# Ants Vs. SomeBees ants.zip (ants.zip)


*The bees are coming!*
*Create a better soldier*
*With inherit-ants.*

## Introduction

**For full credit:**

- Submit with Phase 1 complete by **Thursday 10/17** (worth 1 pt).
- Submit with Phase 1 and Phase 2 complete by **Tuesday 10/22** (worth 1 pt).
- Submit with all phases complete by **Wednesday 10/30**.

Solve the problems in order, since some later problems depend on earlier problems.

The entire project can be completed with a partner.

You can get 1 bonus point by submitting the entire project by **Tuesday 10/29**.

In this project, you will create a tower defense (https://secure.wikimedia.org/wikipedia/en/wiki/Tower_defense) game called Ants Vs. SomeBees. As the ant queen, you populate your colony with the bravest ants you can muster. Your ants must protect their queen from the evil bees that invade your territory. Irritate the bees enough by throwing leaves at them, and they will be vanquished. Fail to pester the airborne intruders adequately, and your queen will succumb to the bees' wrath. This game is inspired by PopCap Games' Plants Vs. Zombies (https://www.ea.com/studios/popcap/plants-vs-zombies).

This project uses an object-oriented programming paradigm, focusing on material from Chapter 2.5 (https://www.composingprograms.com/pages/25-object-oriented-programming.html) of Composing Programs. The project also involves understanding, extending, and testing a large program.

# Download starter files

The ants.zip (ants.zip) archive contains several files, but all of your changes will be made to `ants.py` .

- `ants.py` : The game logic of Ants Vs. SomeBees
- `ants_plans.py` : The details of each difficulty level
- `ucb.py` : Utility functions for CS 61A
- `gui.py:` A graphical user interface (GUI) for Ants Vs. SomeBees.
- `ok` : The autograder
- `proj3.ok` : The `ok` configuration file
- `tests` : A directory of tests used by `ok`
- `libs` : A directory of libraries used by `gui.py`
- `static` : A directory of images and files used by `gui.py`
- `templates` : A directory of HTML templates used by `gui.py`

# Logistics

The project is worth 25 points. 23 points are for correctness, 1 point for submitting Phase 1 by the first checkpoint date **Thursday 10/17**, and 1 point for submitting Phase 1 and Phase 2 by the second checkpoint date **Tuesday 10/22**.

You can get 1 EC point for submitting the entire project by **Tuesday 10/29**.

You will turn in the following files:

- `ants.py`

You do not need to modify or turn in any other files to complete the project. To submit the project, **submit the required files to the appropriate Gradescope assignment.**

You may not use artificial intelligence tools to help you with this project or reference solutions found on the internet.

For the functions that we ask you to complete, there may be some initial code that we provide. If you would rather not use that code, feel free to delete it and start from scratch. You may also add new function definitions as you see fit.

**However, please do not modify any other functions or edit any files not listed above**. Doing so may result in your code failing our autograder tests. Also, please do not change any function signatures (names, argument order, or number of arguments).

Throughout this project, you should be testing the correctness of your code. It is good practice to test often, so that it is easy to isolate any problems. However, you should not be testing *too* often, to allow yourself time to think through problems.

We have provided an **autograder** called `ok` to help you with testing your code and tracking your progress. The first time you run the autograder, you will be asked to **log in with your Ok account using your web browser**. Please do so. Each time you run `ok`, it will back up your work and progress on our servers.

The primary purpose of `ok` is to test your implementations.

If you want to test your code interactively, you can run

```
python3 ok -q [question number] -i
```

with the appropriate question number (e.g. `01`) inserted. This will run the tests for that question until the first one you failed, then give you a chance to test the functions you wrote interactively.

You can also use the debugging print feature in OK by writing

```
print("DEBUG:", x)
```

which will produce an output in your terminal without causing OK tests to fail with extra output.

# The Game

A game of Ants Vs. SomeBees consists of a series of turns. In each turn, new bees may enter the ant colony. Then, new ants are placed to defend their colony. Finally, all insects (ants, then bees) take individual actions. Bees either try to move toward the end of the tunnel or sting ants in their way. Ants perform a different action depending on their type, such as collecting more food or throwing leaves at the bees. The game ends either when a bee reaches the end of the tunnel (ants lose), the bees destroy a `QueenAnt` if it exists (ants lose), or the entire bee fleet has been vanquished (ants win).


## Core concepts

**The Colony**. This is where the game takes place. The colony consists of several `Place` s that are chained together to form tunnels through which the bees travel. The colony also has some quantity of food which can be expended in order to place an ant in a tunnel.

**Places**. A place links to another place to form a tunnel. The player can put a single ant into each place. However, there can be many bees in a single place.

**The Hive**. This is the place where bees originate. Bees exit the beehive to enter the ant colony.

**Ants**. The player places an ant into the colony by selecting from the available ant types at the top of the screen. Each type of ant takes a different action and requires a different amount of colony food to place. The two most basic ant types are the `HarvesterAnt` , which adds one food to the colony during each turn, and the `ThrowerAnt` , which throws a leaf at a bee each turn. You will be implementing many more!

**Bees**. Each turn, a bee either advances to the next place in the tunnel if no ant is in its way, or it stings the ant in its way. Bees win when at least one bee reaches the end of a tunnel. In addition to the orange bees, there are yellow wasps that do double damage and a green boss bee that is quite difficult to vanquish.

