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A product team from Adobe wants to meet with RISD graphic design students to understand their existing workflows and future needs.

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- working in print and digital, ideally across multiple channels
- focused on typography and layout (not web and app design)
- working as part of a collaborative project team
- creating, managing or working with design systems

Details:
Contact Bob Zeleznik (bcz@cs.brown.edu) by Friday 9/16 for a pre-screening interview. Adobe will visit Friday 9/30.

Join our listserv: http://tinyurl.com/jc7yktj

mosaic.plus.brown@gmail.com

Reminder: Lecture slides
- Lecture slides are posted online and are available before class
- Use these during class and outside of class!
- If you can, download the lecture before class so you can take notes on the slides
- Useful to be able to go back a few slides to answer clicker questions

Lecture 3
Introduction to Parameters / Math

This Lecture:
1. Mathematical functions in Java
2. Defining more complicated methods with inputs and outputs
3. The constructor
4. Creating instances of a class
5. Understanding Java flow of control
Defining Methods

- We know how to define simple methods
- Today, we will define more complicated methods that have both inputs and outputs
- Along the way, you will learn the basics of manipulating numbers in Java

BookstoreAccountant

- We will define a BookstoreAccountant class that models an employee in a bookstore, calculating certain costs
  - finding the price of a purchase, calculating change needed, etc.
- Each of the accountant’s methods will have inputs (numbers) and an output (numeric answer)

Basic Math in Java

- First, we’ll talk about numbers and mathematical expressions in Java

Integers

- An integer is a whole number, positive or negative, including 0
- Depending on size of the integer, can use one of four numerical base types (primitive Java data types): byte, short, int, and long, in order of number of bits of precision
- Bit: binary digit, 0 or 1

<table>
<thead>
<tr>
<th>Base Type</th>
<th>Size</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>byte</td>
<td>8</td>
<td>-128 (-2^7)</td>
<td>127 (2^7 - 1)</td>
</tr>
<tr>
<td>short</td>
<td>16</td>
<td>-32,768 (-2^15)</td>
<td>32,767 (2^15 - 1)</td>
</tr>
<tr>
<td>int</td>
<td>32</td>
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<td>2,147,483,647 (2^31 - 1)</td>
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<tr>
<td>long</td>
<td>64</td>
<td>-9,223,372,036,854 (-2^63)</td>
<td>9,223,372,036,857 (2^63 - 1)</td>
</tr>
</tbody>
</table>

In CS15, you will almost always use int – good range and we’re not as memory-starved as we used to be

Floating Point Numbers

- Sometimes, need more precision than integers can provide
- How to represent pi = 3.14159...?
- Floating point numbers - more precise representation
  - called “floating point” because decimal point can “float” – no fixed number of digits before and after it – historical nomenclature
  - used for representing numbers in “scientific notation”, with decimal point and exponent, e.g., 4.3 x 10^8
- Two numerical base types in Java represent floating point numbers: float and double
Floating Point Numbers

<table>
<thead>
<tr>
<th>Base Type</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>float</td>
<td>32 bits</td>
</tr>
<tr>
<td>double</td>
<td>64 bits</td>
</tr>
</tbody>
</table>

Feel free to use both in CS15. Use of `double` is more common in modern Java code, as we are not as memory-starved as we used to be.

Operators and Math Expressions (1/2)

- Example expressions:
  - `4 + 5`  
  - `3.33 * 3`  
  - `11 % 4`  
  - `3.0 / 2.0`  
  - `3 / 2`

Operators and Math Expressions (2/2)

- Example expressions:
  - `4 + 5 → 9`  
  - `3.33 * 3 → 9.99`  
  - `11 % 4 → 3`  
  - `3.0 / 2.0 → 1.50`  
  - `3 / 2 → 1`

- What does each of these expressions evaluate to?
  - `4 + 5 → 9`  
  - `3.33 * 3 → 9.99`  
  - `11 % 4 → 3`  
  - `3.0 / 2.0 → 1.50`  
  - `3 / 2 → 1`

Be careful with integer division!

