Get to know your class!

- Your classmates are concentrating in…
  - CS, APMA, Econ, Math, IAPA, English, Music, History, ar more!
  - And plenty are unsure…that's ok too!
- This course is roughly 45% female and 54% male
- 97% Brown students, 3% RISD students
- Why are you all taking this class?

"I want to learn the basics of coding" "For fun!"

"It's a requirement for my degree"

"The most exciting intro course" "The skits :)"

1/85

Lecture 4

Working with Objects: Part 1

2/85

Review Slides at End of Deck ☺

3/85

Outline

- Storing values in variables
- Instances as parameters
- Variable reassignment
- Delegation pattern and containment
- Local variables vs. instance variables

Variables

- Once we create a `Dog` instance, we want to be able to give it commands by calling methods on it!
- To do this, we need to name our `Dog`
- Can name an instance by storing it in a **variable**

```
Dog effie = new Dog();
```

- In this case, `effie` is the variable, and it stores a newly created instance of `Dog`
  - the variable name `effie` is also known as an "identifier"
- Now we can call methods on `effie`, a specific instance of `Dog`
  - i.e., `effie.wagTail();`

Syntax: Variable Declaration and Assignment

- We can both **declare** and **assign** (i.e., initialize) a variable in a single statement, like: `Dog effie = new Dog();`
  - declaration
  - Instantiation, followed by assignment using `=`

```
<type> <name> = <value>;
```

- The "=" operator **assigns** the instance of `Dog` that we created to the variable `effie`. We say "`effie` **gets** a new `Dog`"
- Note: type of `value` must match declared `type` on left
- We can reassign a variable as many times as we like (example soon)

Assignment vs. Equality

In Java:

```
price = price + 1;
```

- Means "add 1 to the current value of price and assign that to price"

In Algebra:

- price = price + 1 is a logical contradiction

Values vs. References

- A variable stores information as either:
  - a **value** of a **primitive** (aka **base**) **type** (like `int` or `float`)
  - a **reference** to an instance (like an instance of `Dog`) of an arbitrary type stored elsewhere in memory
    - we symbolize a reference with an arrow
- Think of the variable like a box; storing a value or reference is like putting something into the box
- Primitives have a predictable memory size, while instances of classes vary in size. Thus, Java simplifies memory management by having a fixed size reference to an instance elsewhere in memory
  - "one level of indirection"

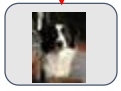
```
int favNumber = 9;
```

favNumber

9

```
Dog effie = new Dog();
```

effie



(somewhere else in memory)

TopHat Question

Join Code: 504547

Given this code, fill in the blanks:

```
int x = 5;
Calculator myCalc = new Calculator();
```

Variable `x` stores a _____, and `myCalc` stores a _____.

A. value, value
B. value, reference
C. reference, value
D. reference, reference

Example: Instantiation (1/2)

- Let's define a new class `PetShop` which has a `testEffie()` method
  - don't worry if the example seems a bit contrived…
- Whenever someone instantiates a `PetShop`, its constructor is called, which calls `testEffie()`
- Then `testEffie()` instantiates a `Dog` and tells it to bark, eat, and wag its tail (see definition of `Dog` for what these methods do)

```
public class PetShop {

   //constructor
   public PetShop() {
      this.testEffie();
   }

   public void testEffie() {
     Dog effie = new Dog();
     effie.bark(5);
     effie.eat();
     effie.wagTail();
   }
}
```


Another Example: Instantiation (2/2)

- *Another example:* can instantiate a `MathStudent` and then call that instance to perform a simple, fixed, calculation, called `performCalculation()`
- First, instantiate a new `Calculator` and store its reference in variable named `myCalc`
- Next, tell `myCalc` to add 2 to 6 and store result in variable named `answer`
- Finally, use `System.out.println` to print value of `answer` to the console!

```
public class MathStudent {

  /* constructor elided */

  public void performCalculation() {
    Calculator myCalc = new Calculator();
    int answer = myCalc.add(2, 6);
    System.out.println(answer);
  }

  /* add() method elided */
        …
}
```


Outline

- Storing values in variables
- Instances as parameters
- Variable reassignment
- Delegation pattern and containment
- Local variables vs. instance variables

Instances as Parameters (1/3)

