Middlebury

CSCI 201: Data Structures

Fall 2024

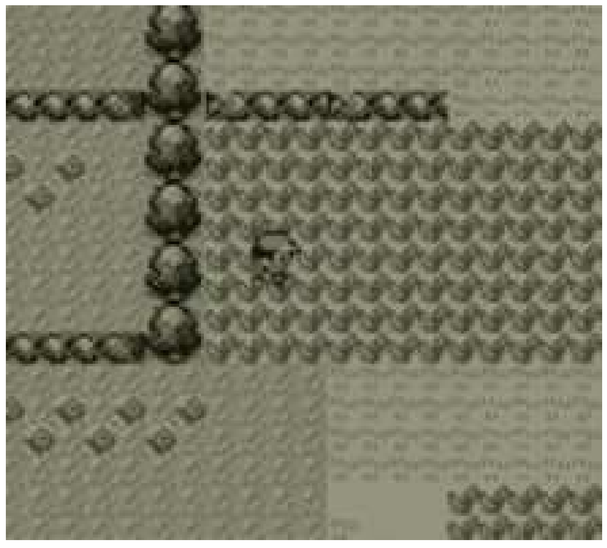
Lecture 3R: `Java` Collections

NO MORE NEW `Java` SYNTAX

(almost: maybe a few small things, but not as much as the last few weeks)

Goals for today:

- Use `javac` and `java` directly!
- Identify the difference between an Abstract Data Type and a Data Structure.
- Use an `ArrayList` to store multiple items (of the same type), in which the number of items can increase/decrease based on the needs of your algorithm.
- Use a `HashMap` to store key-value pairs.



First, let's unpack what the VS Code play button is doing.

Open a Terminal in the `lecture06` folder:

```
username@computer$ javac CompileThenRunWithArguments.java
```

```
username@computer$ java CompileThenRunWithArguments
```

Now try:

```
username@computer$ java CompileThenRunWithArguments x y c 123 MikeWazowski
```

```
public class CompileThenRunWithArguments {
  public static void main(String[] args) {
    System.out.println("Here's what was passed to the program:");
    for (int i = 0; i < args.length; i++) {
      System.out.println("Argument [" + i + "]: " + args[i]);
    }
    if (args.length == 0) System.out.println("Nothing!");
  }
}
```

Brainstorm: How would you keep track of which Pokémon a player has?

This would be a bit hard to do with fixed-size arrays (directly).
Imagine we had a utility to keep track of this - what methods would you like?

add(item): append item to end of list

remove(index): remove item at specific index

sort: sort items

indexOf: finds index of item

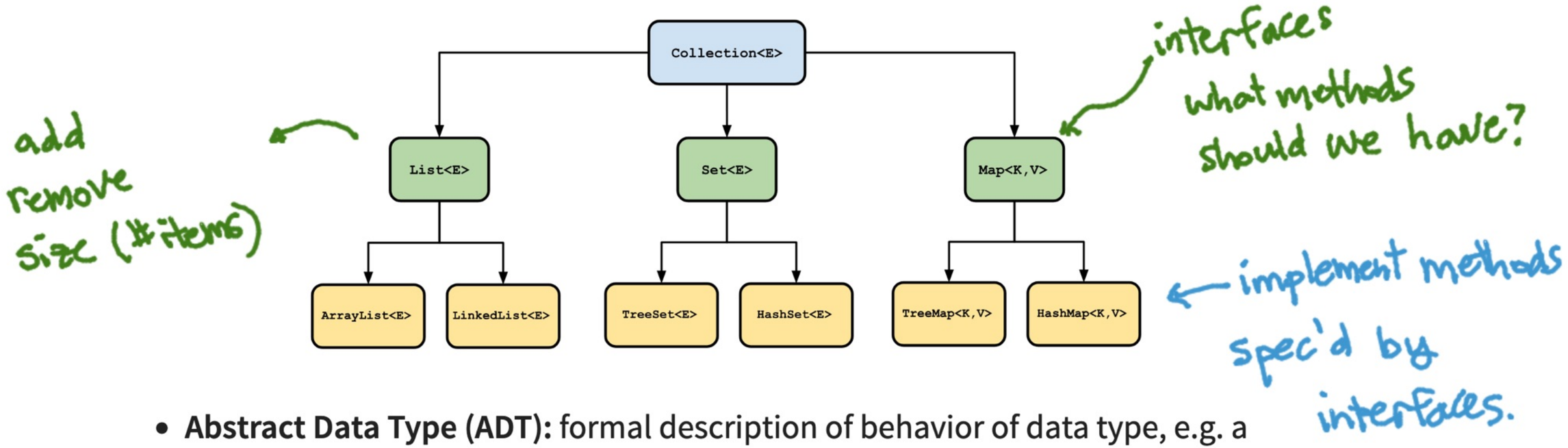
Construct

get(index): retrieve item at index.

