Privacy Leaks and Copying Objects

Inspired by material from:

Nelson Padua-Perez, Ben Bederson, Bonnie Dorr, Fawzi Emad, David Mount, and Jan Plane

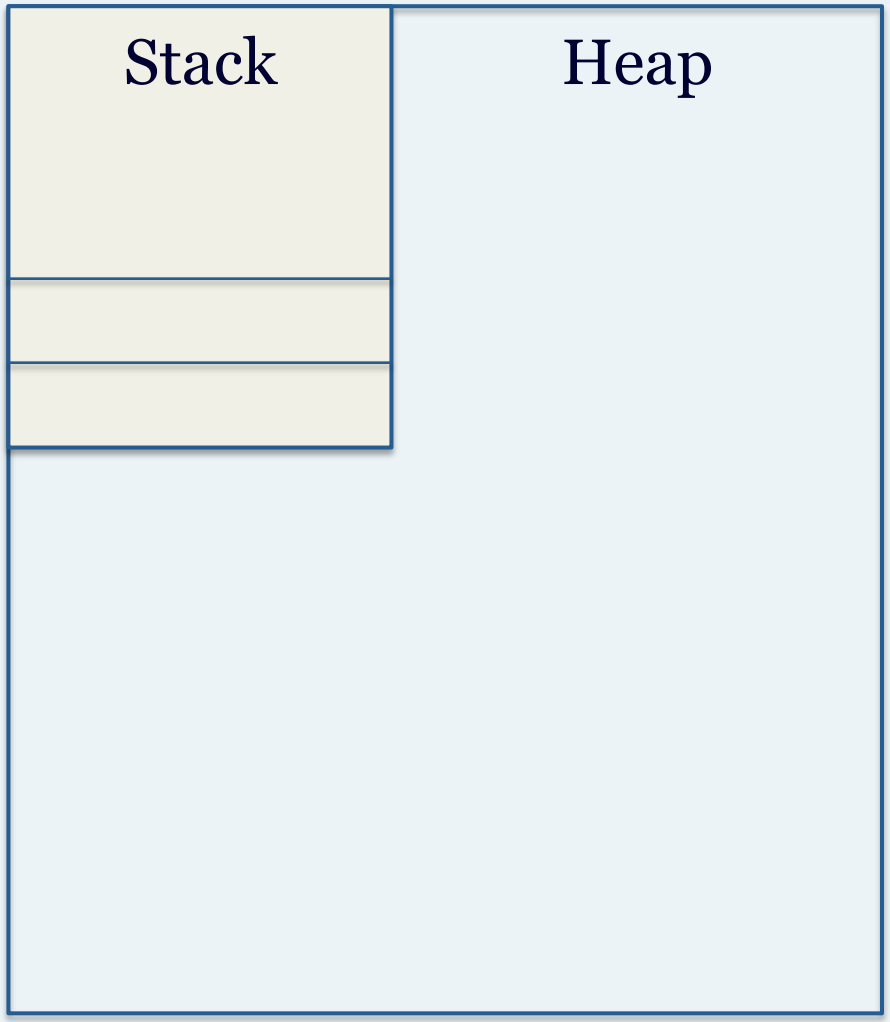
Review: private vs. public

- What is the difference between private and public instance variables?

```
public class Fraction {
        private  int numerator;
        private  int denominator;

        public int getNumerator() {
                return numerator;
        }
        public int getDenominator() { … }

        public static Fraction neg(Fraction frac) {
                return new Fraction(-frac.getNumerator(), frac.getDenominator());
                // Is the following allowed?
                // return new Fraction(-frac.numerator, frac.denominator);
        }
}

Fraction frac = new Fraction();
frac.numerator = 1;                    // Will this give an error?
```

Privacy leaks

```
Public class GasTank {
        private Fraction fuel;
        public GasTank() {
                fuel = new Fraction(1, 1);
        }
        public Fraction getFuel() {
                return fuel;
        }
        public void setFuel(Fraction f) {
                if (f.asDouble <= 1)
                        fuel = f;
        }
}

// What does the following code do?
GasTank tank = new GasTank();
Fraction fuelRead = tank.getFuel();
fuelRead.setNumerator(2);
```