- Methods can take in not just numbers but also instances as parameters
- The `PetShop` class has a method `trimFur()`
- `trimFur` method needs to know which `Dog` instance to trim the fur of
- Method calling `trimFur` will have to supply a specific instance of a `Dog`, called `shaggyDog` in `trimFur`
- Analogous to `void moveForward(int numberOfSteps);`

```
public class PetShop {

    public PetShop() {
        // this is the constructor!
    }

    public void trimFur(Dog shaggyDog) {
        // code that trims the fur of shaggyDog
    }
}
```

type/class — *name of specific instance*

Instances as Parameters (2/3)

- Where to call the `PetShop`'s `trimFur` method?
- Do this in the `PetShopFranchise` method `testGrooming()`, a "helper" method
- Call to `testGrooming()` instantiates a `PetShop` and a `Dog`, then calls the `PetShop` to `trimFur` of the `Dog`
- First two lines could be in either order, since both are instantiated adjacently


```
public class PetShopFranchise {
    public PetShopFranchise() {
        this.testGrooming();
    }

    public void testGrooming() {
        PetShop sarahsPetShop = new PetShop();
        Dog effie = new Dog();
        sarahsPetShop.trimFur(effie);
    }
}
```


Instances as Parameters (3/3): Flow of Control

1. In `App`'s `main` method, call to `testGrooming()` helper method.

2. A `PetShop` is instantiated (thereby calling `PetShop`'s constructor) and a reference to it is stored in the variable `andysPetShop`

3. Next, a `Dog` is instantiated (thereby calling `Dog`'s constructor) and a reference to it is stored in the variable `effie`

4. The `trimFur` method is called on `andysPetShop`, passing in `effie` as an argument

5. `andysPetShop` trims `effie`'s fur; `trimFur` in `andysPetShop` will think of `effie` as `shaggyDog`, a synonym

```
public class App {
    public static void main(String[] args) {
        1. this.testGrooming();
    }

    public void testGrooming() {
        2. PetShop sarahsPetShop = new PetShop();
        3. Dog effie = new Dog();
        4. sarahsPetShop.trimFur(effie);
           //exit method, effie and groomer disappear
    }
}
```

Code from slide 19

```
public class PetShop {
    /* constructor elided */

    public void trimFur(Dog shaggyDog) {
        5. // code that trims the fur of shaggyDog
    }
}
```

Code from slide 18

What is Memory?

- Memory ("system memory" aka RAM, not disk or other peripheral devices) is the hardware in which computers store information during computation
- Think of memory as a list of slots; each slot holds information (e.g., an `int` variable, or a reference to an instance of a class)
- Here, two references are stored in memory: one to a `Dog` instance, and one to a `PetShop` instance

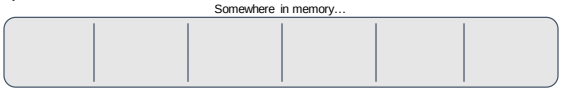

```
public class App
   public static void main(String[] args) {
         this.testGrooming();
   }

   public void testGrooming() {
         PetShop sarahsPetShop = new PetShop();
         Dog effie = new Dog();
         sarahsPetShop.trimFur(effie);
   }
}
```


Instances as Parameters: Under the Hood (1/6)

```
public class App {
   public static void main(String[] args) {
         this.testGrooming();
   }

   public void testGrooming() {
         PetShop andysPetShop = new PetShop();
         Dog effie = new Dog();
         andysPetShop.trimFur(effie);
   }
}
```

```
public class PetShop {

   public Petshop() {
         // this is the constructor!
   }

   public void trimFur(Dog shaggyDog) {
         // code that trims the fur of shaggyDog
   }
}
```

Somewhere in memory…



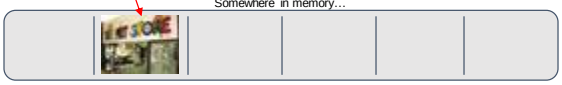
Note: Recall that in Java, each class is stored in its own file. Thus, when creating a program with multiple classes, the program will work as long as all classes are written before the program is run. Order doesn't matter.

Instances as Parameters: Under the Hood (2/6)

```
public class App {
   public static void main(String[] args) {
         this.testGrooming();
   }

   public void testGrooming() {
         PetShop andysPetShop = new PetShop();
         Dog effie = new Dog();
         andysPetShop.trimFur(effie);
   }
}
```

```
public class PetShop {

   public Petshop() {
         // this is the constructor!
   }

   public void trimFur(Dog shaggyDog) {
         // code that trims the fur of shaggyDog
   }
}
```

Somewhere in memory…



When we instantiate a `PetShop`, it's stored somewhere in memory. Our `App` will use the name `andysPetShop` to refer to this particular `PetShop`, at this particular location in memory.