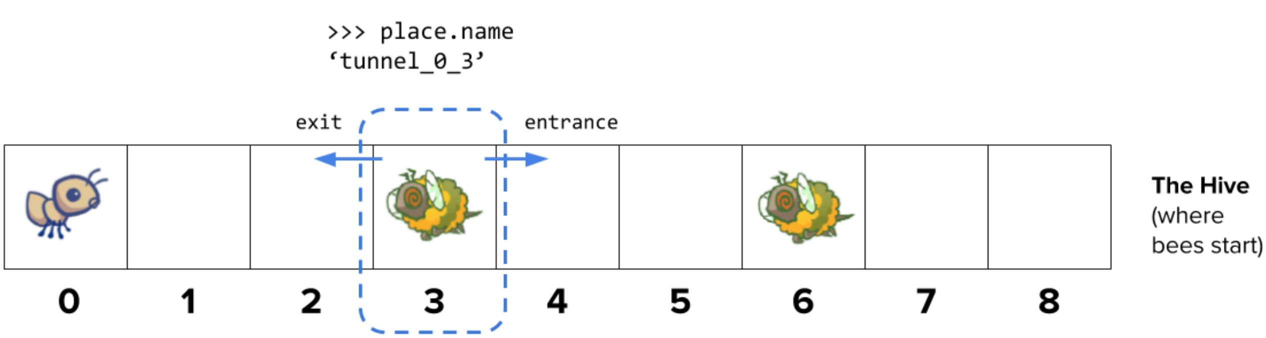
## Core classes

The concepts described above each have a corresponding class that encapsulates the logic for that concept. Here is a summary of the main classes involved in this game:

- **GameState** : Represents the colony and some state information about the game, including how much food is available, how much time has elapsed, where the `AntHomeBase` is, and all the `Place` s in the game.
- **Place** : Represents a single place that holds insects. At most one `Ant` can be in a single place, but there can be many `Bee` s in a single place. `Place` objects have an `exit` to the left and an `entrance` to the right, which are also places. Bees travel through a tunnel by moving to a `Place` 's `exit` .
- **Hive** : Represents the place where `Bee` s start out (on the right of the tunnel).
- **AntHomeBase** : Represents the place `Ant` s are defending (on the left of the tunnel). If `Bee` s get here, they win :(
- **Insect** : A base class for `Ant` and `Bee` . Each insect has a `health` attribute representing its remaining health and a `place` attribute representing the `Place` where it is currently located. Each turn, every active `Insect` in the game performs its `action` .
- **Ant** : Represents ants. Each `Ant` subclass has special attributes or a special `action` that distinguish it from other `Ant` types. For example, a `HarvesterAnt` gets food for the colony and a `ThrowerAnt` attacks `Bee` s. Each ant type also has a `food_cost` attribute that indicates how much it costs to deploy one unit of that type of ant.
- **Bee** : Represents bees. Each turn, a bee either moves to the `exit` of its current `Place` if the `Place` is not `blocked` by an ant, or stings the ant occupying its same `Place` .

## Game Layout

Below is a visualization of a GameState.




**Example: AntColony with dimensions (1, 9)**

To help visualize how all the classes fit together, here (diagram/ants_diagram.pdf) is a diagram of all of the classes and their inheritance relationships.

# Getting Started Videos

These videos may provide some helpful direction for tackling the coding problems on the project.

> To see these videos, you should be logged into your berkeley.edu email.

YouTube link (https://youtu.be/playlist?list=PLx38hZJ5RLZdH1AQFUuP-ixu7nAEK4OLP)

# Phase 1: Basic gameplay

In the first phase you will complete the implementation that will allow for basic gameplay with the two basic `Ant` s: the `HarvesterAnt` and the `ThrowerAnt` .

## Problem 0 (0 pt)

Answer a set of conceptual questions after you have read the *entire* `ants.py` file by running this `ok` command:

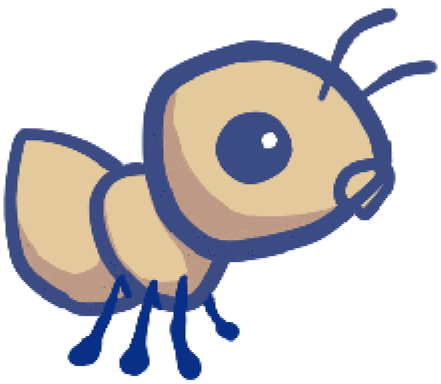
```
python3 ok -q 00 -u
```

If you get stuck while answering these questions, you can try reading through `ants.py` again or asking questions on Ed.

> **A note on unlocking tests**: If you'd like to review the unlocking questions after you have completed the unlocking test, you can navigate to (within the `ants` folder), the `tests` folder. For example, after unlocking Problem 0, you can review the unlocking test at `tests/00.py` .

# Problem 1 (1 pt)

**Part A**: Currently, there is no cost for placing any type of `Ant`, and so there is no challenge to the game. The base class `Ant` has a `food_cost` of zero. Override this class attribute for `HarvesterAnt` and `ThrowerAnt` according to the "Food Cost" column in the table below.

| Class | Food Cost | Initial Health |
|---|---|---|
|  `HarvesterAnt` | 2 | 1 |
|  `ThrowerAnt` | 3 | 1 |