- When dividing two integer types, result is rounded down to an `int`  
  - `3 / 2 → 1`  
  - `3.0 / 2 → 1.50`

- `3 / 2` evaluates to 1  
  - `3 / 2.0 → 1.50`

- If either number involved is floating point, result is floating point: allows greater precision  
  - called mixed-mode arithmetic

Evaluating Math Expressions

- Java follows same evaluation rules that you learned in math class years ago - PEMDAS
  - `2 + 4 * 3 - 7 → 7`
- Evaluation takes place left to right, except:
  - expressions in parentheses evaluated first, starting at the innermost level  
    - `2 + (3 * (11 / 12)) → 5`  
  - operators evaluated in order of precedence/priority (`^` has priority over `*`)

Clicker Question

What does the x evaluate to?

```
int x = (((5/2)*3)+5);
```

A. 12.5  
B. 11  
C. 13  
D. 10
BookstoreAccountant

- BookstoreAccountants should be able to find the price of a set of books.
- When we tell a BookstoreAccountant to calculate a price, we want it to do it and then tell us the answer.
- To do this, we need to learn how to write a method that returns a value - in this case, a number.

Accountant (1/6)

- Let’s write a silly method for BookstoreAccountant called priceTenDollarBook() that finds the cost of a $10 book.
- It will return the value “10” to whoever called it.
- We will generalize this silly example soon...

Accountant (2/6)

- What does it mean for a method to “return a value to whoever calls it”? 
- Another object can call priceTenDollarBook on a BookstoreAccountant from somewhere else in our program and use the result.
- For example, consider a Bookstore class that has an accountant named myAccountant.
- We will demonstrate how the Bookstore can call the method and use the result.

Return Type

- The return type of a method is the kind of data it gives back to whoever called it.
- So far, we have only seen return type void.
- A method with a return type of void doesn’t give back anything when it’s done executing.
- void just means “this method does not return anything.”

Return Type

- If we want a method to return something, replace void with the type of thing we want to return.
- If method should return an integer, specify int return type.
- When return type is not void, we’re promised to end the method with a return statement.
- Any code following the return statement will not be executed.

Return Type

- A silly example:
  
  ```java
  public int giveMeTwo() {
      return 2;
  }
  ```

- If method should return an integer, specify int return type.
- When return type is not void, we’ve promised to end the method with a return statement.
- Any code following the return statement will not be executed.

Accountant (1/6)

- Let’s write a silly method for BookstoreAccountant called priceTenDollarBook() that finds the cost of a $10 book.
- It will return the value “10” to whoever called it.
- We will generalize this silly example soon...

Accountant (2/6)

- What does it mean for a method to “return a value to whoever calls it”? 
- Another object can call priceTenDollarBook on a BookstoreAccountant from somewhere else in our program and use the result.
- For example, consider a Bookstore class that has an accountant named myAccountant.
- We will demonstrate how the Bookstore can call the method and use the result.

```java
public class BookstoreAccountant {
    public int priceTenDollarBook() {
        return 10;
    }
}
```
public class BookstoreAccountant {
    /* Some code elided */
    public int priceTenDollarBook() {
        return 10;
    }
    public void manageBooks() {
        System.out.println(this.priceTenDollarBook());
    }
}

Accountant (6/6)

Accountant: a more generic price calculator

Aside: System.out.println

   System.out.println is an awesome tool for testing and debugging your code – learn to use it!

   Lets you see what is happening in your code by printing out values as it executes – otherwise, methods execute, but you don’t see return value

   If Bookstore program is not behaving properly, can test whether priceTenDollarBook is the problem by printing its return value to verify that it is “10” (yes, obvious in this trivial case, but not in general!)
Accountant: a more generic price calculator

- Method answers the question: given a number of copies and a price per copy, how much do all of the copies cost?
- To put this in algebraic terms, we want a method that will correspond to the function: 
  \[ f(x, y) = x \times y \]
- "x" represents the number of copies; "y" is the price per copy

```java
public class BookstoreAccountant {
    public int priceTenDollarBook() {
        return 10;
    }
    public int priceBooks(int numCps, int price) {
        // let's fill this in!
    }
}
```

Mathematical function: \[ f(x, y) = x \times y \]
Equivalent Java method: 
```java
public int priceBooks(int numCps, int price) {
    return numCps * price;
}
```