Size: # items stored

Luckily, there are tools (built into Java) to help with this.

A collection represents a group of objects, known as its elements.



- **Abstract Data Type (ADT):** formal description of behavior of data type, e.g. a `List` allows accessing item at a specified index (but implementation can vary).
- **Data Structure:** concrete organization/representation of data (implements spec defined by an ADT). Example: `ArrayList`.

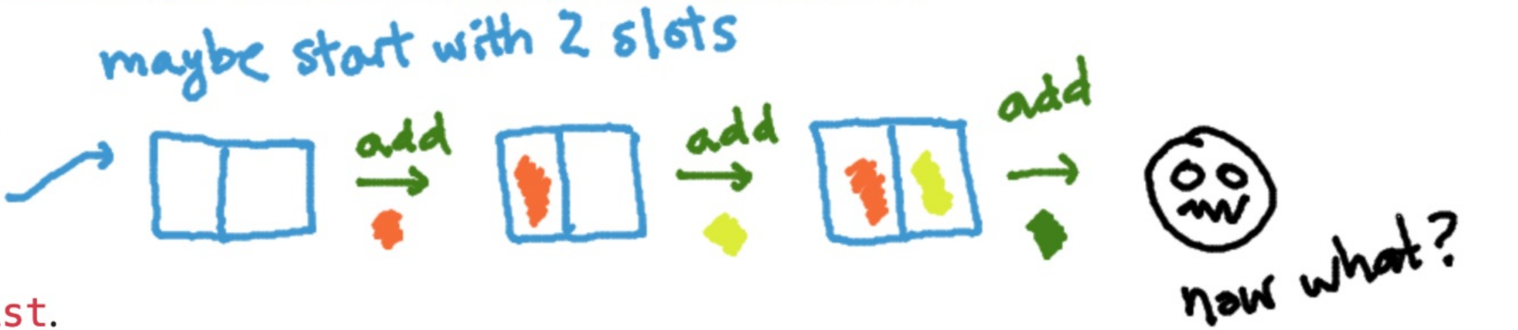
Okay, let's take a shot at a `List` ourselves.

We'll design our own implementation of a `List` called `DIYList`.

But first, we should check the `List` spec:
https://docs.oracle.com/javase/8/docs/api/java/util/List.html

Let's focus on methods to:

1. Construct an empty `DIYList`.
2. `add` an item to a `DIYList`.
3. `remove` an item from a `DIYList`.
4. Retrieve the number of items (`size`) in a `DIYList`.
5. `clear` the items in a `DIYList`.



Idea: use a fixed-size array that has enough space (capacity) to hold our items.

If we need more space, just make this array bigger and copy items!

Adding (add) an item to a DIYList.

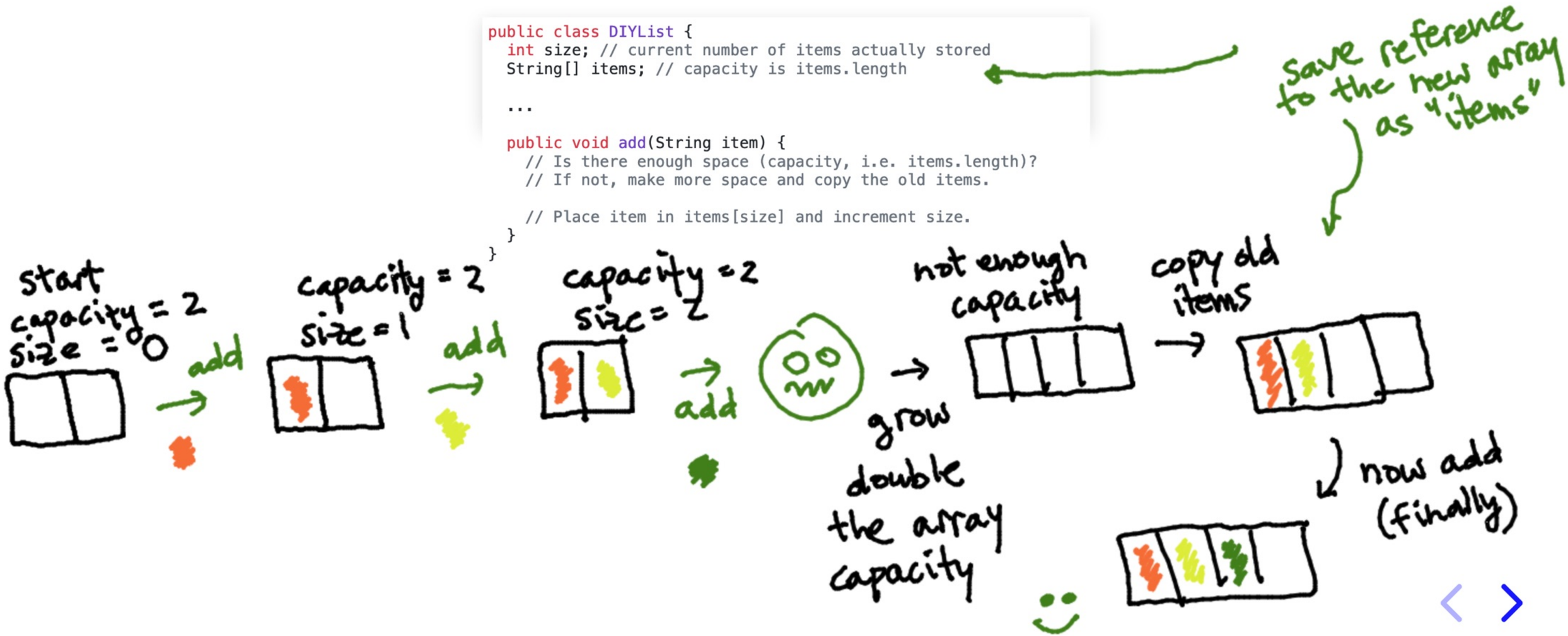
Without loss of generality, imagine our DIYList can only hold String items.

```
public class DIYList {
  int size; // current number of items actually stored
  String[] items; // capacity is items.length

  ...

  public void add(String item) {
    // Is there enough space (capacity, i.e. items.length)?
    // If not, make more space and copy the old items.

    // Place item in items[size] and increment size.
  }
}
```