**Part B**: Now that placing an `Ant` costs food, we need to be able to gather more food! To fix this issue, implement the `HarvesterAnt` class. A `HarvesterAnt` is a type of `Ant` that adds one food to the `gamestate.food` total as its `action`.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 01 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 01
```

# Problem 2 (1 pt)

In this problem, you'll complete `Place.__init__` by adding code that tracks entrances. Right now, a `Place` keeps track only of its `exit`. We would like a `Place` to keep track of its entrance as well. A `Place` needs to track only one `entrance`. Tracking entrances will be useful when an `Ant` needs to see what `Bee`s are in front of it in the tunnel.

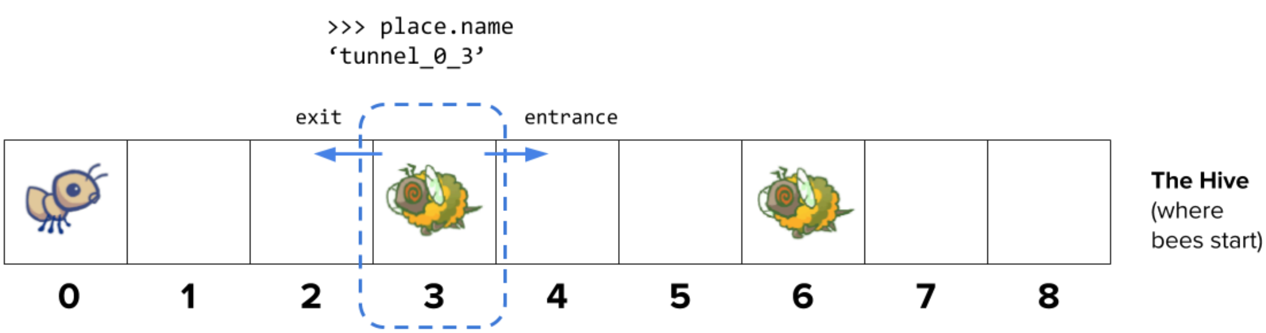
However, simply passing an entrance to a `Place` constructor will be problematic; we would need to have both the exit and the entrance before creating a `Place`! (It's a chicken or the egg (https://en.wikipedia.org/wiki/Chicken_or_the_egg) problem.) To get around this problem, we will keep track of entrances in the following way instead. `Place.__init__` should use this logic:

- A newly created `Place` always starts with its `entrance` as `None`.
- If the `Place` has an `exit`, then the `exit`'s `entrance` is set to that `Place`.

> *Hint:* Remember that when the `__init__` method is called, the first parameter, `self`, is bound to the newly created object

> *Hint:* Try drawing out two `Place`s next to each other if things get confusing. In the GUI, a place's `entrance` is to its right while the `exit` is to its left.

> *Hint:* Remember that `Place`s are not stored in a list, so you can't index into anything to access them. This means that you **can't** do something like `colony[index + 1]` to access an adjacent `Place`. How *can* you move from one place to another?




**Example: AntColony with dimensions (1, 9)**

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 02 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 02
```

## Problem 3 (2 pt)

In order for a `ThrowerAnt` to throw a leaf, it must know which bee to hit. The provided implementation of the `nearest_bee` method in the `ThrowerAnt` class only allows them to hit bees in the same `Place`. Your job is to fix it so that a `ThrowerAnt` will `throw_at` the nearest bee in front of it **that is not still in the `Hive`.** This includes bees that are in the same `Place` as a `ThrowerAnt`

> *Hint:* All `Place` s have an `is_hive` attribute which is `True` when that place is the `Hive`.

Change `nearest_bee` so that it returns a random `Bee` from the nearest place that contains bees. Your implementation should follow this logic:

- Start from the current `Place` of the `ThrowerAnt`.
- For each place, return a random bee if there is any, and if not, inspect the place in front of it (stored as the current place's `entrance`).
- If there is no bee to attack, return `None`.

> *Hint*: The `random_bee` function provided in `ants.py` returns a random bee from a list of bees or `None` if the list is empty.

> *Hint*: As a reminder, if there are no bees present at a `Place`, then the `bees` attribute of that `Place` instance will be an empty list.

> *Hint*: Having trouble visualizing the test cases? Try drawing them out on paper! The sample diagram provided in Game Layout shows the first test case for this problem.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 03 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 03
```

## Playing the game

After implementing `nearest_bee` , a `ThrowerAnt` should be able to `throw_at` a `Bee` in front of it that is not still in the `Hive` .

Now you're ready to try what you've built. To start a graphical game, run:

```
python3 gui.py
```

After you start the graphical version, the game is (usually) available at http://127.0.0.1:31415/.

The game has several options that you will use throughout the project, which you can view with `python3 gui.py --help` .

```
usage: gui.py [-h] [-d DIFFICULTY] [-w] [--food FOOD]

Play Ants vs. SomeBees

optional arguments:
  -h, --help     show this help message and exit
  -d DIFFICULTY  sets difficulty of game (test/easy/normal/hard/extra-hard)
  -w, --water    loads a full layout with water
  --food FOOD    number of food to start with when testing
```

You can refresh the webpage to restart the game, but if you changed your code, you need to terminate `gui.py` and run it again. To terminate `gui.py` , you can hit `Ctrl + C` on the terminal.

You cannot have multiple tabs of this same Ants GUI open simultaneously or they will all error.

## Checkpoint Submission

Check to make sure that you completed all the problems in Phase 1:

