1019, 1031, 1034, 1041, 1032, 1032, 1010, 991, 974, 951, 923, 890, 852, 807, 764, 711, 633, 579, 497, 414, 321, 210, 100, 100, 10
0, 100, 101, 100, 100, 103, 100, 100, 100, 100, 112, 119, 115, 105, 103, 100, 104, 100, 100, 100, 102, 101, 100, 100, 100]
```

Run 1

```
SIMULATION RESULTS
Initial Blob:          50
Blob survived:         62
Initial food:        1000
Food growth:          100
Number of days:        50

Living Blobs [50, 52, 53, 57, 60, 61, 63, 67, 69, 76, 81, 86, 86, 89, 93, 95, 95, 98, 100, 104, 109, 114, 118, 118, 73, 68, 63, 63, 63, 64, 66, 68,
 66, 62, 63, 62, 61, 63, 58, 60, 62, 62, 62, 63, 65, 63, 64, 63, 61, 66]

Food Level [1000, 1021, 1042, 1046, 1049, 1056, 1045, 1035, 1025, 997, 959, 919, 886, 844, 791, 734, 675, 606, 551, 476, 390, 299, 209, 100, 100, 1
00, 100, 100, 108, 112, 107, 105, 100, 100, 100, 100, 100, 100, 100, 111, 109, 100, 100, 102, 100, 100, 100, 100, 100, 100]
```

Run 2

```
 SIMULATION RESULTS
 Initial Blob:          50
 Blob survived:         60
 Initial food:        1000
 Food growth:          100
 Number of days:        50

 Living Blobs [50, 50, 55, 57, 59, 63, 67, 70, 73, 81, 84, 85, 86, 89, 95, 101, 105, 106, 111, 113, 114, 118, 119, 75, 68, 64, 64, 63, 64, 61, 60, 6
 0, 61, 63, 62, 63, 62, 62, 58, 58, 59, 61, 61, 60, 63, 66, 67, 66, 65, 60]

 Food Level [1000, 1014, 1020, 1027, 1024, 1015, 1000, 984, 970, 921, 883, 857, 819, 773, 723, 664, 601, 539, 450, 370, 278, 194, 100, 100, 100, 100
 , 100, 100, 100, 100, 106, 100, 104, 104, 100, 100, 100, 100, 100, 110, 104, 106, 103, 100, 105, 100, 100, 100, 100, 100]
```

averages.py

```python
class HiddenPrints:
    """
    Useful Context manager to suppress the print statements in called functions.
    To be used with the 'with' syntax (see code below).
    """
    def __enter__(self):
        self._original_stdout = sys.stdout
        sys.stdout = open(os.devnull, 'w')