Privacy leaks

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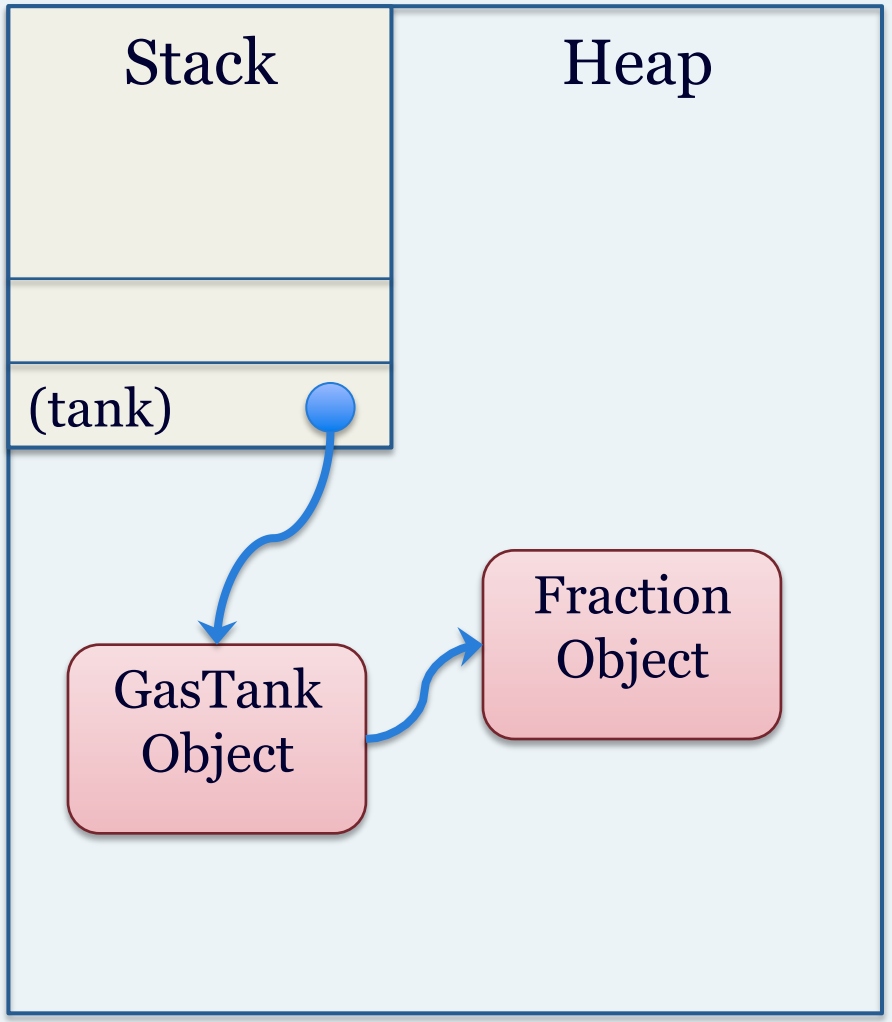