```
python3 ok --score
```

Then, submit `ants.py` to the **Ants Checkpoint 1** assignment on **Gradescope** before the checkpoint 1 deadline.

When you run `ok` commands, you'll still see that some tests are locked because you haven't completed the whole project yet. You'll get full credit for the checkpoint if you complete all the problems up to this point.

Congratulations! You have finished Phase 1 of this project!

# Phase 2: More Ants!

Now that you've implemented basic gameplay with two types of `Ant` s, let's add some flavor to the ways ants can attack bees. In this problem and on, you'll be implementing several different `Ant` s with different attack strategies.

**After you implement each `Ant` subclass in these sections, you'll need to set its `implemented` class attribute to `True`** so that that type of ant will show up in the GUI. Feel free to try out the game with each new ant to test the functionality!

With all following ants from now on, try `python3 gui.py` to play against a full swarm of bees in a multi-tunnel layout and try `-d hard` or `-d extra-hard` if you want a real challenge! If the bees are too numerous to vanquish, you might need to create some new ants.

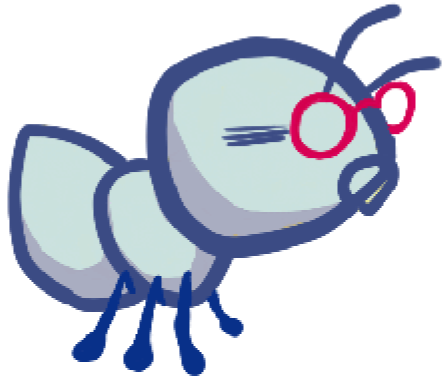
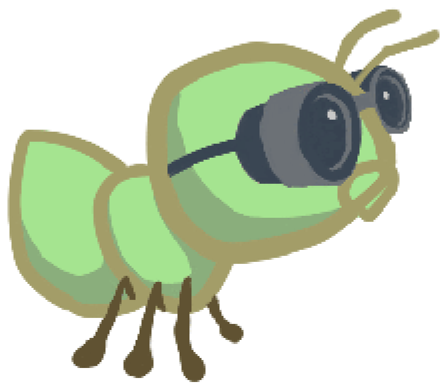
## Problem 4 (2 pt)

A `ThrowerAnt` is a powerful threat to the bees, but it has a high food cost. In this problem, you'll implement two subclasses of `ThrowerAnt` that are less costly but have constraints on the distance they can throw:

- The `LongThrower` can only `throw_at` a `Bee` that is found after following at least 5 `entrance` transitions. It cannot hit `Bee` s that are in the same `Place` as it or the first 4 `Place` s in front of it. If there are two `Bee` s, one too close to the `LongThrower` and the other within its range, the `LongThrower` should only throw at the farther `Bee` , which is within its range, instead of trying to hit the closer `Bee` .
- The `ShortThrower` can only `throw_at` a `Bee` that is found after following at most 3 `entrance` transitions. It cannot throw at any bees further than 3 `Place` s in front of it.

Neither of these specialized throwers can `throw_at` a `Bee` that is exactly 4 `Place` s away.

| Class | Food Cost | Initial Health |
|---|---|---|

| | | |
|---|---|---|
|  ShortThrower | 2 | 1 |
|  LongThrower | 2 | 1 |

To implement these new throwing ants, your `ShortThrower` and `LongThrower` classes should inherit the `nearest_bee` method from the base `ThrowerAnt` class. The logic of choosing which bee a thrower ant will attack is the same, except the `ShortThrower` and `LongThrower` ants where their range is limited by a lower and upper bound, respectively.

To do this, modify the `nearest_bee` method to reference `lower_bound` and `upper_bound` attributes, and only return a bee if it is within range.

Make sure to give these `lower_bound` and `upper_bound` attributes appropriate values in the `ThrowerAnt` class so that the behavior of `ThrowerAnt` is unchanged. Then, implement the subclasses `LongThrower` and `ShortThrower` with appropriately constrained ranges.

You should **not** need to repeat any code between `ThrowerAnt`, `ShortThrower`, and `LongThrower`.

> *Hint:* `float('inf')` returns an infinite positive value represented as a float that can be compared with other numbers.

> *Hint:* `lower_bound` and `upper_bound` should mark an inclusive range.

> **Important:** Make sure your class attributes are called `upper_bound` and `lower_bound` The tests directly reference these attribute names, and will error if you use another name for these attributes.

Don't forget to set the `implemented` class attribute of `LongThrower` and `ShortThrower` to `True` .

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 04 -u
```

After writing code, test your implementation (rerun the tests for 03 to make sure they still work):

```
python3 ok -q 03
python3 ok -q 04
```

👩🏽‍💻👨🏿‍💻 [Pair programming? (/articles/pair-programming)](/articles/pair-programming) Remember to alternate between driver and navigator roles. The driver controls the keyboard; the navigator watches, asks questions, and suggests ideas.

## Problem 5 (3 pt)

Implement the `FireAnt` , which does damage when it receives damage. Specifically, if it is damaged by `amount` health units, it does a damage of `amount` to all bees in its place (this is called *reflected damage*). If it dies, it does an additional amount of damage, as specified by its `damage` attribute, which has a default value of `3` as defined in the `FireAnt` class.

To implement this, override `Insect` 's `reduce_health` method. Your overriden method should call the `reduce_health` method inherited from the superclass ( `Ant` ) *which inherits from it's superclass Insect* to reduce the current `FireAnt` instance's health. Calling the *inherited* `reduce_health` method on a `FireAnt` instance reduces the insect's `health` by the given `amount` and removes the insect from its place if its `health` reaches zero or lower.

> *Hint:* Do *not* call `self.reduce_health` , or you'll end up stuck in a recursive loop. (Can you see why?)

However, your method needs to also include the reflective damage logic:

- Determine the reflective damage amount: start with the `amount` inflicted on the ant, and then add `damage` if the ant's health has dropped to or below 0.

- For each bee in the place, damage them with the total amount by calling the appropriate `reduce_health` method for each bee.

> **Important:** Remember that when any `Ant` loses all its health, it is removed from its `place`, so pay careful attention to the order of your logic in `reduce_health`.

| Class | Food Cost | Initial Health |
|---|---|---|
|  FireAnt | 5 | 3 |

> **Important**: Damaging a bee may cause it to be removed from its place; when an insect dies, it is removed from its current place. If you iterate over a list, but change the contents of that list at the same time, you may not visit all the elements (https://docs.python.org/3/tutorial/controlflow.html#for-statements). This can be prevented by making a copy of the list. You can either use a list slice, or use the built-in `list` function to make sure the original list is not affected.

```
>>> s = [1,2,3,4]
>>> s[:]
[1, 2, 3, 4]
>>> list(s)
[1, 2, 3, 4]
>>> (s[:] is not s) and (list(s) is not s)
True
```

Once you've finished implementing the `FireAnt`, give it a class attribute `implemented` with the value `True`.