    def __exit__(self, exc_type, exc_val, exc_tb):
        sys.stdout.close()
        sys.stdout = self._original_stdout
```

Suppress printing

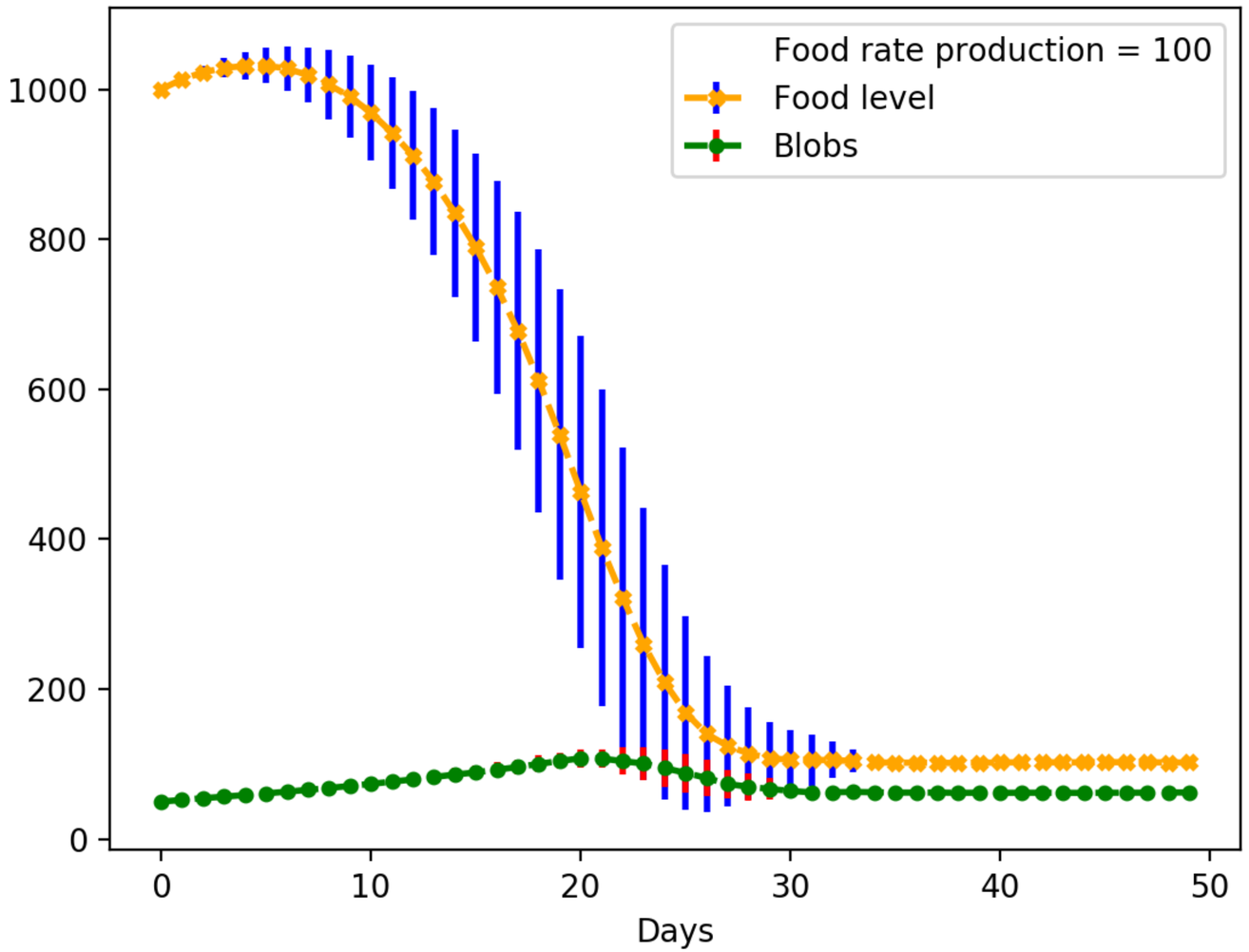
```python
results = []
foods = []
# In this way the print statements in bs.main() are suppressed
with HiddenPrints():
    for i in tqdm(range(NUM_SIMULATIONS)):
        # results.append(np.array(bs.main(start_blob = NUM_BLOB, start_food = INITIAL_FOOD, food_rate = FODD_RATE_PRODUCTION)))
        _res = bs.main(start_blob = NUM_BLOB, start_food = INITIAL_FOOD, food_rate = FOOD_RATE_PRODUCTION, num_days = NUM_DAYS)
        results.append(np.array(_res[0]))
        foods.append(np.array(_res[1]))

results = np.array(results)
foods = np.array(foods)

# Some processing of the data with Numpy builtin functions 'mean' ans 'std'
mean_blobs = np.mean(results, axis=0)
std_blobs = np.sqrt(np.var(results, axis = 0))