Parameters (1/3)
- General form of a method you are defining that takes in parameters:
  ```java
  <visibility> <returnType> <methodName>(<type1> <name1>, <type2> <name2>...) {
    <body of method>
  }
  ```
- Parameters are specified as comma-separated list
  - for each parameter, specify type (for example, int or double), and then name ("x", "y", "banana"... whatever you want!)
- In algebra, do not specify type because context makes clear what kind of number we want. In programming use many different types, and must tell Java explicitly what we intend
  - Java is a "strictly typed" language, i.e., makes sure the user of a method passes the right number of parameters of the specified type, in the right order – if not, compiler error! In short, the compiler checks for a one-to-one correspondence

Parameters (2/3)
- Name of each parameter is almost completely up to you
  - Java naming restriction: needs to start with a letter
  - refer to CS15 style guide for naming conventions
- It is the name by which you will refer to the parameter throughout method

The following methods are completely equivalent:
```java
public int priceBooks(int numCps, int price) {
    return numCps * price;
}
```
Remember Robot class from last lecture?
- Its `moveForward` method took in a parameter—an int named `numberOfSteps`.
- Follows same parameter format: `type, then name`.

```java
public void moveForward(int numberOfSteps) {
    // code that moves the robot
    // forward goes here!
}
```

With great power comes great responsibility...
- Try to come up with descriptive names for parameters that make their purpose clear to anyone reading your code.
- Robot’s `moveForward` method calls its parameter “`numberOfSteps`”, not “`x`” or “`thingy`”.
- We used “`numCps`” and “`price`”.
- Try to avoid single-letter names for anything that is not strictly mathematical; be more descriptive.

Let’s give `BookstoreAccountant` class more functionality by defining more methods!
- Methods to calculate change needed or how many books a customer can afford.
- Each method will take in parameters, perform operations on them, and return an answer.
- We choose arbitrary but helpful parameter names.

```java
public class BookstoreAccountant {
    public int priceBooks(int numCps, int price) {
        return numCps * price;
    }
    // calculates a customer's change
    public int calcChange(int amtPaid, int price) {
        return amtPaid - price;
    }
    // calculates max # of books you can buy
    public int calcMaxBks(int bookPr, int myMoney) {
        return myMoney / bookPr;
    }
}
```

Calling Methods with Parameters
- Now that we’ve defined `priceBooks`, `calcChange`, and `calcMaxBks` methods, can call them on any `BookstoreAccountant`.
- Want to call `calcChange` method and tell it how much was paid and how much the purchase cost.
- How do we `call` a method that takes in parameters?

Calling Methods with Parameters
- You already know how to call a method that takes in one parameter!
- Remember `moveForward`?
Calling Methods with Parameters

- When we call a method, we pass it any extra piece of information it needs as an argument within parentheses.
- When we call `moveForward`, we must supply one `int` as an argument.

```java
public class RobotMover {
    /* additional code elided */
    public void moveRobot(Robot samBot) {
        // code that moves the robot
        samBot.moveForward(4);
        samBot.turnRight();
        samBot.moveForward(1);
        samBot.turnRight();
        samBot.moveForward(3);
    }
    // within the Robot class
    public void moveForward(int numberOfSteps) {
        // code that moves the robot
        // forward goes here!
    }
    // within the RobotMover class
    public void moveRobot(Robot samBot) {
        samBot.moveForward(4);
        samBot.turnRight();
        samBot.moveForward(1);
        samBot.turnRight();
        samBot.moveForward(3);
    }
}
```

Arguments vs. Parameters

- In defining a method, the parameter is the name by which a method refers to a piece of information passed to it—e.g. "x" and "y" in the function \( f(x, y) = x + y \) —it is a "dummy name" determined by definer.
- In calling a method, an argument is the actual value passed in—e.g. 2 and 3 in `add(2, 3)`.