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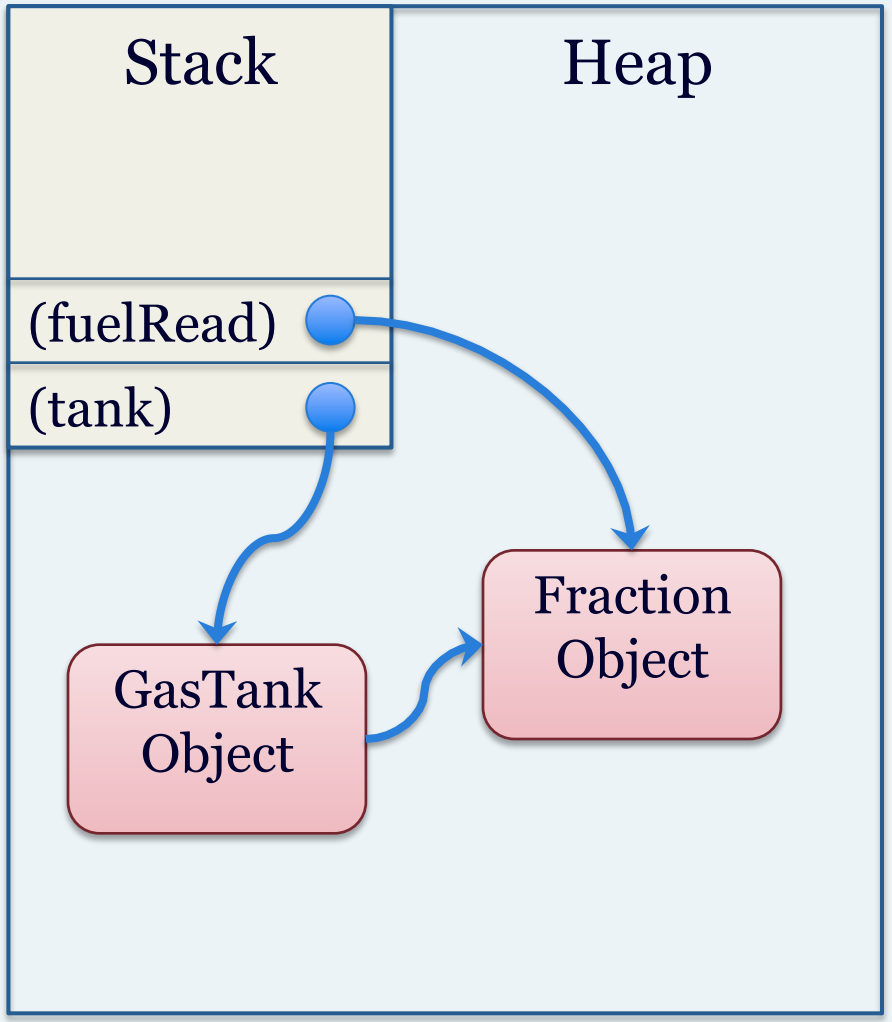
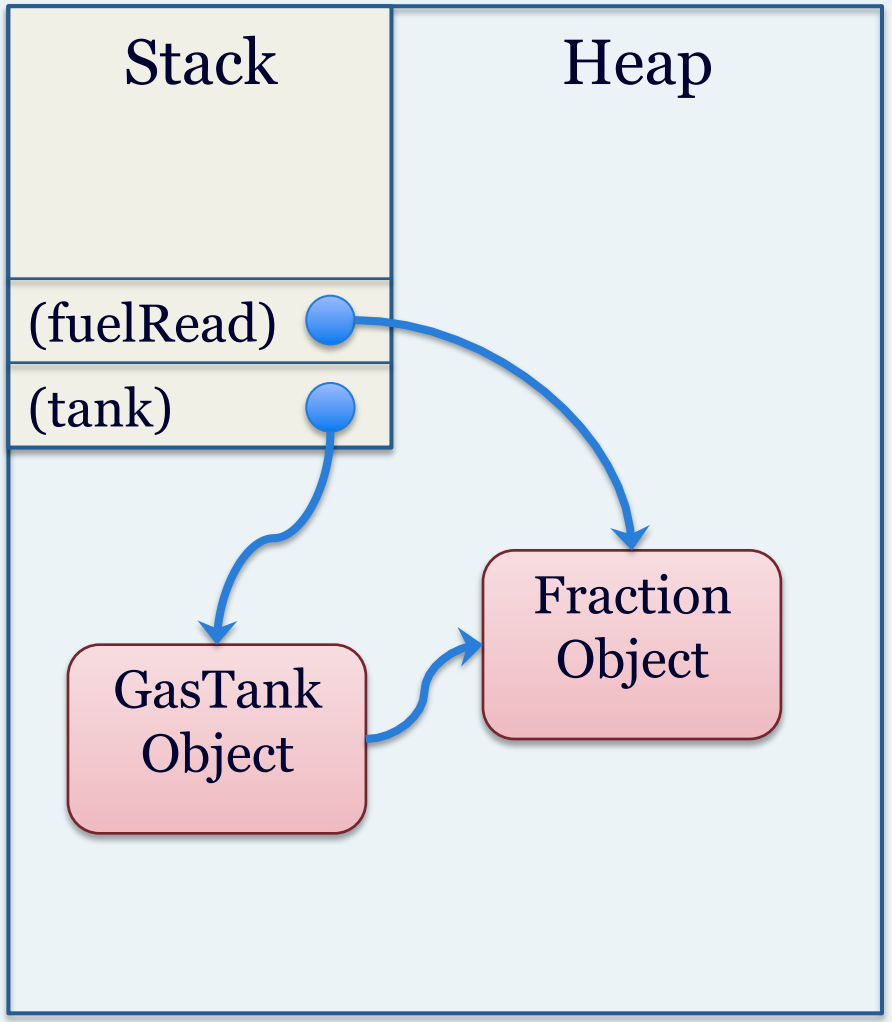


Privacy leaks and fixing them

- A privacy leak occurs when a private instance variable can be modified outside of its class
- This happens because of aliasing, two references to the same object
- What if we rewrite getFuel()?

```
public Fraction getFuel() {
        return new Fraction(fuel);
}
```