mean_foods = np.mean(foods, axis=0)
std_foods = np.sqrt(np.var(foods, axis=0))
```

tqdm **is a nice progress bar for Python**

Imports bio_sim.py **and executes the simulation** NUM_SIMULATIONS **times**

Basic analysis of the results using Numpy:
mean **and** standard deviation

averages.py

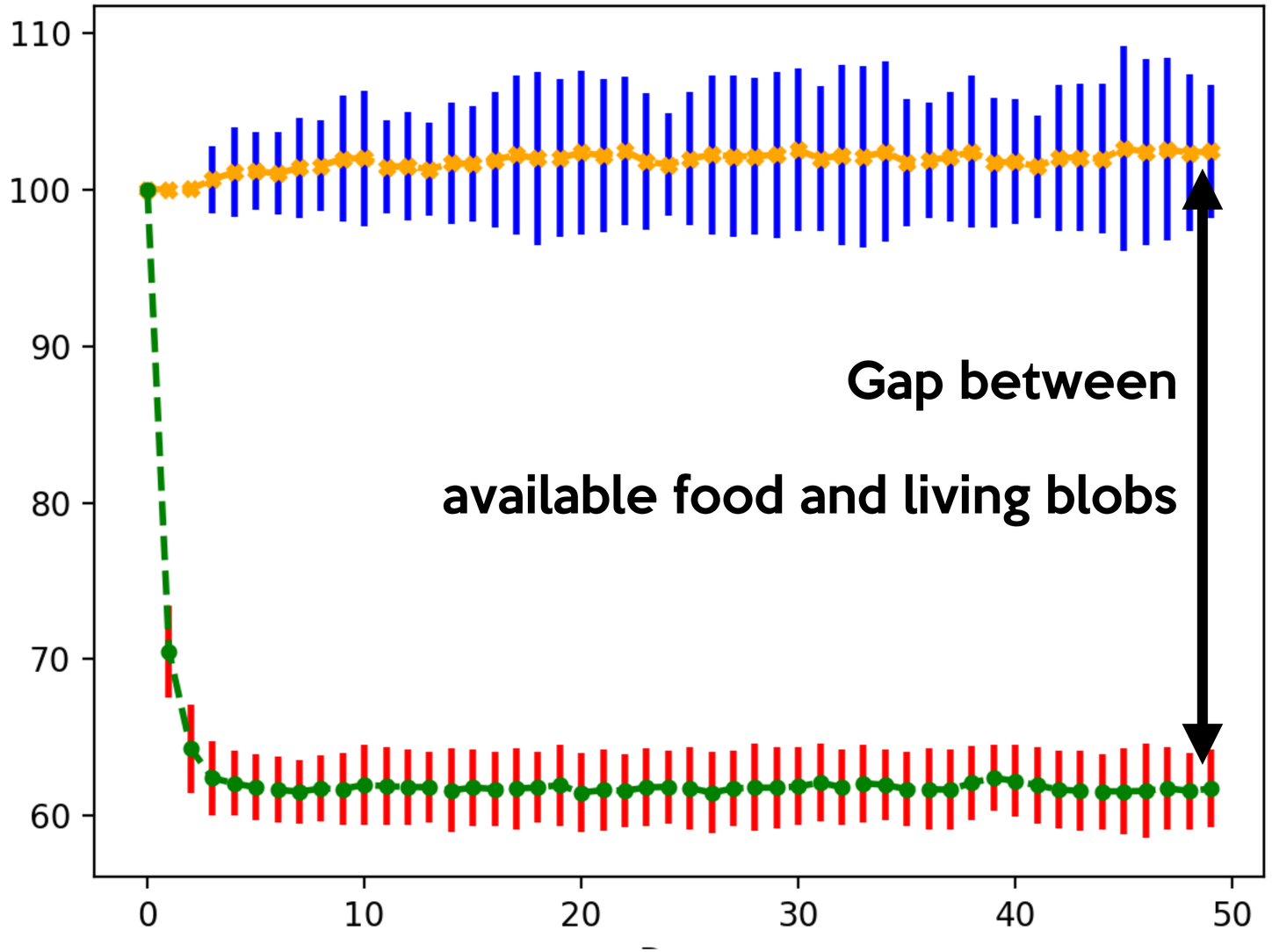


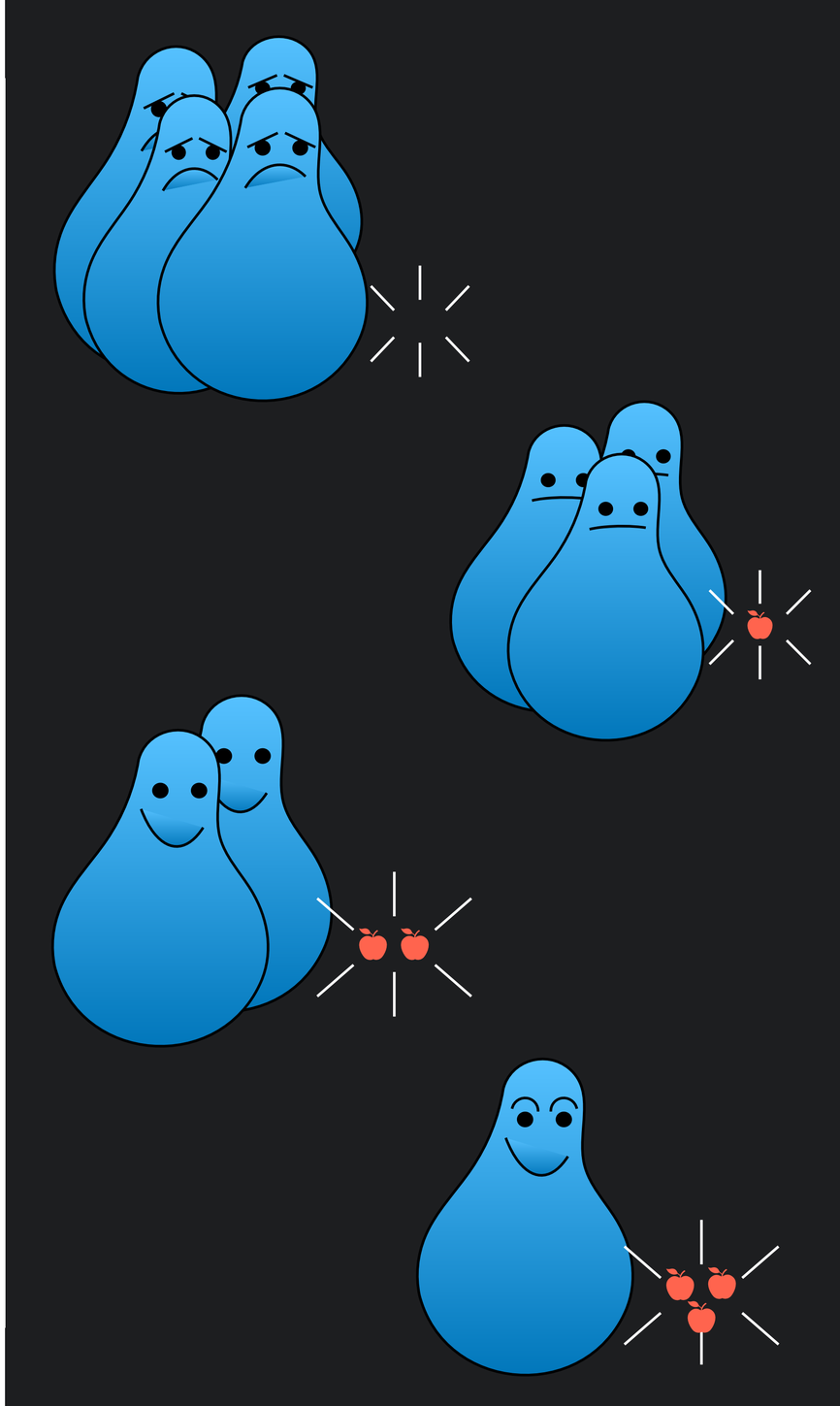