Instances as Parameters: Under the Hood (3/6)

```
public class App {
   public static void main(String[] args) {
          this.testGrooming();
   }

   public void testGrooming() {
          PetShop andysPetShop = new PetShop();
          Dog effie = new Dog();
          andysPetShop.trimFur(effie);
   }
}
```

```
public class PetShop {

   public Petshop() {
          // this is the constructor!
   }

   public void trimFur(Dog shaggyDog) {
          // code that trims the fur of shaggyDog
   }
}
```

Somewhere in memory…

Same goes for the Dog—we store a particular Dog somewhere in memory. Our App knows this Dog by the name effie.

Instances as Parameters: Under the Hood (4/6)

```
public class App {
   public static void main(String[] args) {
          this.testGrooming();
   }

   public void testGrooming() {
          PetShop andysPetShop = new PetShop();
          Dog effie = new Dog();
          andysPetShop.trimFur(effie);
   }
}
```

```
public class PetShop {

   public Petshop() {
          // this is the constructor!
   }

   public void trimFur(Dog shaggyDog) {
          // code that trims the fur of shaggyDog
   }
}
```

Somewhere in memory…

We call the trimFur method on our PetShop, andysPetShop. We need to tell it which Dog to trimFur (since the trimFur method takes in a parameter of type Dog). We tell it to trim effie.

Instances as Parameters: Under the Hood (5/6)

```
public class App {
   public static void main(String[] args) {
          this.testGrooming();
   }

   public void testGrooming() {
          PetShop andysPetShop = new PetShop();
          Dog effie = new Dog();
          andysPetShop.trimFur(effie);
   }
}
```

```
public class PetShop {

   public Petshop() {
          // this is the constructor!
   }

   public void trimFur(Dog shaggyDog) {
          // code that trims the fur of shaggyDog
   }
}
```

Somewhere in memory…

When we pass in effie as an argument to the trimFur method, we're telling the trimFur method about him. When trimFur executes, it sees that it has been passed that particular Dog.

Instances as Parameters: Under the Hood (6/6)

```
public class App {
   public static void main(String[] args) {
          this.testGrooming();
   }

   public void testGrooming() {
          PetShop andysPetShop = new PetShop();
          Dog effie = new Dog();
          andysPetShop.trimFur(effie);
   }
}
```

```
public class PetShop {

   public Petshop() {
          // this is the constructor!
   }

   public void trimFur(Dog shaggyDog) {
          // code that trims the fur of shaggyDog
   }
}
```

The `trimFur` method doesn't really care which `Dog` it's told to `trimFur`—no matter what another instance's name for the `Dog` is, `trimFur` is going to know it by the name `shaggyDog`.

Outline

- Storing values in variables
- Instances as parameters
- Variable reassignment
- Delegation pattern and containment
- Local variables vs. instance variables

Variable Reassignment (1/3)

- After giving a variable an initial value or reference, we can **reassign** it (make it refer to a different instance)
- What if we wanted our `PetShop` to `trimFur` two different `Dog`s?
- Could create another variable, or re-use the variable `effie` to first point to one `Dog`, then another!

```
public class App {
   public static void main(String[] args) {
          this.testGrooming();
   }

   public void testGrooming() {
          PetShop andysPetShop = new PetShop();
          Dog effie = new Dog();
          andysPetShop.trimFur(effie);
   }
}
```

Variable Reassignment (2/3)

- First, instantiate another `Dog`, and **reassign** variable `effie` to point to it
- Now `effie` no longer refers to the first `Dog` instance we created, which was already groomed
- Then tell `PetShop` to `trimFur` the new `Dog`. It will also be known as `shaggyDog` inside the `trimFur` method

```
public class App {
    public static void main(String[] args) {
        this.testGrooming();
    }

    public void testGrooming() {
        PetShop andysPetShop = new PetShop();
        Dog effie = new Dog();
        andysPetShop.trimFur(effie);
        effie = new Dog(); // reassign effie
        andysPetShop.trimFur(effie);
    }
}
```


Variable Reassignment (3/3)

- When we **reassign** a variable, we do not declare its type again, Java remembers from first time
- Can **reassign** to a brand new instance (like in `PetShop`) or to an already existing instance by using its identifier

```
Dog effie = new Dog();
Dog scooby = new Dog();
effie = scooby; // reassigns effie to refer to the same Dog as scooby
```

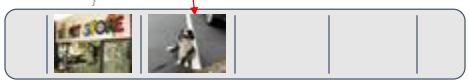
- Now `effie` and `scooby` refer to the same `Dog`, specifically the one that was originally referenced by `scooby`