- Returns a copy of fuel
- Changes to this copy won't affect the original



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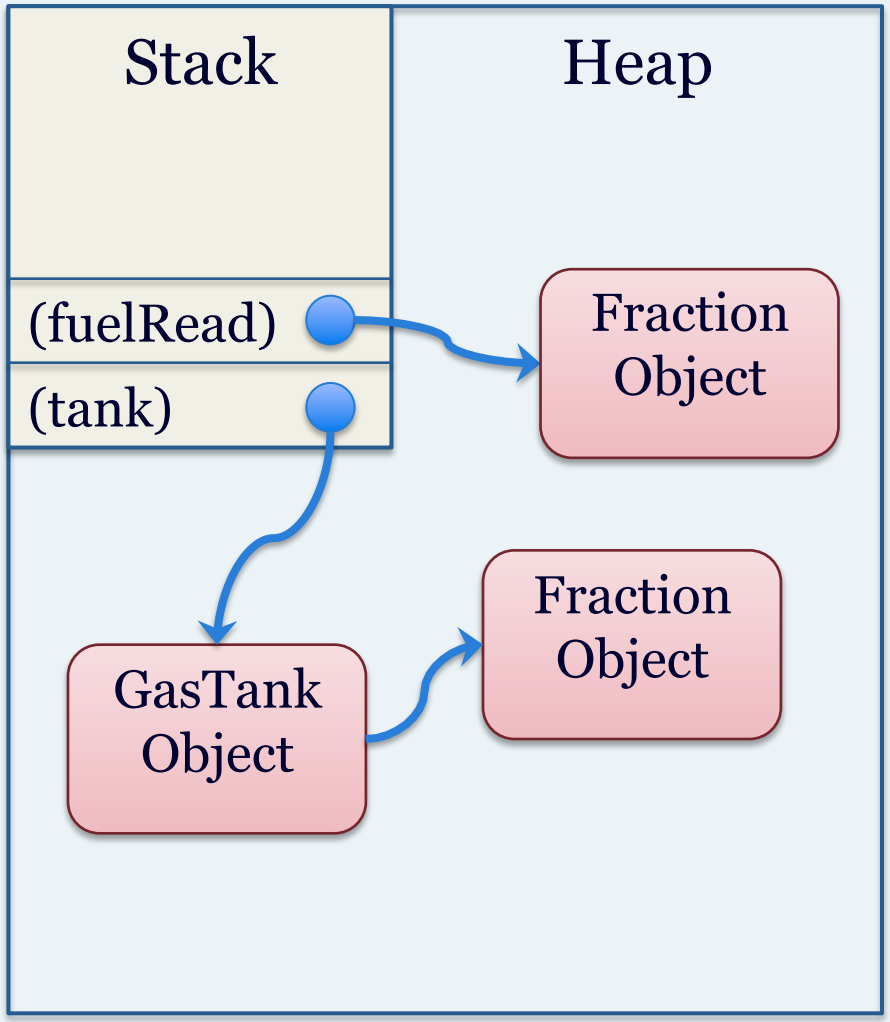


Copying objects

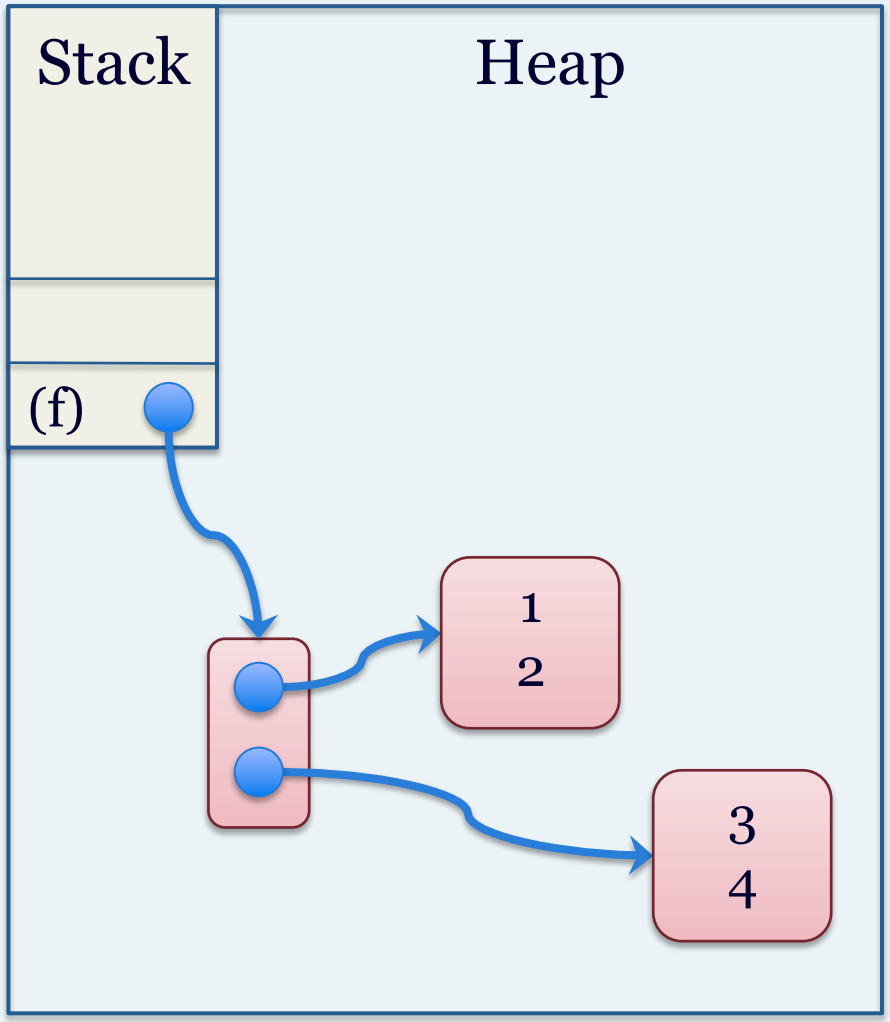
- Three ways to copy objects
  - Reference copy
  - Shallow copy
  - Deep copy
- Let's start by looking at how to copy an ArrayList of Fractions each way

Reference copy

```
ArrayList<Fraction> f =
                    new ArrayList<Fraction>();

f.add(new Fraction(1, 2));
f.add(new Fraction(3, 4));

ArrayList<Fraction> g = f;
```