Removing (`remove`) an item from a `DIYList`.

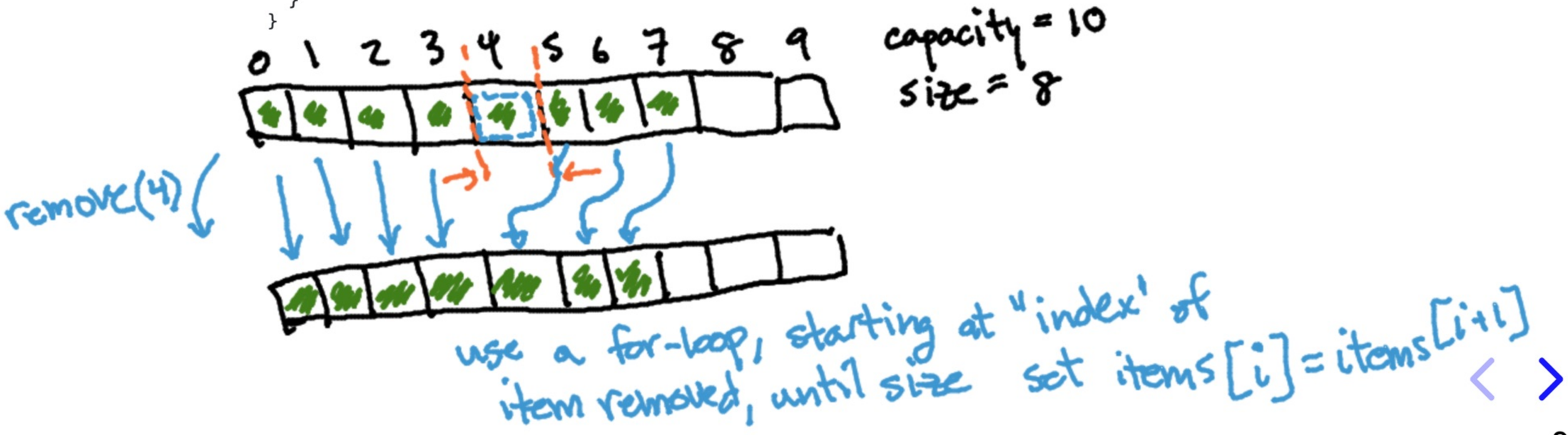
```
public class DIYList {
  int size; // current number of items actually stored
  String[] items; // capacity is items.length

  ...

  public void remove(int index) {
    // if index is beyond the index of the last item, nothing to do -> return

    // replace the item at index with the item at index + 1
    // replace the item at index + 1 with the item at index + 2
    // replace the item at index + 2 with the item at index + 3
    // ... until all items after the index have been shifted left

    // decrement size (because we removed an item)
  }
}
```



Clearing (`clear`) the items in a `DIYList`.

```
public class DIYList {
  int size; // current number of items actually stored
  String[] items; // capacity is items.length

  ...

  public void clear() {
    // set all items to null

    // set size to 0
  }
}
```

The truth is that we just implemented an `ArrayList`!