Calling Methods That Have Parameters

- When calling a method that takes in parameters, must provide a valid argument for each parameter:
  - loose analogy: parameter is like parking space, argument is like car.
- Means that number and type of arguments must match number and type of parameters: one-to-one correspondence.
- Order matters! The first argument you provide will correspond to the first parameter, second to second, etc.

```java
public class BookstoreAccountant {
    public int priceBooks(int numCps, int price) {
        return numCps * price;
    }
    public int calcChange(int amatPaid, int price) {
        return amatPaid - price;
    }
    public int calcMaxBks(int bookPr, int myMoney) {
        return myMoney / bookPr;
    }
    /* somewhere else in our code… */
    myAccountant.priceBooks(2, 16);
    myAccountant.calcChange(18, 12);
    myAccountant.calcMaxBks(6, 33);
}
```

Calling Methods That Have Parameters

- Let's say we have an instance of `BookstoreAccountant` named `myAccountant`.
- When we call a method on `myAccountant`, we provide a comma-separated list of arguments (in this case, `ints`) in parentheses:
  - `arguments` are values we want the method to use for first and second parameter when it runs. Note `calcChange(6, 4)` isn’t `calcChange(4, 6)` — order matters!

```java
myAccountant.priceBooks(2, 16);
myAccountant.calcChange(18, 12);
myAccountant.calcMaxBks(6, 33);
```
Calling Methods That Have Parameters

myAccountant.priceBooks(2, 16);

- Java does "parameter passing" by:
  - first checking that one-to-one correspondence is honored,
  - then substituting arguments for parameters,
  - and finally executing the method body using the arguments

/* somewhere else in our code… */

```
public int priceBooks(int numCps, int price) {
    return numCps * price;
}
```

Calling Methods That Have Parameters

/* somewhere else in our code… */

```
myAccountant.priceBooks(2, 16);
```

- Java does "parameter passing" by:
  - first checking that one-to-one correspondence is honored,
  - then substituting arguments for parameters,
  - and finally executing the method body using the arguments

32 is returned

Calling Methods That Have Parameters

/* somewhere else in our code… */

```
myAccountant.priceBooks(2, 16);
```

- Java does "parameter passing" by:
  - first checking that one-to-one correspondence is honored,
  - then substituting arguments for parameters,
  - and finally executing the method body using the arguments

32 is returned

Calling Methods That Have Parameters

/* somewhere else in our code… */

```
myAccountant.priceBooks(2, 16);
```

- Java does "parameter passing" by:
  - first checking that one-to-one correspondence is honored,
  - then substituting arguments for parameters,
  - and finally executing the method body using the arguments

```
public int priceBooks(int numCps, int price) {
    return numCps * price;
}
```

Where did myAccountant come from?

- We know how to send messages to an instance of a class by calling methods
- So far, we have called methods on samBot, an instance of Robot, and myAccountant, an instance of BookstoreAccountant...
- Where did we get these objects from?
- Next: how to use a class as a blueprint to actually build instances!

Clicker Question

Which of the following contains arguments that satisfy the parameters of the method calcChange in the BookstoreAccountant class?

A. BookstoreAccountant.calcChange(20, 14.50)
B. BookstoreAccountant.calcChange(10.00, 5.00)
C. BookstoreAccountant.calcChange(20, 10)
D. None of the above
Constructors (1/3)
- Accountants can priceBooks, calcChange, and calcMaxBks
- Can call any of these methods on any instance of BookstoreAccountant
- But how did these instances get created in the first place?
- Define a special kind of method in the BookstoreAccountant class: a constructor
- Note: every object must have a constructor

```java
public class BookstoreAccountant {
    public int priceBooks(int numCps, int price) {
        return numCps * price;
    }
    public int calcChange(int amtPaid, int price) {
        return amtPaid - price;
    }
    public int calcMaxBks(int bookPr, int myMoney) {
        return myMoney / bookPr;
    }
}
```

Constructors (2/3)
- A constructor is a special kind of method that is called whenever an object is to be "born", i.e., created – see shortly how it is called
- Constructor's name is always same as name of class
- If class is called "BookstoreAccountant", its constructor had better be called "BookstoreAccountant"

```java
public class BookstoreAccountant {
    public BookstoreAccountant() {
        // this is the constructor!
    }
}
```

Constructors (3/3)
- Constructors are special methods: used only once, to create and return the instance
- And we never specify a return value in its declaration
- Constructor for BookstoreAccountant does not take in any parameters (notice empty parentheses)
- Constructors can, and often do, take in parameters—stay tuned for next lecture

Clicker Question
Which of the following is not true of constructors?
A. Constructors are methods  
B. Constructors always have the same name as their class
C. Constructors should specify a return value
D. Constructors can take in parameters

