CSCI 1103: Object-Oriented Objects

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Logistics

Reading from Eck

Ch 5 on Objects/Classes

Goals

- Finish arrays of objects
- Static fields
- Non-static methods

Lab08: Simple object definitions

- Stock object
- Methods in same java file

Project

- Spec up
- Due a week from Wed

Static/Non-static Stuff so far

- The keyword `static` in Java roughly translates to "belongs to the whole class and all objects"
- So far we have written the following

`static` methods

```
public class MyClass{
  public static
    int doSomething(...){
    ...
  }
```

- Nothing special about them, invoked with

  `MyClass.doSomethig(..)`
- Must pass in all parameters to the methods

Non-static fields

```
public class Thing{
  int part1;
  double part2;
  String part3;
}
```

- Each `Thing` has its own `part1, part2, part3`
- 4 `Things` means 12 pieces of data, 4 `ints`, 4 `doubles`, 4 `String` references

Static Class Fields

- A `static` field indicates there is only 1 memory location for the entire class, NOT one per object
- Closest thing Java has to a *global variable*
- Seen examples of static fields from some classes

```
double pie = Math.PI;
double natbase = Math.E;
PrintStream ps = System.out;
```

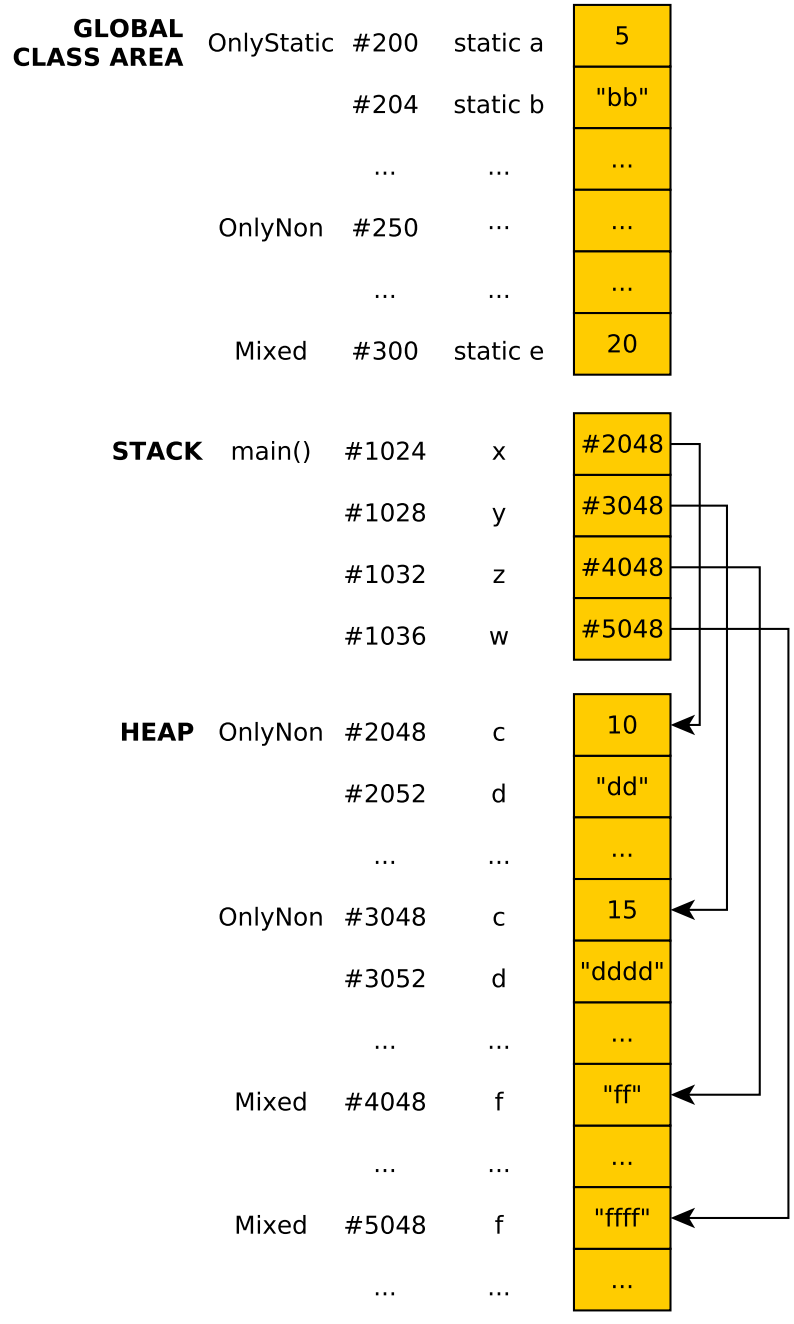
- Syntax static establish a static field is simple

```
public class Mixed{
  public static int e;  // static field
  public String f;      // non-static field
}
```