```
 label='Food rate production')
Initial Food Level')
')
er = 'X', linestyle='dashed', linewidth=2, markers
'o', linestyle='dashed', linewidth=2, markersize=4
```

Initial population: 500

Initial Food: 1000

Food rate production: 500


110
100
90
80
70
60
0
10
20
30
40
50
Gap between
available food and living blobs



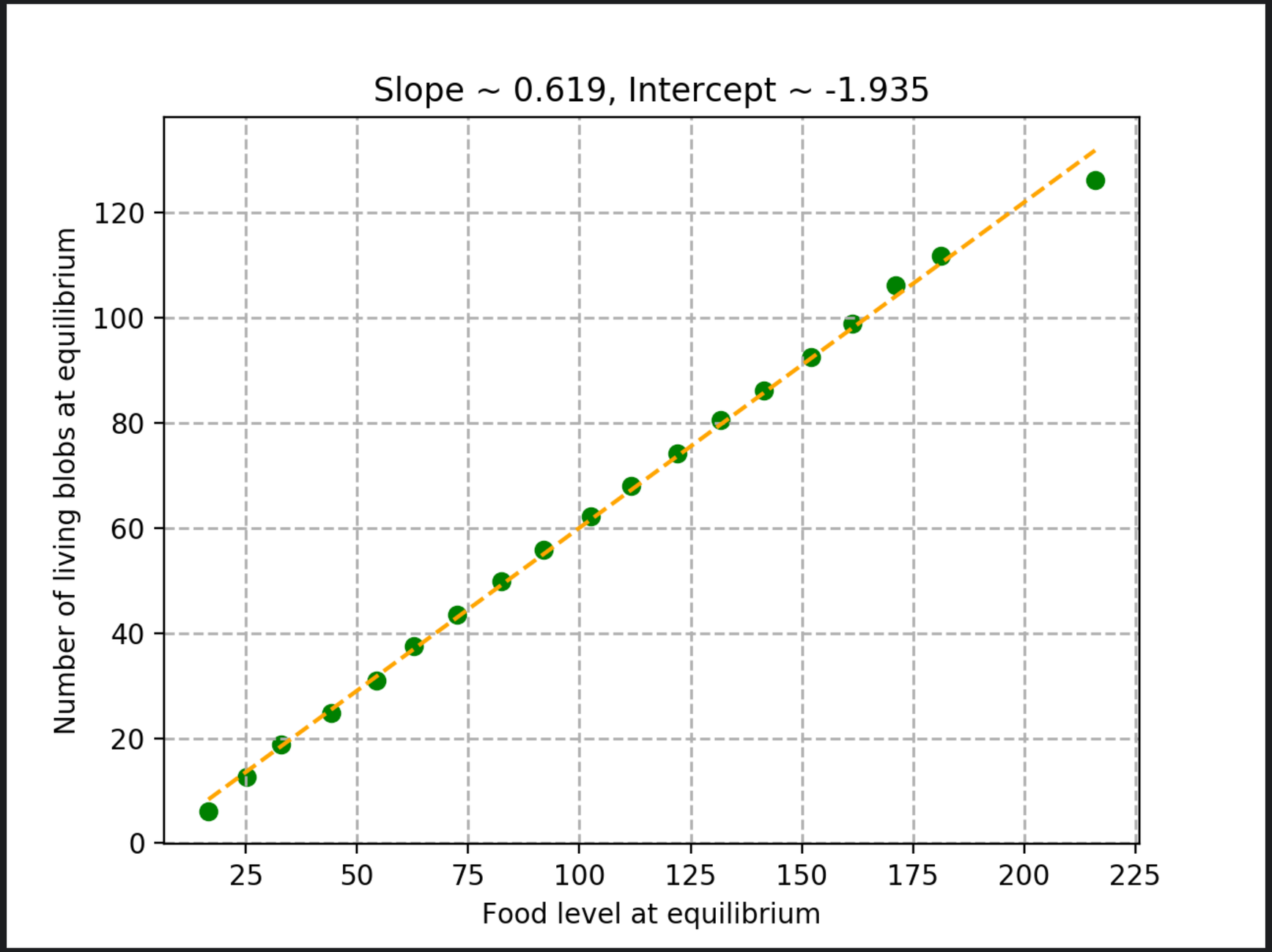
equilibrium.py

```
### Run the main.py file multiple times changing the food_rate_production parameters, and saves the ending food level and living blob Number
### for further plotting and analysis

results = []
foods = []
food_rates_list = [10*i for i in range(1,20)]
# In this way the print statements in bs.main() are suppressed
with HiddenPrints():
    for foodrate in tqdm(food_rates_list):
        # results.append(np.array(bs.main(start_blob = NUM_BLOB, start_food = INITIAL_FOOD, food_rate = FODD_RATE_PRODUCTION)))
        _res = mn.main(food_rate_production = foodrate, plotting = False)
        results.append(np.array(_res[0]))
        foods.append(np.array(_res[1]))

# Linear fit of the data using SciPy
from scipy import stats
slope, intercept, r_value, p_value, std_err = stats.linregress(foods, results)
def predict_y_for(x):
    return slope * x + intercept
```

Change the food_rate_production **parameter**

Execute averages.py with varying parameter

Using Scipy, **fit with a linear regressione of obtained results**


Slope ~ 0.619, Intercept ~ -1.935
Number of living blobs at equilibrium
Food level at equilibrium
0
20
40
60
80
100
120
25
50
75
100
125
150
175
200
225

So again...

maybe better
Object Oriented Programming (OOP)