Instantiating Objects (1/3)
- Now that the BookstoreAccountant class has a constructor, we can create instances of it!
- Here is how we create a BookstoreAccountant in Java:
  ```java
  new BookstoreAccountant();
  ```
- This means "use the BookstoreAccountant class as a blueprint to create a new BookstoreAccountant instance"
- BookstoreAccountant() is a call to BookstoreAccountant's constructor, so any code in constructor will be executed as soon as you create a BookstoreAccountant

Instantiating Objects (2/3)
- We refer to "creating" an object as instantiating it
- When we say:  
  ```java
  new BookstoreAccountant();
  ```
- ... We're creating an instance of the BookstoreAccountant class, a.k.a. instantiating a new BookstoreAccountant
- Where exactly does this code get executed?
- Stay tuned for the next lecture to see how this constructor is used by another instance to create a new BookstoreAccountant!
Aside: Nesting

- Our `calcChange` method takes in two `ints` - the amount the customer paid, and price of the purchase
- Our `priceBooks` method finds the price of the purchase
- What if we want to use result of `priceBooks` as an argument to `calcChange`?
- Say we have got 3 copies of an $11 book. We also have $40 in cash to pay with. `priceBooks` will tell us that purchase costs $33 - we want to use this as "price" parameter for `calcChange`
- How do we do this? Nesting!

Aside: Nesting

- `myAccountant.priceBooks(3, 11)` returns "33" - we want to pass this number into `calcChange`
- We can nest `myAccountant.priceBooks` method within `myAccountant.calcChange` method:
  ```java
  myAccountant.priceBooks(3, 11))
  myAccountant.calcChange(40, myAccountant.priceBooks(3, 11));
  ```
- And `calcChange` will return 7!

Clicker Question

You have an instance of `BookstoreAccountant`, `accountant`. With the methods given from before, what is the proper way to calculate the change you will have if you pay with a $50 bill for 5 books at a cost of $8 each?

A. `accountant.priceBooks(5, 8)`
B. `accountant.priceBooks(8, 5)`
C. `accountant.calcChange(accountant.priceBooks(5, 8))`
D. `accountant.calcChange(50, accountant.priceBooks(5, 8));`

Important Techniques

- Defining methods that take in `parameters` as input
- Defining methods that `return` something as an output
- Defining a `constructor` for a class
- Creating an `instance` of a class with the `new` keyword
- Up next: Flow of Control

What is Flow of Control?

- We've already seen lots of examples of Java code in lecture
- But how does all of this code actually get executed, and in what order?
- Flow of control or control flow is order in which individual statements in a program (lines of code) are executed
- Understanding flow of control is essential for hand simulation and debugging

Overview: How Programs are Executed

- Code in Java is executed sequentially, line by line
- Think of an arrow "pointing" to the current line of code
- Where does execution start?
  - in Java, first line of code executed is in a special method called the `main` method
The Main Method

- Every Java program begins at first line of code in `main` method
  - and ends after last line of code in `main` is executed—you will see this shortly!
- You will see this method in every project or lab stencil, typically in `App.java` (the `App` class)
  - by CS15 convention, start our programs in `App`
- Program starts when you run file that contains `main` method
- Every other part of application is invoked from `main`

Method Calls and Constructors

- When a method is called, execution steps into the method
  - next line to execute will be first line of method definition
- Entire method is executed sequentially
  - when end is reached (when method returns), execution returns to the line following the method call
- Constructor is special type of method—flow of control works in same way
  - when `new <object>()` is called, code inside constructor is executed

Example: Baking Cookies

- Some of your TAs are trying to bake cookies for a grading meeting
  - they’ve decided to make snickerdoodles, the HTAs’ favorite kind
- Let’s write a program that will have a baker make a batch of cookies

The `bakeCookies` Method

- First, let’s define a method to make cookies, in the `Baker` class
- What are the steps of making cookies?
  - combine wet ingredients (and sugars) in one bowl
  - mix this
  - combine dry ingredients in another bowl, and mix
  - combine wet and dry ingredient bowls
  - form balls of dough
  - bake for 10 minutes
  - sometime before baking, preheat oven to 400º
- Order is not fixed, but some steps must be done before others
- Let’s write methods for these steps and call them in order in `bakeCookies()`