Reference copy

```
ArrayList<Fraction> f =
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f.add(new Fraction(1, 2));
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ArrayList<Fraction> g = f;
```
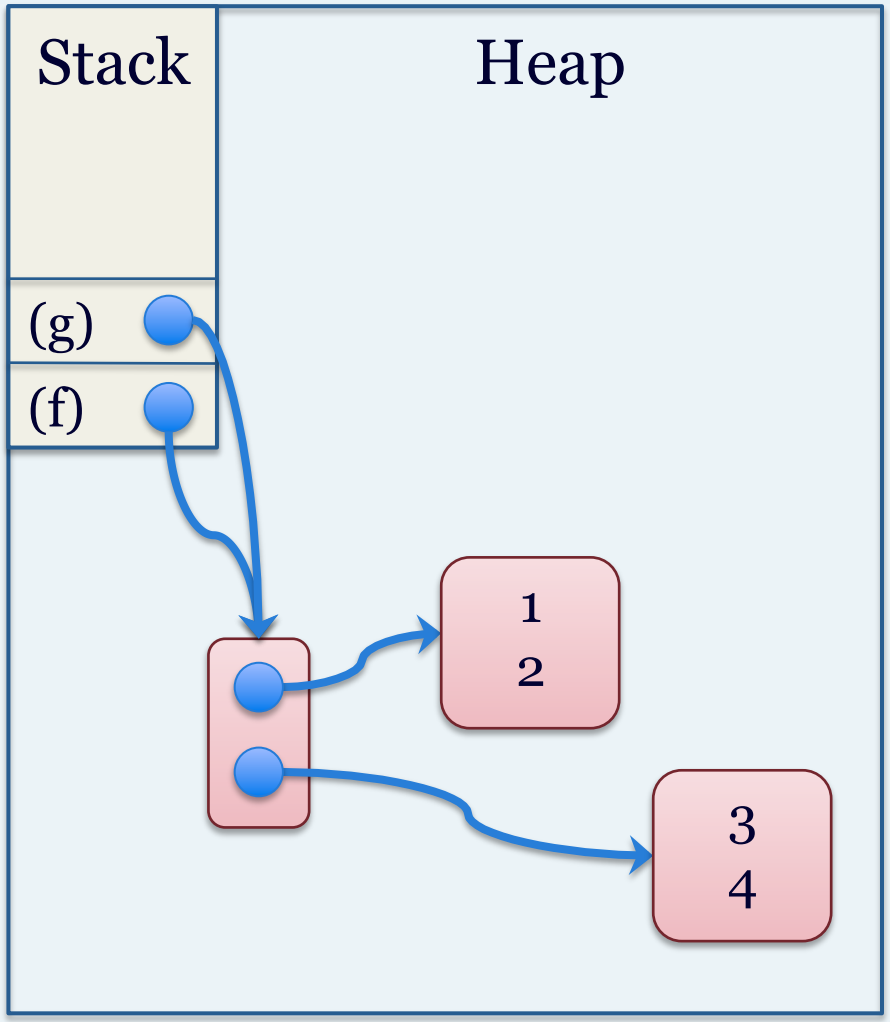
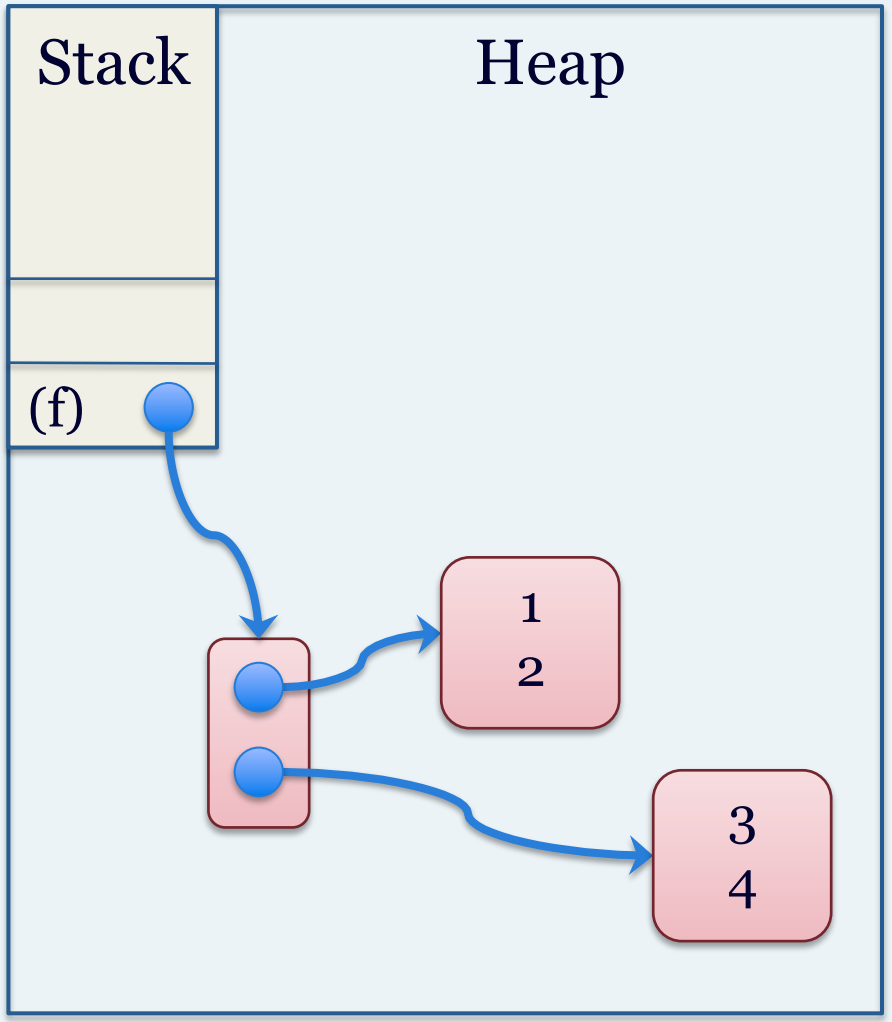