> *Note:* Even though you are overriding the superclass's `reduce_health` function (`Ant.reduce_health`), you can still use this method in your implementation by calling it.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 05 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 05
```

You can also test your program by playing a game or two! A `FireAnt` should destroy all co-located `Bee` s when it is stung. To start a game with ten food (for easy testing):

```
python3 gui.py --food 10
```

## Problem 6 (1 pt)

We are going to add some protection to our glorious home base by implementing the `WallAnt`, an ant that does nothing each turn. A `WallAnt` is useful because it has a large `health` value.

| Class | Food Cost | Initial Health |
|---|---|---|
|  `WallAnt` | 4 | 4 |

Unlike with previous ants, we have not provided you with a class statement. Implement the `WallAnt` class from scratch. Give it a class attribute `name` with the value `'Wall'` (so that the graphics work) and a class attribute `implemented` with the value `True` (so that you can use it in a game).

> *Hint*: Make sure you implement the `__init__` method too so the `WallAnt` starts off with the appropriate amount of `health`!

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 06 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

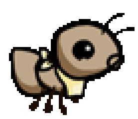
```
python3 ok -q 06
```

# Problem 7 (3 pt)

Implement the `HungryAnt`, which will select a random `Bee` from its `place` and deal damage to the `Bee` equal to the `Bee`'s health, eating it whole. After eating a `Bee`, a `HungryAnt` must spend 3 turns chewing before being able to eat again. While the `HungryAnt` is chewing, it is not able to eat (deal damage to) any `Bee`s. If there is no bee in its place available to eat, the `HungryAnt` will do nothing.

We have not provided you with a class header. Implement the `HungryAnt` class from scratch. Give it a class attribute `name` with the value `'Hungry'` (so that the graphics work) and a class attribute `implemented` with the value `True` (so that you can use it in a game).

> *Hint:* When a `Bee` is eaten, its health should be reduced by its health.

| Class | Food Cost | Initial Health |
|---|---|---|
|  HungryAnt | 4 | 1 |

Give `HungryAnt` a `chew_cooldown` **class** attribute that stores the number of turns that it will take a `HungryAnt` to chew (set to 3). Also, give each `HungryAnt` an **instance** attribute `cooldown` that counts the number of turns it has left to chew, initialized to 0, since it hasn't eaten anything at the beginning. You can also think of `cooldown` as the number of turns until a `HungryAnt` can eat another `Bee`.

Implement the `action` method of the `HungryAnt`: First, check if it is chewing; if so, decrement its `cooldown`. Otherwise, eat a random `Bee` in its `place` by reducing the `Bee`'s health to 0. Make sure to set the `cooldown` when a `Bee` is eaten!

> *Hint*: Other than the `action` method, make sure you implement the `__init__` method too in order to define any instance variables and make sure that `HungryAnt` starts off with the appropriate amount of `health`!

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 07 -u
```

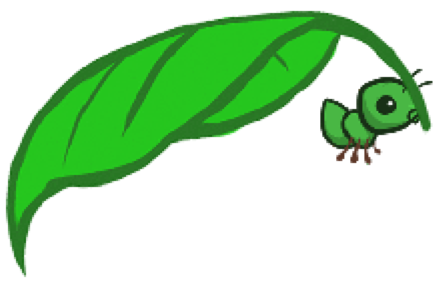
Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 07
```

Pair programming? (/articles/pair-programming) This would be a good time to switch roles. Switching roles makes sure that you both benefit from the learning experience of being in each role.

## Problem 8 (3 pt)

Right now, our ants are quite frail. We'd like to provide a way to help them last longer against the onslaught of the bees. Enter the `BodyguardAnt`.

| Class | Food Cost | Initial Health |
|---|---|---|
|  `BodyguardAnt` | 4 | 2 |

To more easily implement the `BodyguardAnt`, we will break up this problem into 3 subparts. In each part, we will making changes in either the `ContainerAnt` class, `Ant` class, or `BodyguardAnt` class.

> *Note:* We have separated out Question 8 into three different subparts. We recommend going through the unlocking test for each subpart before writing any code for it. You will be tested through each subpart and each subpart is worth one point (for a total of three for the whole question).

### Problem 8a

First, we will define and work in a `ContainerAnt` parent class that we will later use for our `BodyguardAnt`.

A `BodyguardAnt` differs from a normal ant because it is a `ContainerAnt`; it can contain another ant and protect it, all in one `Place`. When a `Bee` stings the ant in a `Place` where one ant contains another, only the container is damaged. The ant inside the container can still perform its original action. If the container perishes, the contained ant still remains in the place (and can then be damaged).

Each `ContainerAnt` has an instance attribute `ant_contained` that stores the ant it contains. This ant, `ant_contained`, initially starts off as `None` to indicate that there is no ant being stored yet. Implement the `store_ant` method so that it sets the `ContainerAnt`'s `ant_contained` instance attribute to the `ant` argument passed in. Then implement the `ContainerAnt`'s `action` method. This method will ensure that if our `ContainerAnt` currently contains an ant, `ant_contained`'s action is performed.

In addition, to ensure that a container and its contained ant can both occupy a place at the same time (a maximum of two ants per place), but only if exactly one is a container, we can create an `can_contain` method.

There is already an `Ant.can_contain` method, but it always returns `False`. **Override** the method `can_contain` in `ContainerAnt` so that it takes an ant `other` as an argument and returns `True` if:

- This `ContainerAnt` does not already contain another ant.
- The other ant is not a container.

> *Hint:* You may find the `is_container` attribute that each `Ant` has useful for checking if a specific `Ant` is a container.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 08a -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 08a
```

## Problem 8b

Next, we will be working in the `Ant` class.

Modify `Ant.add_to` to allow a container and its contained ant to occupy the same place according to the following rules:

- If the ant originally occupying a place can contain the ant being added, then both ants occupy the place and original ant contains the ant being added.

- If the ant being added can contain the ant originally in the space, then both ants occupy the place and the (container) ant being added contains the original ant.
- If neither `Ant` can contain the other, raise the same `AssertionError` as before (the one already present in the starter code).
- **Important:** If there are two ants in a specific `Place`, the `ant` attribute of the `Place` instance should **refer to the container ant**, and the container ant should contain the non-container ant.