- Every instance of a `Mixed` has its own `f`
- There is only one integer e, accessible via `Mixed.e`

Demo of Static vs Non-Static Fields

```
 1  class OnlyStatic{
 2    public static int a;       // both static
 3    public static String b;
 4  }
 5  class OnlyNon{
 6    public int c;              // both non-static
 7    public String d;
 8  }
 9  class Mixed{
10    public static int e;       // one static
11    public String f;           // one non-static
12  }
13
14  public class StaticFields{
15    public static void main(String args[]){
16      OnlyStatic.a = 5;  OnlyStatic.b = "bb";
17
18      // OnlyNon.c = 4;      // ERROR: non-static fi
19      // OnlyNon.d = "ddd";  // ERROR: non-static fi
20      OnlyNon x = new OnlyNon();
21      x.c = 10;   x.d = "dd";
22      OnlyNon y = new OnlyNon();
23      y.c = 15;   y.d = "dddd";
24
25      Mixed.e = 20;
26      // Mixed.f = "ff";     // ERROR: non-static fi
27
28      Mixed z = new Mixed();
29      z.f = "ff";
30      Mixed w = new Mixed();
31      w.f = "ffff";
32    }
33  }
```



Exercise: Recap what we learned about static fields

1. What's the difference between a `static` and a non-static field?
2. How many of each kind of field are gotten when calling `new`
3. Draw a quick diagram of the following.

```
public class Thing{
  public int red;
  public double blue;
  public static int green;

  public static void main(String args[]){
    Thing x = new Thing();
    Thing y = new Thing();

    x.red = 5;
    y.blue = 7.0;

    ///////// DRAW HERE ///////////

    // which works / doesn't?
    Thing.green = 9;
    Thing.red   = 10;
  }
}
```

Non-static Methods

- `static` roughly means *class-level*, as in belonging to the entire class
- Non `static` roughly means *instance-level*, as in associated with a specific instance/object
- Non-static methods are ALWAYS invoked with a specific object/instance

```
String s = "hello";
String t = "goodbye";

int len1 = s.length(); // 5
int len2 = t.length(); // 7
```

- During a the execution of a non-static method, the keyword `this` refers to the object on which the method is running

Compare: Static vs Non-static Method Defs/Calls

Static

```
 1  public class Omelet{
 2    int eggs;
 3    int cheese;
 4    double cookedFor;
 5    String extras;
 6
 7    static void cookFor(Omelet om,
 8                        double time){
 9      om.cookedFor += time;
10    }
11    static void addEgg(Omelet om){
12      om.eggs++;
13    }
14  }
15  main(){
16    Omelet standard = new Omelet();
17    int x = 5;
18    Omelet.addEgg(standard);
19    Omelet.cookFor(standard, 2.5);
20  }
```

Non-static

```
 1  public class OOOmelet{
 2    int eggs;
 3    int cheese;
 4    double cookedFor;
 5    String extras;
 6
 7    void cookFor(double time){
 8      this.cookedFor += time;
 9    }
10
11    void addEgg(){
12      this.eggs++;
13    }
14  }
15  main(){
16    OOOmelet standard = new OOOmelet();
17    int x = 5;
18    standard.addEgg();
19    standard.cookFor(2.5);
20  }
```