Variable Reassignment: Under the Hood (1/5)

```
public class App {
    public static void main(String[] args) {
        this.testGrooming();
    }

    public void testGrooming() {
        PetShop andysPetShop = new PetShop();
        Dog effie = new Dog();
        andysPetShop.trimFur(effie);
        effie = new Dog();
        andysPetShop.trimFur(effie);
    }
}
```

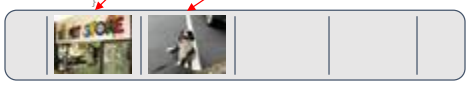
Variable Reassignment: Under the Hood (2/5)

```
public class App {
   public static void main(String[] args) {
          this.testGrooming();
   }

   public void testGrooming() {
          PetShop andysPetShop = new PetShop();
          Dog effie = new Dog();
          andysPetShop.trimFur(effie);
          effie = new Dog();
          andysPetShop.trimFur(effie);
   }
}
```



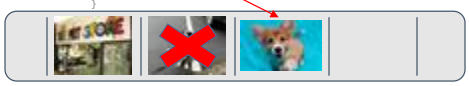
Variable Reassignment: Under the Hood (3/5)

```
public class App {
   public static void main(String[] args) {
          this.testGrooming();
   }

   public void testGrooming() {
          PetShop andysPetShop = new PetShop();
          Dog effie = new Dog();
          andysPetShop.trimFur(effie);
          effie = new Dog();
          andysPetShop.trimFur(effie);
   }
}
```



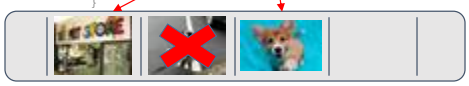
Variable Reassignment: Under the Hood (4/5)

```
public class App {
   public static void main(String[] args) {
          this.testGrooming();
   }

   public void testGrooming() {
          PetShop andysPetShop = new PetShop();
          Dog effie = new Dog();
          andysPetShop.trimFur(effie);
          effie = new Dog(); //old ref garbage collected – stay tuned!
          andysPetShop.trimFur(effie);
   }
}
```



Variable Reassignment: Under the Hood (5/5)

```
public class App {
    public static void main(String[] args) {
        this.testGrooming();
    }

    public void testGrooming() {
        PetShop andysPetShop = new PetShop();
        Dog effie = new Dog();
        andysPetShop.trimFur(effie);
        effie = new Dog(); //old ref garbage collected – stay tuned!
        andysPetShop.trimFur(effie);
    }
}
```



Outline

- Storing values in variables
- Instances as parameters
- Variable reassignment
- Delegation pattern and containment
- Local variables vs. instance variables

Adding `PetShop` Capabilities

- The `PetShop` only has the capability (method) to `trimFur`
- What if we want the `PetShop` to expand with more functionality?
- `PetShop` class would be long!

- `trimFur`
- `shampooFur`
- `dryFur`
- `teachSit`
- `teachBark`
- `teachFetch`
- `sellDogToy`
- and more…

Delegation Pattern (1/3)

- Just like a real-life pet shop would hire employees to **delegate** work, we should create new classes to **delegate** code
- Pass responsibility to something / someone else to manage parts of a task
- `PetShop` doesn't need to care *how* the dog gets trimmed, if it gets done properly

Delegation Pattern (2/3)

- Delegation results in a **chain of abstraction**, where each level deals with more specifics to complete an action

Delegation Pattern (3/3)

- We delegate responsibilities to `DogGroomer`!
- `trimFur` becomes a capability of `DogGroomer` instead of `PetShop`
- `teachSit` and `teachBark` can be delegated to `DogTrainer`

```
public class DogGroomer {
  /* constructor elided */

  public void trimFur(Dog shaggyDog) {
      //code that trims the fur of shaggyDog
  }

  public void shampooFur(Dog dirtyDog) {
      //code that shampoos the fur of dirtyDog
  }

  public void dryFur(Dog wetDog) {
      //code that dries the fur of wetDog
  }
}
```

Aside: Design Patterns and Principles

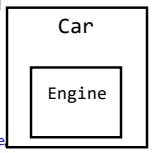
- **Delegation** is the first **design pattern** we're learning
- We'll learn many throughout the course – these are crucial to OOP
- OOP is about much more than **functionality** of programs
  - `PetShop` could operate fine without `DogGroomer` or `DogTrainer`; delegating is our design choice to make code easier to read, more modular and extensible
- Later, assignment grades will be based as much on your design choices as functionality
- In future projects, YOU will have to decide how to delegate your program to different classes!
  - (not quite yet though)