Defining the Baker Class

- First, here are more methods of the `Baker` class—method definitions are elided
  ```java
  public class Baker {
    public Baker() {
      // constructor code elided for now
    }
    public void combineWetIngredients() {
      // code to mix eggs, sugar, butter, vanilla
    }
    public void combineDryIngredients() {
      // code to mix flour, salt, baking soda
    }
    public void combineAllIngredients() {
      // code to combine wet and dry ingredients
    }
    public void formDoughBalls(int numBalls) {
      // code to form balls of dough
    }
    public void bake(int cookTime) {
      // code to bake cookies and remove from oven
    }
    public void preheatOven(int temp) {
      // code to preheat oven to a temp
    }
  }
  ```

The `bakeCookies` method

- ```java
  public void bakeCookies() {
    this.preheatOven(400);
    this.combineWetIngredients();
    this.combineDryIngredients();
    this.combineAllIngredients();
    this.formDoughBalls(24);
    this.bake(10);
  }
  ```
Clicker Question

Using the Baker class from before, is the following method correct for creating cookie dough? Why or why not?

```java
public class Baker {
    //constructor elided
    public void createDough() {
        this.combineWetIngredients();
        this.combineAllIngredients();
        this.combineDryIngredients();
    }
    //other methods elided
}
```

A. Yes, it has all the necessary methods in proper order
B. No, it uses this instead of Baker
C. No, it has the methods in the wrong order
D. No, it is inefficient

Flow of Control Illustrated

- Each of the methods we call in `bakeCookies()` has various substeps involved
  - `combineWetIngredients()` involves adding sugar, butter, vanilla, eggs and mixing them together
  - `bake(int cookTime)` involves putting cookies in oven, waiting, taking them out
- In current code, every substep of `combineWetIngredients()` is completed before `combineDryIngredients()` is called
  - execution steps into a called method, executes everything within method
  - both sets of baking steps must be complete before combining bowls, so these methods are called before `combineAllIngredients()`
  - could easily switch order in which those two methods are called

Putting it Together

- Now that Bakers have a method to bake cookies, let’s put an app together to make them do so
- Our app starts in the `main` method, in `App`
  - generally, use `App` class to start our program and nothing else

Putting it Together

- First, we need a `Baker`
- Calling `new Baker()` will execute `Baker`’s constructor
  - currently empty
- How do we get our `Baker` to bake cookies?
  - call the `bakeCookies` method from constructor!
  - this is not the only way - stay tuned for next lecture

Following Flow of Control

```java
public class App {
    public static void main(String[] args) {
        new Baker();
    }
}
```

```java
public class Baker {
    public Baker() {
        this.bakeCookies();
    }
    public void bakeCookies() {
        this.preheatOven(400);
        this.combineWetIngredients();
        this.combineDryIngredients();
        this.combineAllIngredients();
        this.formDoughBalls(24);
        this.bake(10);
    }
    public void preheatOven(int temp) {
        // code to preheat oven to a temp
    }
    public void combineWetIngredients() {
        // code to mix eggs, sugar, butter, vanilla
    }
    public void combineDryIngredients() {
        // code to mix flour, salt, baking soda
    }
    public void combineAllIngredients() {
        // code to combine wet and dry ingredients
    }
    public void formDoughBalls(int numBalls) {
        // code to form balls of dough
    }
    public void bake(int cookTime) {
        // code to bake cookies and remove from oven
    }
}
```

Modifying Flow of Control

- In Java, various control flow statements modify sequence of execution
  - these cause some lines of code to be executed multiple times, or skipped over entirely
- We’ll learn more about these statements in Making Decisions and Loops lectures later on
Announcements

- AndyBot and HW1 are out now!
  - HW1 is due on 9/18 at 3PM
  - AndyBot is due on 9/20 at 11:59pm
  - These must be turned in through the cs015_handin script
- Lab 0 is due by your next lab
  - If you went to Tues at 5pm last week, you must get lab0 checked off by Tues at 6:30pm (end of lab)
- Review sessions start today
  - Twice/week, Thurs 7:30-9, Sun 12-1:30 at MacMillan 115
- Questions on homeworks or course material?
  - Sign up for Piazza at https://piazza.com/class/iohq4igg3922l
  - Make sure your questions are private
- Remember to sign your collab policy!