Examine `OOOmelet.java` to see full implementation

`this` variable: reference to current object

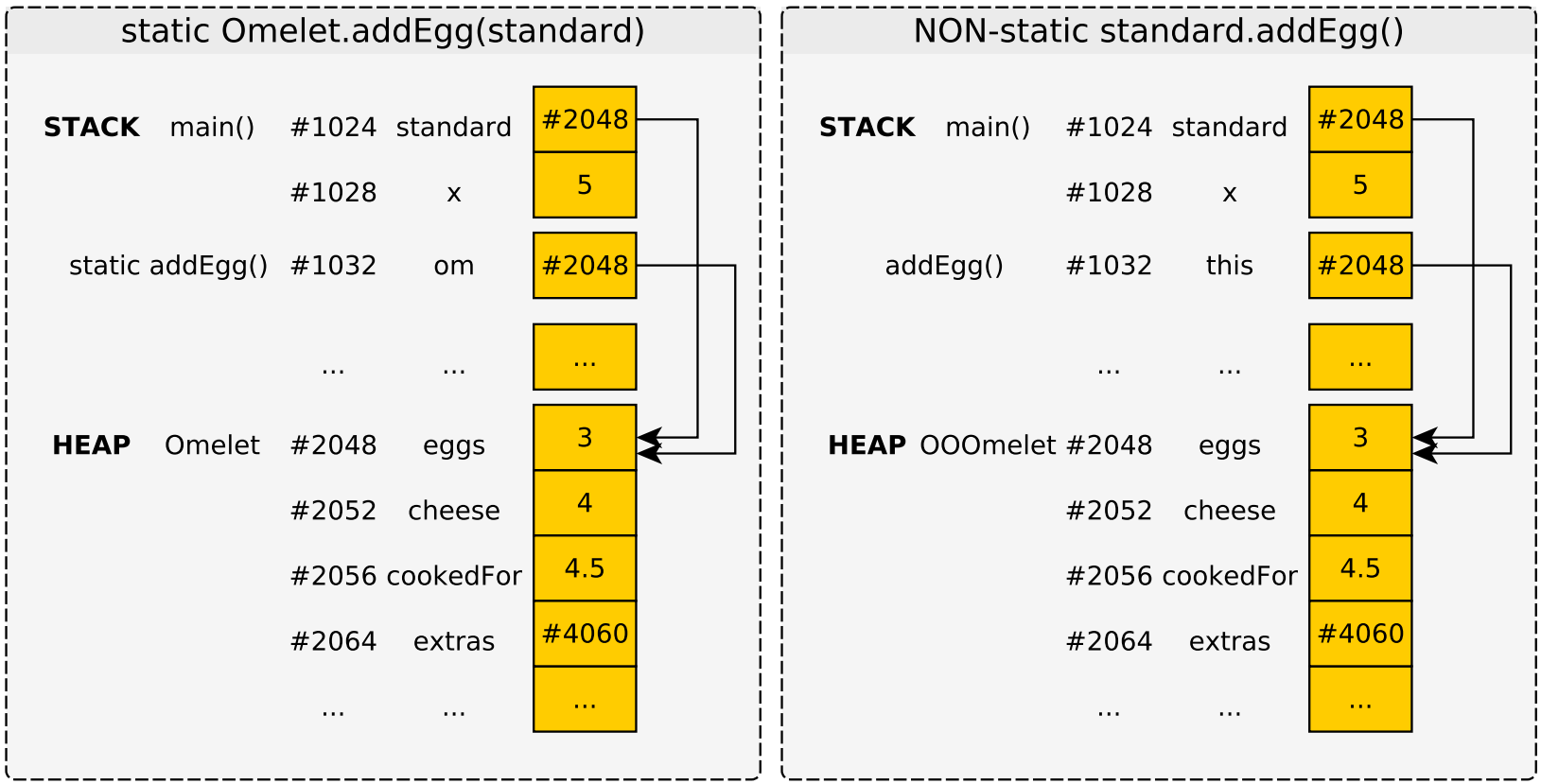
- Variable `this` is automatically created in non-static methods
- Gets filled in with the value of the object being operated on

```
standard.addEgg();
^^^^^^^^
```

```
during addEgg(), this will
refer to OOOmelet standard
```

```
coronary.addEgg()
^^^^^^^^
```

```
during addEgg(), this will
refer to OOOmelet coronary
```



Constructors

- Objects usually have necessary fields initialized at creation
- Special method called a constrctor
- Method name is always identical to class name, return type is omitted
- CK commonly uses `this.field = param;` to initialize fields

```
public class OOOmelet{
  ...
  // Constructor to initialize fields to given values. cookedFor is
  // always initialized to 0.0.
  public OOOmelet(int eggs, int cheese, String extras){
    this.eggs = eggs;           // set field eggs to parameter eggs
    this.cheese = cheese;       // set field cheese to parameter cheese
    this.extras = extras;       // set field extras to parameter extras
    this.cookedFor = 0.0;       // always set cookedFor to 0.0
  }
  ...
}
public class OOOmeletMain{
  public static void main(String args[]){
    OOOmelet small = new OOOmelet(2,5,"ham");   // smallish OOOmelet
    OOOmelet large = new OOOmelet(5,8,"bacon"); // largeish OOOmelet
    ...
  }
}
```