Consequence of Delegation

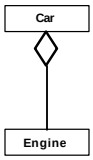
- With delegation, we'll use multiple classes to accomplish one task
  - `PetShop`, `DogGroomer`, `Bath`, `HairDyer`, and `Clippers` all involved with dog grooming
- Must ask ourselves - **How are different classes related to each other so their instances can communicate to collaborate?**
- Two key concepts to establish these relationships are **containment** and **association**

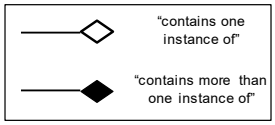
Containment

- Often a class A will need as a component an instance of class B, so A will create the instance of B by using the `new` keyword
- Any time class A creates a new instance of class B, we say A **contains** that instance of class B
- A knows about B and can call B's methods on that instance
- Note this is **not symmetrical**: B can't call methods on A!
  - thus, a `Car` can call methods on a contained instance of `Engine`, but the `Engine` instance can't call methods on the `Car` instance – it doesn't know about the `Car` instance that it is contained in



Visualizing Containment





- Notation comes from UML (Unified Modeling Language) standard used to model software systems

Example: Containment

- Now that we've delegated responsibilities to the `DogGroomer`, the `PetShop` can **contain** an instance of `DogGroomer`
- In the `testGrooming` method, `PetShop` can call `DogGroomer`'s methods on `groomer`
- It may seem unnatural to have a `PetShop` contain a `DogGroomer`, but it works in the kind of modeling that OOP makes possible

```
public class PetShop {

    public PetShop() {
        this.testGrooming();
    }

    public void testGrooming() {
        DogGroomer groomer = new DogGroomer();
        Dog effie = new Dog();
        groomer.shampooFur(effie);
        groomer.trimFur(effie);
        groomer.dryFur(effie);
    }
}
```

(Notice the methods being called on `groomer` are defined in `DogGroomer`)

Delegating to Top-Level Class (1/2)

- `App` class should never have more than a few lines of code

```
public class App {
   public static void main(String[] args) {
       this.testGrooming();
   }

   public void testGrooming() {
       DogGroomer groomer = new DogGroomer();
       Dog effie = new Dog();
       groomer.shampooFur(effie);
       groomer.trimFur(effie);
       groomer.dryFur(effie);
   }
}
```

Delegating to Top-Level Class (2/2)

- **Top-level class** is class that contains high-level logic of program
- `App` **delegates** to **top-level class** (here, `PetShop`) to simplify `App` as much as possible
- Same **functionality** of the program, with a different **code design**
  - easier to visually follow program's high-level control flow
- As CS15 programs increase in complexity, purpose of separating top-level class from `App` will become clearer

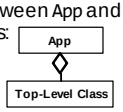
```
public class App {
    public static void main(String[] args) {
        new PetShop();
    }
}

public class PetShop {

    public PetShop() {
        this.testGrooming();
    }

    public void testGrooming() {
        DogGroomer groomer = new DogGroomer();
        Dog effie = new Dog();
        groomer.shampooFur(effie);
        groomer.trimFur(effie);
        groomer.dryFur(effie);
    }
}
```

TopHat Question

Join Code: 504547

Which of the following is NOT true?

A. `App` should delegate to the top-level class
B. The top-level class should never have more than a few lines of code
C. `App` should contain the top-level class
D. The relationship between App and the top-level class can be visualized as:



Outline

- Storing values in variables
- Instances as parameters
- Variable reassignment
- Delegation pattern and containment
- Local variables vs. instance variables

Local Variables (1/2)

- All variables we've seen so far have been **local variables**: variables declared **inside a method**
- Problem: the **scope** of a local variable (where it is known and can be accessed) is limited to its own method—it cannot be accessed from anywhere else
  - same is true of method's parameters

```
public class PetShop {

    public PetShop() {
        this.testGrooming();
    }

    public void testGrooming() {
        Dog effie = new Dog();
        DogGroomer groomer = new DogGroomer();
        groomer.shampooFur(effie);
        groomer.trimFur(effie);
        groomer.dryFur(effie);
    }

}
```

local variables

Local Variables (2/2)