- We only copied a reference to an ArrayList



Shallow copy

```
ArrayList<Fraction> f =
                    new ArrayList<Fraction>();

f.add(new Fraction(1, 2));
f.add(new Fraction(3, 4));

ArrayList<Fraction> g =
                    new ArrayList<Fraction>();

for (Fraction frac : f) {
        g.add(frac);
}
```



Shallow copy

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ArrayList<Fraction> f =
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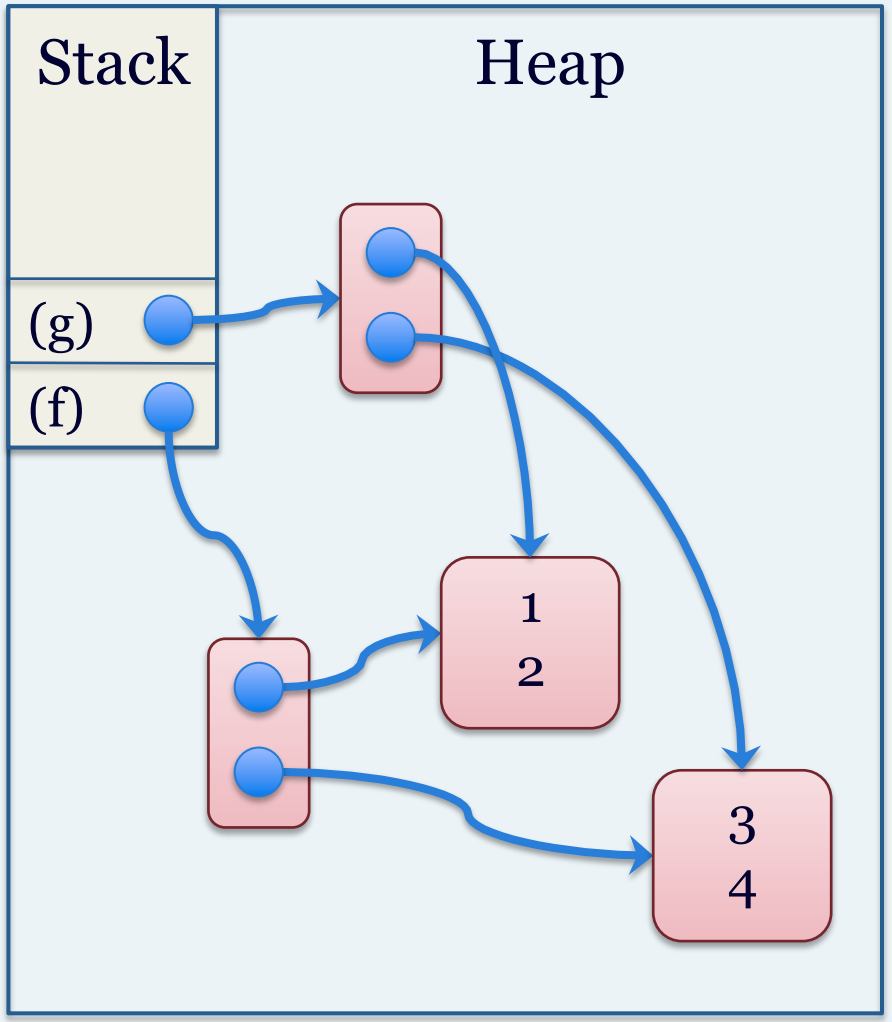
f.add(new Fraction(1, 2));
f.add(new Fraction(3, 4));