> *Hint*: You should also take advantage of the `can_contain` method you wrote and avoid repeating code.

> **Note:** If you're getting an "unreachable code" warning for `Ant.add_to` via the VSCode Pylance extension, it's fine to ignore this specific warning, as the code is actually run (the warning *in this case* is inaccurate).

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 08b -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 08b
```

### Problem 8c

Finally, we can work on implementing our `BodyguardAnt` class.

Add a `BodyguardAnt.__init__` that sets the initial amount of health for the Bodyguard ant. We do not need to create an `action` method here since the `BodyguardAnt` class inherits it from the `ContainerAnt` class. Also note that the `BodyguardAnt` does not do any damage.

Once you've finished implementing the `BodyguardAnt`, give it a class attribute `implemented` with the value `True`.

Before writing any code, unlock the tests to verify your understanding of the question:

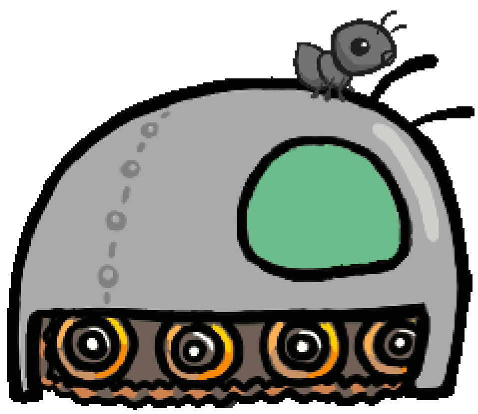
```
python3 ok -q 08c -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 08c
```

## Problem 9 (2 pt)

The `BodyguardAnt` provides great defense, but they say the best defense is a good offense. The `TankAnt` is a `ContainerAnt` that protects an ant in its place and also deals 1 damage to all bees in its place each turn. Like any `ContainerAnt`, a `TankAnt` allows the ant that it contains to perform its action each turn.

| Class | Food Cost | Initial Health |
|---|---|---|
|  TankAnt | 6 | 2 |

We have not provided you with a class header. Implement the `TankAnt` class from scratch. Give it a class attribute `name` with the value `'Tank'` (so that the graphics work) and a class attribute `implemented` with the value `True` (so that you can use it in a game).

You should not need to modify any code outside of the `TankAnt` class. If you find yourself needing to make changes elsewhere, look for a way to write your code for the previous question such that it applies not just to `BodyguardAnt` and `TankAnt` objects, but to container ants in general.

> *Hint*: The only methods you need to override from `TankAnt`'s parent class are `__init__` and `action`.

> *Hint*: Like with `FireAnt`, it is possible that damaging a bee will cause it to be removed from its place.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 09 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 09
```

## Checkpoint Submission

Check to make sure that you completed all the problems in Phase 1 and Phase 2:

```
python3 ok --score
```

Then, submit `ants.py` to the **Ants Checkpoint 2** assignment on **Gradescope** before the checkpoint 2 deadline.

When you run `ok` commands, you'll still see that some tests are locked because you haven't completed the whole project yet. You'll get full credit for the checkpoint if you complete all the problems up to this point.

Congratulations! You have finished Phase 1 and Phase 2 of this project!

# Phase 3: Water and Might

In the final phase, you're going to add one last kick to the game by introducing a new type of place and new ants that are able to occupy this place. One of these ants is the most important ant of them all: the queen of the colony!

## Problem 10 (1 pt)

Let's add water to the colony! Currently there are only two types of places, the `Hive` and a basic `Place`. To make things more interesting, we're going to create a new type of `Place` called `Water`.

Only an insect that is waterproof can be placed in `Water`. In order to determine whether an `Insect` is waterproof, add a new class attribute to the `Insect` class named `is_waterproof` that is set to `False`. Since bees can fly, their `is_waterproof` attribute is `True`, overriding the inherited value.

Now, implement the `add_insect` method for `Water`. First, add the insect to the place regardless of whether it is waterproof. Then, if the insect is not waterproof, reduce the insect's health to 0. *Do not repeat code from elsewhere in the program.* Instead, use methods that have already been defined.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 10 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 10
```

Once you've finished this problem, play a game that includes water. To access the `wet_layout`, which includes water, add the `--water` option (or `-w` for short) when you start the game.

```
python3 gui.py --water
```

[Pair programming? (/articles/pair-programming)](/articles/pair-programming) Remember to alternate between driver and navigator roles. The driver controls the keyboard; the navigator watches, asks questions, and suggests ideas.

## Problem 11 (2 pt)

Currently there are no ants that can be placed on `Water`. Implement the `ScubaThrower`, which is a subclass of `ThrowerAnt` that is more costly and waterproof, *but otherwise identical to its base class*. A `ScubaThrower` should not lose its health when placed in `Water`.

| Class | Food Cost | Initial Health |
|---|---|---|
|  ScubaThrower | 6 | 1 |

We have not provided you with a class header. Implement the `ScubaThrower` class from scratch. Give it a class attribute `name` with the value `'Scuba'` (so that the graphics work) and remember to set the class attribute `implemented` with the value `True` (so that you can use it in a game).

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 11 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 11
```

## Problem 12 (2 pt)

Finally, implement the `QueenAnt`. A queen is a `ThrowerAnt` that inspires her fellow ants through her bravery. In addition to the standard `ThrowerAnt` action, a `QueenAnt` doubles the damage of all the ants behind her each time she performs an action. However, once an ant's damage has been doubled, it *cannot* be doubled again. Try to think of a way to keep track of whether an ant's damage has already been doubled (Hint: Use an instance attribute!)