- We created `groomer` and `effie` in our `PetShop`'s `testGrooming` method, but as far as the rest of the class is concerned, they don't exist and cannot be used
- Once the method is completely executed, they're gone :(
  - this is known as "Garbage Collection"

```
public class PetShop {

    public PetShop() {
        this.testGrooming();
    }

    public void testGrooming() {
        Dog effie = new Dog();
        DogGroomer groomer = new DogGroomer();
        groomer.shampooFur(effie);
        groomer.trimFur(effie);
        groomer.dryFur(effie);
    }

}
```

local variables

Garbage Collection

- If an instance referred to by a variable goes out of scope, we can no longer access it. Because we can't access the instance, it gets garbage collected
  - in garbage collection, the space that the instance took up in memory is freed and the instance no longer exists
- Lose access to an instance when:
  - at the end of method execution, local variables created within that method go out of scope
  - variables lose their reference to an instance during variable reassignment (`effie`, slide 35)

Accessing Local Variables

- If you try to access a local variable outside of its method, you'll receive a "cannot find symbol" compilation error

In Terminal after `javac *.java`:

```
PetShop.java:13: error: cannot find symbol
  groomer.sweep();
  ^
  symbol: variable groomer
  location: class PetShop
```

scope of ***groomer***

```
public class PetShop {

    public PetShop() {
        DogGroomer groomer = new DogGroomer();
        this.cleanShop();
    }

    public void cleanShop() {
        //assume we've added a sweep method
        //to DogGroomer
        groomer.sweep();
    }
}
```


Introducing… Instance Variables!

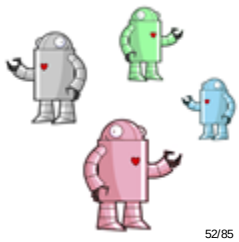
- Local variables aren't always what we want. We'd like every `PetShop` to come with a `DogGroomer` who exists for as long as the `PetShop` exists
- That way, as long as the `PetShop` is in business, we'll have our `DogGroomer` on hand
- We accomplish this by storing the `DogGroomer` in an **instance variable**

What's an Instance Variable?

- An **instance variable** models a **property** that all instances of a class have
  - its ***value*** can differ from instance to instance
- Instance variables are declared within a class, not within a single method, and therefore are accessible from anywhere within the class, unlike local variables – their **scope** is the entire class
- Instance variables and local variables are identical in terms of what they can store—either can store a base type (like an `int`) or a reference to an instance of some other class

Modeling Properties with Instance Variables (1/2)

- Methods model **capabilities** of a class (e.g., move, dance)
- All instances of same class have exact same methods (capabilities) **and the same properties**
- BUT: the **values** of those **properties** can be different and can differentiate one instance from other instances of the same class
- We use instance variables to model these properties and their values (e.g., the robot's size, position, orientation, color, …)



Modeling Properties with Instance Variables (2/2)

- All instances of a class have same set of properties, but ***values*** of these properties will differ
- E.g., `CS15Students` might have property "height"
  - for one student, the value of "height" is 5'2". For another, it's 6'4"
- `CS15Student` class would have an **instance variable** to represent height
  - all `CS15Student`s have a "height", but the value stored in instance variable would differ from instanc to instance

Instance Variables (1/4)

- We've modified `PetShop` example to make our `DogGroomer` an **instance variable** for the benefit of multiple methods
- Split up declaration and assignment of instance variable:
  - **declare** instance variable at the top of the class above the constructor, to notify Java compiler
  - **initialize** the instance variable by assigning a value to it in the constructor
  - **primary purpose of constructor is to initialize all instance variables so each instance has a valid initial "state" at its "birth"; it typically should do no other work**
  - **state** is the set of all values for all properties—local variables don't hold properties; they are "temporaries". State typically varies over time

```
public class PetShop {                          declaration
   private DogGroomer groomer;

   public PetShop() {                           initialization
      this.groomer = new DogGroomer();
      this.testGrooming();
   }

   public void testGrooming() {
      Dog effie = new Dog();//local var
      this.groomer.trimFur(effie);
   }

   public void payGroomer () {
      this.groomer.getPaidDollars(5);
   }
}
```

Instance Variables (2/4)

- Like we use `this` when an instance calls a method on itself, we also use `this` when an instance references one of its instance variables after declaration
  - Java compiler will work without it, **but required in CS15** to easily distinguish instance variables from local variables
- Thus, we use `this` to refer to capabilities (methods) and properties (instance variables) of an instance

```
public class PetShop {

   private DogGroomer groomer;

   public PetShop() {
      this.groomer = new DogGroomer();
      this.testGrooming();
   }

   public void testGrooming() {
      Dog effie = new Dog();//local var
      this.groomer.trimFur(effie);
   }
   //payGroomer() method elided
}
```