Exercise: Draw a Memory Diagram

- Show the `OOOMeletMain.java` and `OOOMelet.java.exercise`
- Running the `main()` method, trace execution
- Draw memory diagrams of what things look like at the numbered locations
- Note: May hit some locations more than once
- Important: Don't forget the automatic `this` variable in non-static methods

Easy Printing: `toString()` method

- Most complex objects provide a `toString()` method to produce nice output
- Compare

  ```
  OOOmelet small = new OOOmelet(2,5,"ham");
  System.out.println(small);
  ```

- NO toString() method:

  ```
  OOOmelet@2a139a55
  ```

- WITH toString() method:

  ```
  3 eggs, 5 oz cheese, cooked for 1.5 mins, extras: ham
  ```

```
public class OOOmelet{
  private int eggs;          private int cheese;
  private double cookedFor; private String extras;

  // Create a pretty string version of the OOOmelet.
  public String toString(){
    return
      String.format("%d eggs, %d oz cheese, cooked for %.1f mins, extras: %s",
                    this.eggs, this.cheese, this.cookedFor, this.extras);
  }
```

String.format() for toString()

- Extremely useful method `static` method of `String` class
- Works like `printf()` but instead of printing to the screen, creates a string and returns it
- Example:

```
String s =
  String.format("apples: %d  weight: %.1f  kind: %s",
                          5,         1.27,   "Honeycrisp");

System.out.println(s);
// apples: 5  weight: 1.3  kind: Honeycrisp
```

- Often used in `toString()` methods to format info on object for display
- Also used in testing files to produce error messages containing data for debugging

Exercise: Dog Constructor and `toString()`

- Define constructor for Dog class to the right
- Infer arguments/defaults from use in `main()`
- Define `toString()` method
- Infer format from use in `main()`
- Make use of `String.format()`

```
public class Dog{
  public String name;
  public int age;
  public boolean hasBone;

  // CONSTRUCTOR

  // toString()

  public static void main(String args[]){
    Dog s = new Dog("Stout",3);
    Dog r = new Dog("Rufus",1);
    r.hasBone = true;
    System.out.println(s.toString());
    System.out.println(r.toString());
  }
}
```

```
> javac Dog.java
> java Dog
Name: Stout  Age: 3  Bone? false
Name: Rufus  Age: 1  Bone? true
```

Access Modifiers

Access Levels for Fields/Methods by other stuff

Modifier	Class	Package	Subclass	World
public	Y	Y	Y	Y
protected	Y	Y	Y	N
no modifier	Y	Y	N	N
private	Y	N	N	N

- Mostly concerned with `public` and `private`, read about others on your own
- Most projects will specify required `public` methods, maybe `public` fields
- Most of the time you are free to create additional `private` methods and fields to accomplish your task

Official docs on access modifiers

http://docs.oracle.com/javase/tutorial/java/javaOO/accesscontrol.html

Accessor, Mutator, Class Invariant

- Common Java convention is to make all fields `private`
- `private` fields are only visible within on `.java` file accessor and mutator methods provided to work with object data
- Accessor often referred to as "getter" as in `getEggs()`
- Mutator sometimes called a "setters" but often have other names, intended to change object data
- Important: changing object data preserves any invariants of the class: related fields

```
public class OOOmelet{
  public int eggs;
  public int cheese;

  // Retrieve number of eggs
  public int getEggs(){
    return this.eggs;
  }

  // Add an egg to the omelet
  // if cooking hasn't begun
  public void addEgg(){
    if(this.cookedFor > 0){
      System.out.println("Yuck");
    }
    else{
      this.eggs++;
    }
  }
}
```

Invariants in Classes

OOOmelets (In-class)

- Once cooking starts, cannot add eggs
- Can only add time to cooking, not subtract
- Extra ingredients must be specified up front

Linear Equations (Lab09)

- $y = m \cdot x + b$
- Left and right sides of equation are always equal
- Changing `x` updates `y`, vice versa

Portfolio (Proj4)

- Adding a stock increases the `stockCount`
- Buying stocks deducts from cash
- Selling stocks adds to cash
- Cannot `withdraw()` more cash than is available
- Cannot sell more shares than available