> Note: The reflected damage of a `FireAnt` should not be doubled, only the extra damage it deals when its health is reduced to 0.

| Class | Food Cost | Initial Health |
|---|---|---|
|  `QueenAnt` | 7 | 1 |

However, with great power comes great responsibility. If a queen ever has its health reduced to 0, the ants lose. You will need to override `Insect.reduce_health` in `QueenAnt` and call `ants_lose()` in that case in order to signal to the simulator that the game is over. (The ants also still lose if any bee reaches the end of a tunnel.)

> *Hint:* For doubling the damage of all ants behind her, you may fill out the `double` method defined in the `Ant` class, then call it from the `QueenAnt` class.

> *Hint:* When doubling the ants' damage, keep in mind that there can be more than one ant in a `Place`, like in the case of container ants storing another.

> *Hint:* Remember that QueenAnt's `reduce_health` method adds the additional task of calling `ants_lose` to the superclass's `reduce_health` method. How can we make sure we still do everything from the superclass's method without repeating code?

> *Hint:* You can find each `Place` in a tunnel behind a `QueenAnt` by starting at the queen's `place.exit` and then repeatedly moving back to the previous place's `exit`. The `exit` of a `Place` at the end of a tunnel is `None`.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q 12 -u
```

Once you are done unlocking, begin implementing your solution. You can check your correctness with:

```
python3 ok -q 12
```

# Project submission

Run `ok` on all problems to make sure all tests are unlocked and pass:

```
python3 ok
```

You can also check your score on each part of the project:

```
python3 ok --score
```

Once you are satisfied, submit this assignment by uploading `ants.py` to the **Ants** assignment on **Gradescope.** For a refresher on how to do this, refer to Lab 00 (/lab/lab00/#task-c-submitting-the-assignment).

You can add a partner to your Gradescope submission by clicking on **+ Add Group Member** under your name on the right hand side of your submission. Only one partner needs to submit to Gradescope.

**You are now done with the project!** If you haven't yet, you should try playing the game!

```
python3 gui.py [-h] [-d DIFFICULTY] [-w] [--food FOOD]
```

# Extra Challenges (Optional)

> **Note**: These problems are **optional** and **are not worth any points**.

> During Office Hours and Project Parties, the staff will prioritize helping students with required questions. We will not be offering help with this question unless the queue (https://oh.cs61a.org/) is empty.

Implement two final thrower ants that do zero damage, but instead apply a temporary effect on the `action` method of a `Bee` instance that they `throw_at`. This "status" lasts for a certain number of turns, after which it ceases to take effect.

## Problem EC 1 (0 pt)

We will be implementing a new ant, `SlowThrower`, which inherits from `ThrowerAnt`.

`SlowThrower` throws sticky syrup at a bee, slowing it for 5 turns. When a bee is slowed, it does its regular Bee action when `gamestate.time` is even, and takes no action (does not move or sting) otherwise. If a bee is hit by syrup while it is already slowed, it is slowed for 5 turns starting from the *most recent* time it is hit by syrup. That is, if a bee is hit by syrup, takes 2 turns, and is hit by syrup again, it will now be slowed for 5 turns after the *second* time it is hit by syrup. So it will have been slowed for 7 turns total (not 10!).

| Class | Food Cost | Initial Health |
|---|---|---|
|  `SlowThrower` | 6 | 1 |

In order to complete the implementations of this `SlowThrower`, you will need to set its class attributes appropriately and implement the `throw_at` method in `SlowThrower`.

**Important Restriction:** You may *not* modify any code outside the `SlowThrower` class for this problem. That means you may *not* modify the `Bee.action` method directly. Our tests will check for this.

> **Hint**: Take a look at `SlowThrower` 's parent class, `ThrowerAnt` . `ThrowerAnt` 's `action` method calls `throw_at` , which is what you should be overriding in `SlowThrower` . What is passed into the `target` parameter in `SlowThrower` 's `throw_at` function and why? What is `target.action` referring to?
>
> **Implementation Hint**: Assign `target.action` to a new function that conditionally calls `Bee.action` . You can create and use an instance attribute to track how many more turns the bee will be slowed. Once the slowing effect is over, `Bee.action` should be called *every* turn again.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q EC1 -u
```

You can run some provided tests, but they are not exhaustive:

```
python3 ok -q EC1
```

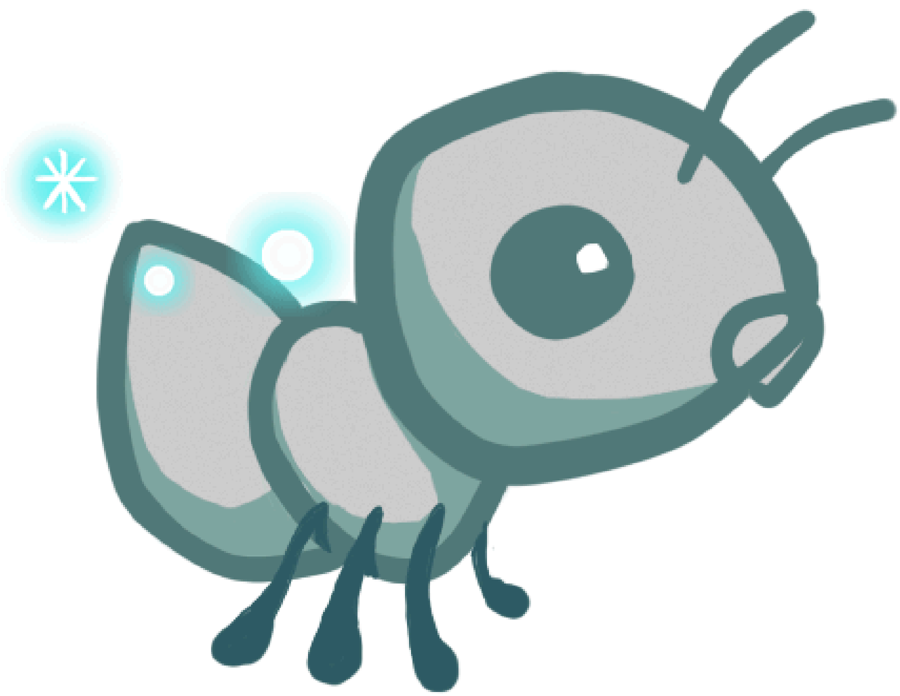
Make sure to test your code! Your code should be able to apply multiple statuses on a target; each new status applies to the current (possibly previously affected) action method of the bee.