Instance Variables (3/4)

- Note we include the keyword `private` in declaration of our instance variable
- `private` is an **access modifier**, just like `public`, which we've been using in our method declarations

access modifier

```
public class PetShop {

   private DogGroomer groomer;

   public PetShop() {
      this.groomer = new DogGroomer();
      this.testGrooming();
   }

   public void testGrooming() {
      Dog effie = new Dog();//local var
      this.groomer.trimFur(effie);
   }
   //payGroomer() method elided
}
```


Instance Variables (4/4)

- If declared as `private`, the method or instance variable can only be accessed inside the class – their **scope** is the entire class
- If declared as `public`, can be accessed from anywhere – their **scope** can include multiple classes – very unsafe!
- **In CS15, you'll declare instance variables as `private`, with rare exception!**
- Note that local variables don't have access modifiers – they always have the same scope (their own method)

access modifier

```
public class PetShop {

   private DogGroomer groomer;

   public PetShop() {
      this.groomer = new DogGroomer();
      this.testGrooming();
   }

   public void testGrooming() {
      Dog effie = new Dog();//local var
      this.groomer.trimFur(effie);
   }
   //payGroomer() method elided
}
```

Encapsulation Design Pattern

- Why `private` instance variables?
- **Encapsulation** for safety… your properties are your private business
- Allows for **chain of abstraction** so classes don't need to worry about the inner workings of contained classes
  - we will also show you safe ways of allowing other classes to have selective access to designated properties… stay tuned



DogOwner PetShop DogGroomer

Always Remember to Initialize!

- What if you declare an instance variable, but forget to initialize it? What if you don't supply a constructor and your instance variables are not initialized?
- The instance variable will assume a "default value"
  - if it's an `int`, it will be 0
  - if it's an instance, it will be `null` — a special value that means your variable is not referencing any instance at the moment

```
public class PetShop {

  private DogGroomer groomer;

  public PetShop() {
      //oops! Forgot to initialize groomer
      this.testGrooming();
  }

  public void testGrooming() {
      Dog effie = new Dog();//local var
      this.groomer.trimFur(effie);
  }
}
```


NullPointerExceptions

- If a variable's value is null and you try to give it a command, you'll be rewarded with a ***runtime error***—you can't call a method on "nothing"!
- `groomer`'s default value is `null`, so this particular error yields a `NullPointerException`
- When you run into one of these (we promise, you will), make sure all instance variables have been explicitly initialized, preferably in the constructor, and no variables are initialized as null.

```
public class PetShop {

  private DogGroomer groomer;

  public PetShop() {
      //oops! Forgot to initialize groomer
      this.testGrooming();
  }

  public void testGrooming() {
      Dog effie = new Dog(); //local var
      this.groomer.trimFur(effie);
  }
}
```

NullPointerException

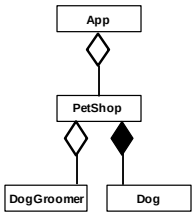
Our PetShop Program

```
public class PetShop {

   private DogGroomer groomer;

   public PetShop() {
       this.groomer = new DogGroomer();
       this.testGrooming();
   }

   public void testGrooming() {
       Dog effie = new Dog(); //local var
       this.groomer.shampooFur(effie);
       this.groomer.trimFur(effie);
       effie = new Dog();
       this.groomer.shampooFur(effie);
       this.groomer.trimFur(effie);
   }
}
```

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

```
public class DogGroomer {
   /* constructor elided */

   public void trimFur(Dog shaggyDog) {
       //code that trims the fur of shaggyDog
   }

   public void shampooFur(Dog dirtyDog) {
       //code that shampoos the fur of dirtyDog
   }
   ...
}
```


Visualizing Our PetShop Program



TopHat Question

Join Code: 504547

Which of the following most accurately describes the containment relationships in this program?