ArrayList<Fraction> g =
                    new ArrayList<Fraction>();

for (Fraction frac : f) {
      g.add(frac);
}
```

- We created a new ArrayList, but copied references to each Fraction



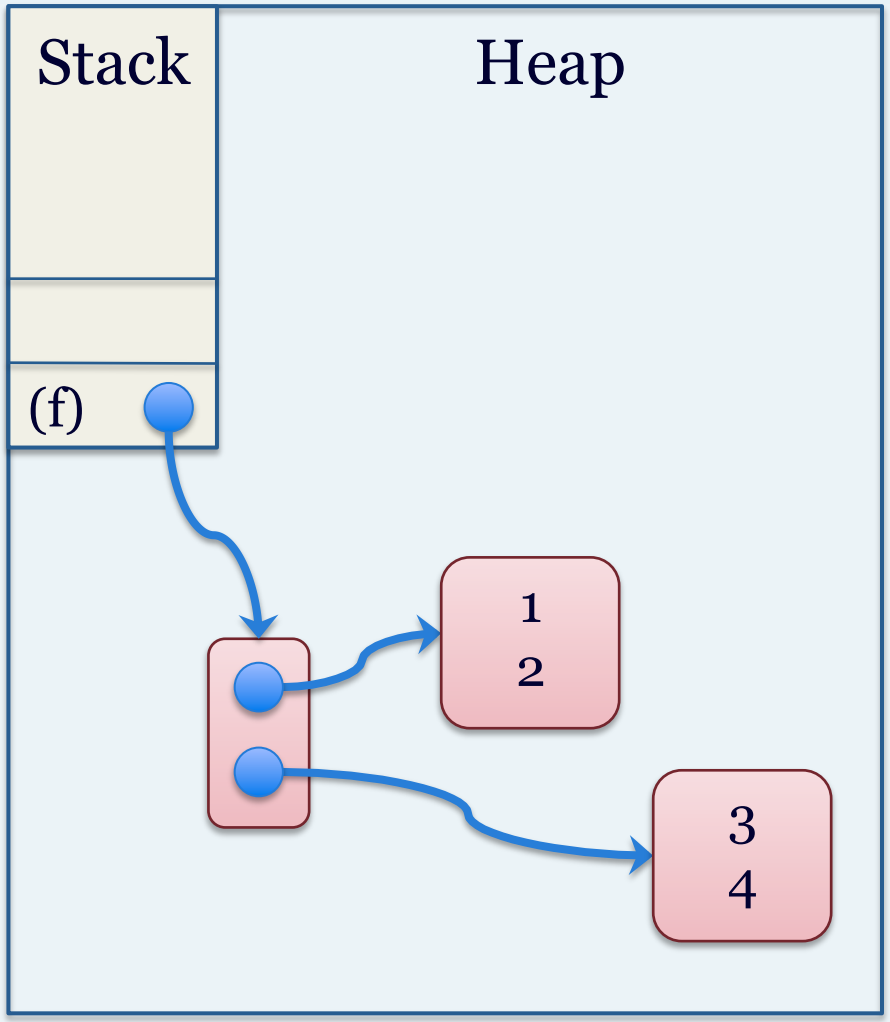
Deep copy

```
ArrayList<Fraction> f =
                    new ArrayList<Fraction>();

f.add(new Fraction(1, 2));
f.add(new Fraction(3, 4));

ArrayList<Fraction> g =
                    new ArrayList<Fraction>();

for (Fraction frac : f) {
        g.add(new Fraction(frac)); // New!
}
```



Deep copy

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f.add(new Fraction(1, 2));
f.add(new Fraction(3, 4));

ArrayList<Fraction> g =
                    new ArrayList<Fraction>();

for (Fraction frac : f) {
      g.add(new Fraction(frac)); // New!
}
```
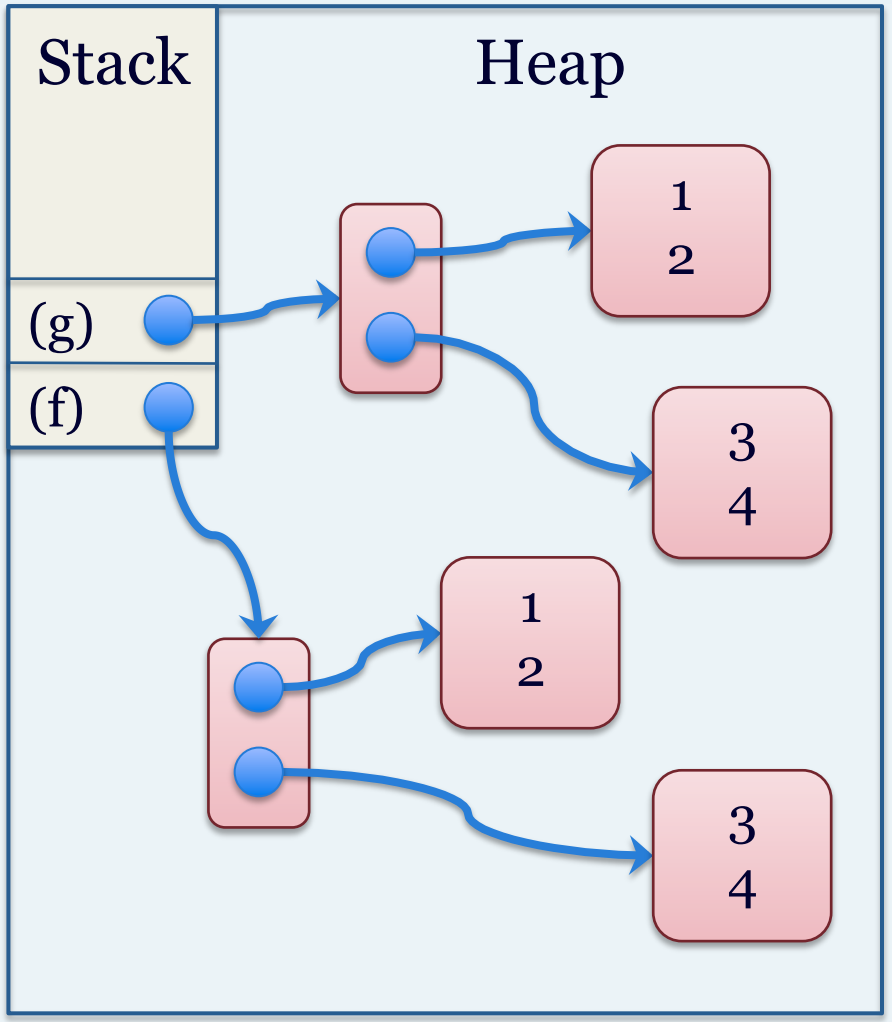