## Problem EC 2 (0 pt)

> You must implement Problem EC 1 (SlowThrower) correctly in order to pass the tests for this problem. We will be implementing a new ant, `ScaryThrower` , which inherits from `ThrowerAnt` .

`ScaryThrower` intimidates a nearby bee, causing it to back away instead of advancing. Here are some rules to keep in mind:

1. If the bee is already right next to the Hive and cannot go back further, it should not move. To check if a bee is next to the Hive, you might find the `is_hive` instance attribute of `Place` useful.
2. Bees remain scared until they have tried to back away *twice*. So, the back away effect lasts two turns.
3. Bees cannot try to back away if they are *slowed* and `gamestate.time` is *odd*. This would be a turn they're frozen by SlowThrower!
4. Once a bee has been scared once, it can't be scared ever again.

| Class | Food Cost | Initial Health |
|---|---|---|
|  `ScaryThrower` | 6 | 1 |

In order to complete the implementation of this `ScaryThrower`, you will need to set its class attributes appropriately and implement the `scare` method in `Bee`, which applies the scared status on a particular bee. You may also have to edit some other methods of `Bee` such as action.

Before writing any code, unlock the tests to verify your understanding of the question:

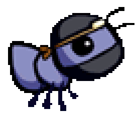
```
python3 ok -q EC2 -u
```

```
python3 ok -q EC2
```

Make sure to test your code! Your code should be able to apply multiple statuses on a target; each new status applies to the current (possibly previously affected) action method of the bee.

## Problem EC 3 (0 pt)

Implement the `NinjaAnt`, which damages all `Bee`s that pass by, but can never be stung.

| Class | Food Cost | Initial Health |
|---|---|---|
|  `NinjaAnt` | 5 | 1 |

A `NinjaAnt` does not block the path of a `Bee` that flies by. To implement this behavior, first modify the `Ant` class to include a new class attribute `blocks_path` that is set to `True`, then override the value of `blocks_path` to `False` in the `NinjaAnt` class.

Second, modify the `Bee`'s method `blocked` to return `False` if either there is no `Ant` in the `Bee`'s `place` or if there is an `Ant`, but its `blocks_path` attribute is `False`. Now `Bee`s will just fly past `NinjaAnt`s.

Finally, we want to make the `NinjaAnt` damage all `Bee`s that fly past. Implement the `action` method in `NinjaAnt` to reduce the health of all `Bee`s in the same `place` as the `NinjaAnt` by its `damage` attribute. Similar to the `FireAnt`, you must iterate over a potentially changing list of bees.

> **Hint**: Having trouble visualizing the test cases? Try drawing them out on paper! See the example in Game Layout for help.

Before writing any code, unlock the tests to verify your understanding of the question:

```
python3 ok -q EC3 -u
```

```
python3 ok -q EC3
```

For a challenge, try to win a game using only `HarvesterAnt` and `NinjaAnt`.

## Problem EC 4 (0 pt)

We've been developing this ant for a long time in secret. It's so dangerous that we had to lock it in the super hidden underground vault, but we finally think it is ready to test out on the field. In this problem, you'll be implementing the final ant -- `LaserAnt`, a `ThrowerAnt` with a twist.

| Class | Food Cost | Initial Health |
|---|---|---|
|  LaserAnt | 10 | 1 |

The LaserAnt shoots out a powerful laser, damaging all that dare to stand in its path. Both Bee s and Ant s, of all types, are at risk of being damaged by LaserAnt . When a LaserAnt takes its action, it will damage all Insect s in its place (excluding itself, but including its container if it has one) and the Place s in front of it, excluding the Hive .

If that were it, LaserAnt would be too powerful for us to contain. The LaserAnt has a base damage of 2 . But, LaserAnt 's laser comes with some quirks. The laser is weakened by 0.25 each place it travels away from LaserAnt 's place. Additionally, LaserAnt has limited battery. Each time LaserAnt actually damages an Insect , its laser's total damage goes down by 0.0625 (1/16). This reduction is immediate so if there are two Bee s in front of LaserAnt and on the same tile, it will do less damage to the second Bee . If LaserAnt 's damage becomes negative due to these restrictions, it simply does 0 damage instead.

> The exact order in which things are damaged within a turn does not matter.

In order to complete the implementation of this ultimate ant, read through the LaserAnt class, set the class attributes appropriately, and implement the following two functions:

1. insects_in_front is an instance method, called by the action method, that returns a dictionary where each key is an Insect and each corresponding value is the distance (in places) that that Insect is away from LaserAnt . The dictionary should include all Insects on the same place or in front of the LaserAnt , excluding LaserAnt itself.
2. calculate_damage is an instance method that takes in distance , the distance that an insect is away from the LaserAnt instance. It returns the damage that the LaserAnt instance should afflict based on:
   - The distance away from the LaserAnt instance that an Insect is.
   - The number of Insect s that this LaserAnt has already damaged, stored in the insects_shot instance attribute.

In addition to implementing the methods above, you may need to modify, add, or use class or instance attributes in the `LaserAnt` class as needed.

> **Important**: If an insect's health is unaffected, its health should *remain as a whole number (integer)*, as it was when the insect was initially created.
>
> **Note**: There are no unlocking tests for this question.

```
python3 ok -q EC4
```

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