Why Getters vs. Public Fields

- Simple objects can probably have `public` fields, direct access
  - Don't do this as you'll be penalized on manual inspection
- Slightly more complex objects like `OOOmelet` might get away with public fields but would allow ..
  - "Uncooking" of omelets: `o.cookedFor = 0.0;`
  - Add eggs after being cooked
  - Using private fields prevents this
- Complex objects like `Printstream` from `System.out` must preserve invariants: different parts must agree with each other.
  - Changing one field might screw up another one
  - Deny direct access via `private` fields
  - Mutation methods like `println()` keep all fields synchronized

Abstraction Up and Down

Break a problem into smaller parts. Define `public` methods between those parts. Think about internal details for one part at a time. Recurse for subparts as needed.

private Fields / public methods

OOOmelet.java

```
public class OOOmelet{
  private int eggs;
  private int cheese;
  private double cookedFor;
  private String extras;

  public double getEggs(){
    return this.eggs;
  }
  public double getCookTime(){
    return this.cookedFor;
  }
  public void addEgg(){
    ...
  }
  ...
}
```

Must access fields through public methods

UseOOOmelet.java

```
public class UseOOOmelet{
 public static
void main(String args[]){
  OOOmelet om =
    new OOOmelet(2,4,"ham");

  // CORRECT: public methods
  int eggs = om.getEggs();
  om.addEgg();

  // INCORRECT: No such symbol
  om.eggs = 5;  // compile error

  // CORRECT: public method
  om.cookeFor(1.0);

  // INCORRECT: No such symbol
  om.cookedFor=0.0; // compile error
 }
}
```

`private` Fields Visible only in One Java File

- `private` means visible in current Java File only
- Within `OOOmelet.java`, the name `eggs` is visible for all `OOOmelets`
- Even if that name is associated with "some other" `OOOmelet`
- See `moreEggs()` method: accessing `that.eggs` despite it being a private variable

```
// OOOmelet.java
public class OOOmelet{
  private int eggs;
  // Return true if this omelet has more
  // eggs than the parameter omelet
  public boolean moreEggsThan(OOOmelet that){
    if(this.eggs > that.eggs){    //  OK!!!
      return true;
    }
    else{
      return false;
    }
  }
}
// OOOmeletMain.java
public class OOOmeletMain{
  public static void main(String args[]){
    OOOmelet small = new OOOmelet(2,5,"ham");
    OOOmelet large = new OOOmelet(5,8,"bacon");
    boolean moreEggs = small.moreEggsThan(large)
  }
}
```

Name Binding Resolution Mechanics

- Java follows rules to determine where names are defined: name binding
- Resolution matters for bare names: no class/object association

```
om.eggs = 5;                  // specific object's field
this.cookedFor = 5;           // specific object's field
int c = om.getCalories();     // specific object's method
this.addEgg);                 // specific object's method
Omelet.egg_cals = 123;        // specific class (static)
cookedFor = 1.23;             // BARE NAME for field
addEgg();                     // BARE NAME for method
```

- To determine where name `var` binds look at
  1. Local variables
  2. Parameters to method
  3. Fields of class
  4. Potentially outside class (won't do this in CS 1103)

Exercise: Binding Resolution

- NUMBERS declare a name
- LETTERS are bare name references
- Match LETTERS to NUMBERS to match bare name to where it is defined

To determine where name var binds look at

1. Local variables
2. Parameters to method
3. Fields of class

```
 1  public class OOOmelet{
 2    private int eggs;                        // 1
 3    private int cheese;                      // 2
 4    private double cookedFor;                // 3
 5    private String extras;                   // 4
 6
 7    public int getEggs(){                    // 5
 8      return eggs; //// A
 9    }
10
11    public void cookFor(double time){
12      double cookedFor =                     // 6
13        this.cookedFor;  //// B
14      cookedFor += time; //// C
15    }
16
17    public void addCheese(int cheese){ // 7
18      cheese += cheese;
19      //// D   and   E
20    }
21
22    public boolean foodPoisoningIminent(){
23      return cookedFor < (1.0 * getEggs());
24      ////        F                  G
25    }
26  }
```