Main idea of an `ArrayList`:

- Internally use an array to hold the items.
- This array needs to have enough space (capacity) to hold the items.
- To add an item:
  - First check if there is enough space.
    If not, make a new array with more space and copy the old items into this array.
  - Add the new item to the next empty slot.
- How should we increase the capacity?

https://docs.oracle.com/javase/8/docs/api/java/util/ArrayList.html#ensureCapacity-int-

Each ArrayList instance has a *capacity*. The capacity is the size of the array used to store the elements in the list. It is always at least as large as the list size. As elements are added to an ArrayList, its capacity grows automatically. The details of the growth policy are not specified beyond the fact that adding an element has constant amortized time cost.

An application can increase the capacity of an ArrayList instance before adding a large number of elements using the ensureCapacity operation. This may reduce the amount of incremental reallocation.

Let's practice with `ArrayList`s.

Note that `Java Collection`s only work with reference types
We cannot directly use primitive types.

How do we use them with `int`, `double`, `char` etc.?
Luckily, there are wrapper classes called `Integer`, `Double`, `Character`, etc.

```java
import java.util.ArrayList; // don't forget this!
// import java.util.*; // can also be convenient to import everything in java.util

public class ArrayListExamples {
  public static void main(String[] args) {
    // initialize empty array list
    ArrayList<Integer> list = new ArrayList<>();

    list.add(3);
    list.add(12);
    list.add(4);

    System.out.println("list size = " + list.size()); // 3

    for (int i = 0; i < list.size(); i++) {
      System.out.println("Item[" + i + "]: " + list.get(i));
    }

    list.remove(1); // remove item at index 1 (i.e. the 12)
    System.out.println("list size = " + list.size()); // 2
  }
}
```

`HashMap`: another useful collection to know about.

- `HashMap<K, V>`: stores key-value pairs (keys have type `K` and values have type `V`).
- **Useful methods:** `containsKey` (checks if a key of type `K` exists), `put` (inserts a key-value pair), `get` (retrieves the value associated with some key), `keySet` (retrieves a `Set` of all keys).

```java
import java.util.HashMap;
// import java.util.*; // <-- this can be more convenient!

public class HashMapExample {
  public static void main(String[] args) {
    String lyric = "and i love vermont, but it's the season of the sticks";

    HashMap<Character, Integer> frequency = new HashMap<>();
    for (int i = 0; i < lyric.length(); i++) {
      char c = lyric.charAt(i);
      if (frequency.containsKey(c)) {
        frequency.put(c, frequency.get(c) + 1);
      } else {
        frequency.put(c, 0);
      }
    }

    Set<Character> characters = frequency.keySet();
    for (Character c : characters) {
      System.out.println("Character " + c + " appears " + frequency.get(c) + " times");
    }
  }
}
```

Find The Bug!

Here it is! 

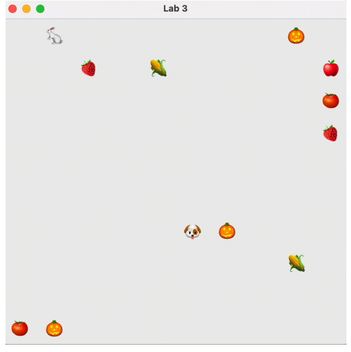
```java
import java.util.HashMap;
// import java.util.*; // <-- this can be more convenient!

public class HashMapExample {
  public static void main(String[] args) {
    String lyric = "and i love vermont, but it's the season of the sticks";

    HashMap<Character, Integer> frequency = new HashMap<>();
    for (int i = 0; i < lyric.length(); i++) {
      char c = lyric.charAt(i);
      if (frequency.containsKey(c)) {
        frequency.put(c, frequency.get(c) + 1);
      } else {
        frequency.put(c, 1); // first time we encounter a character, it counts, so insert 1 not 0
      }
    }

    Set<Character> characters = frequency.keySet();
    for (Character c : characters) {
      System.out.println("Character " + c + " appears " + frequency.get(c) + " times");
    }
  }
}
```

See you tomorrow!



- We'll practice using `ArrayList`s in tomorrow's lab.
- `HashMap`s were just introduced now in case you find them helpful to solve problems (we'll talk about the underlying data structures later in the semester).
- `HashSet`s can also be useful if you want to store an unordered set of items.
- **Moving forward:** labs will be due on Tuesday nights and homeworks will be due on Fridays (released on Sundays): **Homework 2 due 9/27 at 11:59pm.**
- Reminder that Noah (go/noah) and Smith (go/smith) have office hours throughout the week and the 201 Course Assistants have drop-in hours in the late afternoons/evenings (go/cshelp).
- Submit exit ticket 3R today.