- We created a new ArrayList and created new copies of each object in the original ArrayList



This reference and copy constructors

- The “this” reference represents a reference to the current object being operated on by a non-static method
  - It has automatically been initialized for you
  - It cannot be used in a static method
- A copy constructor is a special type of constructor that takes an instance of the same class as a parameter
  - It uses the data from the parameter object to initialize a new object
  - Example:
    - String s = “example”;
    - String t = new String(s);

Deep copy with copy constructor

```
public class Fraction {
        private  int numerator;
        private  int denominator;

        public Fraction(int num, int den) {
                numerator = num;
                denominator = den;
        }

        public Fraction(Fraction f) {
                this(f.numerator, f.denominator);
        }
}
```

```
public class GasTank {
        private Fraction fuel;

        public GasTank(Fraction fuel) {
                this.fuel = fuel;
        }
        public GasTank(GasTank tank) {
                this(new Fraction(tank.fuel);
        }

        public Fraction getFuel() {
                return new Fraction(fuel);
        }
        public void setFuel(Fraction f) {
                if (f.asDouble <= 1)
                        fuel = f;
        }
}
```

Copy comparison

- Which type of copy offers the most protection against aliasing and privacy leaks?
  - Deep copy
- Which type uses the most time and space?
  - Deep copy
- Which type uses the least time and space?
  - Reference copy
- What if the object can't be modified?
  - These are called immutable objects

Mutable vs. Immutable objects

- A mutable object is changeable (root word: “mutate”)
  - It can have:
    - Setters and other methods that modify instance variables
    - Public instance variables
  - Example: Fraction object
- An immutable object cannot be changed or modified after creation
  - It cannot have:
    - Setters and other methods that modify instance variables
    - Methods that return a reference to a mutable instance variable
    - Public instance variables (instance variables must be private
  - Example: String object

Immutable object example

```
Public final class ImmutableFraction {          // The class is final
    private final int numerator;                // The variables are private and final
    private final int denominator;

    public Fraction(int num, int den) {         // Instance variables must be set during
        numerator = num;                        // construction of the object
        denominator = den;
    }

    public int getNumerator() {                 // Getters, but no setters
        return numerator;                       // Returning a primitive type is okay
    }
    public int getDenominator() {
        return denominator;
    }
    public String toString() {
        return numerator + "/" + denominator;
    }
}
```

Another way to protect GasTank

```
Public class GasTank {
        private ImmutableFraction fuel;      // Now using an ImmutableFraction
        public GasTank() {
                fuel = new Fraction(1, 1);
        }
        public Fraction getFuel() {
                return fuel;                 // Returns a reference to an object which cannot
        }                                    // be modified
        public void setFuel(Fraction f) {
                if (f.asDouble <= 1)
                        fuel = f;
        }
}

// What does the following code do now?
GasTank tank = new GasTank();
Fraction fuelRead = tank.getFuel();
fuelRead.setNumerator(2);            // Not possible, ImmutableFraction has no setters!
```

Another “this” example

```
Public class PersonWithANameAndAge {
        private String name;
        private int age;

        public PersonWithANameAndAge (String name, int age) {
                this.name = name;
                this.age = age;
        }

        public PersonWithANameAndAge (PersonWithANameAndAge p) {
                this(new String(p.name), p.age);
        }

        public Fraction getName() {
                return new String(name);
        }
}
```

Code example

- Lets look at some CopyLectureCode.zip
  - Will be available on ELMS