Answers: Binding Resolution

Let	Num	Note
A	1	field eggs
B	2	field cookedFor
C	6	local cookedFor
D	7	param cheese
E	7	param cheese
F	3	field cookedFor
G	5	this.getEggs()

```
 1  public class OOOmelet{
 2    private int eggs;                      // 1
 3    private int cheese;                    // 2
 4    private double cookedFor;              // 3
 5    private String extras;                 // 4
 6
 7    public int getEggs(){                  // 5
 8      return eggs; //// A
 9    }
10
11    public void cookFor(double time){
12      double cookedFor =                   // 6
13        this.cookedFor;  //// B
14      cookedFor += time; //// C
15    }
16
17    public void addCheese(int cheese){ // 7
18      cheese += cheese;
19      //// D   and   E
20    }
21
22    public boolean foodPoisoningIminent(){
23      return cookedFor < (1.0 * getEggs());
24      ////       F                  G
25    }
26  }
```

Exercise: Gotchya's with Constructor Name Binding

- Common to initialize fields in constructors
- Determine what's wrong with these constructors
- Give a correct constructor

```
public class OOOmelet{
  public int eggs;
  public int cheese;
  public double cookedFor;
  public String extras;

  // BAD CONSTRUCTOR 1
  public OOOmelet(int eggs,
                  int cheese,
                  String extras)
  {
    eggs = eggs;
    cheese = cheese;
    extras = extras;
    cookedFor = 0.0;
  }
```

```
public class OOOmelet{
  public int eggs;
  public int cheese;
  public double cookedFor;
  public String extras;

  // BAD CONSTRUCTOR 2
  public OOOmelet(int eg,
                  int ch,
                  String ex)
  {
    int eggs = eg;
    int cheese = ch;
    String extras = ex;
    double cookedFor = 0.0;
  }
```

Answer: Gotchya's with Constructor Name Binding

- The names of parameters like eggs or local variable `int eggs` can *shadow* fields
- Fields never get modified as shadows receive assignments
- Use `this.name = name;` or change names of parameters

```
public class OOOmelet{
  public int eggs;
  public int cheese;
  public double cookedFor;
  public String extras;

  // CORRECT CONSTRUCTOR 1
  // Use this.field to specify
  // field initialization
  public OOOmelet(int eggs,
                  int cheese,
                  String extras)
  {
    this.eggs = eggs;
    this.cheese = cheese;
    this.extras = extras;
    this.cookedFor = 0.0;
  }
```

```
public class OOOmelet{
  public int eggs;
  public int cheese;
  public double cookedFor;
  public String extras;

  // CORRECT CONSTRUCTOR 2
  // Vary names of parameters to
  // avoid conflicts
  public OOOmelet(int eg,
                  int ch,
                  String ex)
  {
    eggs = eg;
    cheese = ch;
    extras = ex;
    cookedFor = 0.0;
  }
```

Multiple Methods: Overloading

- In Java, several methods can share the same name SO LONG as each has a distinct a number and/or type of arguments
- Called overloading a method

```
public class OOOmelet{

// Constructor to initialize fields to
// given values. cookedFor is always
// initialized to 0.0.
public OOOmelet(int eggs,
                int cheese,
                String extras) {
  this.eggs = eggs;
  this.cheese = cheese;
  this.extras = extras;
  this.cookedFor = 0.0;
}

// Constructor to initialize fields to
// given values. extras is blank and
// cookedFor is 0.0.
public OOOmelet(int eggs,
                int cheese) {
  this.eggs = eggs;
  this.cheese = cheese;
  this.extras = "";
  this.cookedFor = 0.0;
}
```

```
// Add an egg to the omelet
public void addEgg(){
  if(this.cookedFor > 0){
    System.out.println("Yuck");
  }
  else{
    this.eggs++;
  }
}
// Add multiple eggs to the omelet
public void addEgg(int nEggs){
  for(int i=0; i<nEggs; i++){
    addEgg();
  }
}
public static void main(String args[]){
  OOOmelet omA = new OOOMelet(3,2,"ham");
  OOOmelet omB = new OOOMelet(4,6);
  omA.addEgg(2);
  omB.addEgg();
}
```

Exercise: Review Questions on Object-Oriented Objects

1. Describe the difference between a `static` field and a non-static field. How many of each exit when a class is used?
2. The class `Foo` has a `static` method called `double bar(int x, String s)`. Describe how to invoke/call this method.
3. What is a constructor? How are they named? Give an example of how they are called.
4. The class `Flurbo` has a non-static method named `int schmeckle(double z)`. Describe how to invoke/call it.
5. In what context can the keyword `this` be used? Where can it not be used?
6. What does the keyword `this` refer to? Can it ever be `null`?
7. What order does the Java compiler search for bindings of bare variable names to variable declarations?
8. Why would one choose to make fields of a class `private`?
9. What are accessor methods? What are mutator methods?