A. `App` contains a `Farm`
B. `App` contains a `House`, a `Pig`, and multiple `Cow`s
C. `Farm` contains a `House`, a `Pig`, and multiple `Cow`s
D. A and C
E. A, B, and C

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

public class Farm {
    private House farmHouse;
    private Pig wilbur;
    private Cow bessy;
    private Cow betty;

    public Farm() {
        this.farmHouse = new House();
        this.wilbur = new Pig();
        this.bessy = new Cow();
        this.betty = new Cow();
    }
}
```

TopHat Question

Join Code: 504547

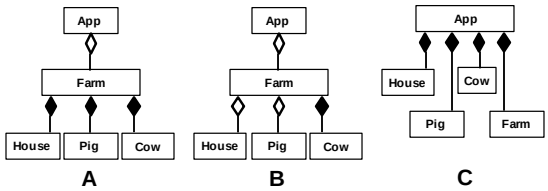
What visualization most accurately describes the containment relationships in this program?

Take a minute to sketch on your own, then we'll show options on the next slide

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

public class Farm {
    private House farmHouse;
    private Pig wilbur;
    private Cow bessy;
    private Cow betty;

    public Farm() {
        this.farmHouse = new House();
        this.wilbur = new Pig();
        this.bessy = new Cow();
        this.betty = new Cow();
    }
}
```


TopHat Question Join Code: 504547

What visualization most accurately describes the containment relationships in the program?



Summary

- **containment**: when one instance is a component of another class so the container can therefore send messages to the component it created
- **delegation pattern**: passing responsibility of task details to another class to maintain clean code design
  - results in a **chain of abstraction**
- **local variables**: scope is limited to a method
- **instance variables**: store the properties of instances of a class for use by multiple methods—use them only for that purpose
- A variable that "goes out of scope" is **garbage collected**
  - for a local variable, when the method ends
  - for an instance variable, when the last reference to it is deleted

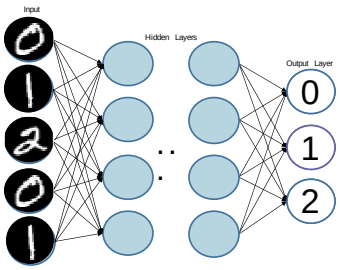
Announcements

- Lab 1 (Intro to Java) begins today
  - Some section rooms assignments have changed, so be sure to read email from section TAs
- AndyBot due tomorrow 9/20
  - No late deadline = no credit for code submitted past the deadline
- If you feel like you could use extra practice writing code, attend code-alongs! (This week on Writing Classes!)
  - Check website for code-along schedule

Neural Nets and Large Language Models (LLMs)

CS15 Fall 2023

Neural Network vs. a Human Brain



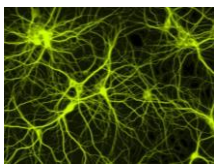
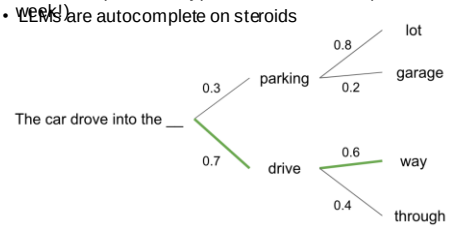


Illustration of neural networks in our brain.

Source:

Large Language Models (LLMS)

- A LLM is a particular type of Neural Network (more on this next week)
- LLMs are autocomplete on steroids



70/85

Image source: Towards Data Sci

LLMs as "Stochastic Parrots"

	Parrot	Chat-GPT
Learns random sentences from people	☑	☑

New York lawyers sanctioned for using fake ChatGPT cases in legal brief

By Sara Merken

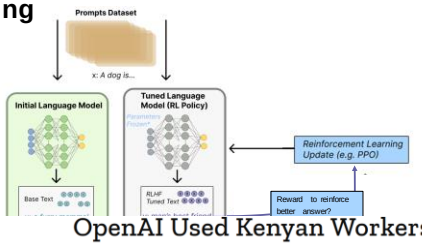
June 26, 2023 4:28 AM EDT · Updated 2 months ago

Is a cute little bird	☑	✗

71/85

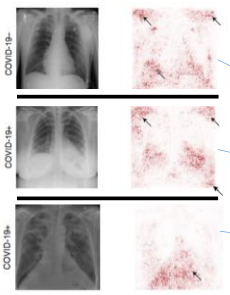
Image source: National Geographic, Rea

Second Training Phase – Reinforcement Learning



OpenAI Used Kenyan Workers on Less Than $2 Per Hour to Make ChatGPT Less Toxic

Image Source: Time, HuggingFa



Uncertainty in AI

The concentration of red pigment denotes the areas in which the AI is searching for patterns

Identifies COVID by corner and lung area

Identifies COVID by corners of image

Identifies COVID by solely diaphragm area

- Explainable AI focuses on understanding neural net activity

Source: AI for radiographic COVID-19 detection selects shortcuts over signal

Review: Methods

- **Call methods**: used on an instance of a class

```
samBot.turnRight();
```

- **Define methods**: give a class specific capabilities

```
public void turnLeft() {
    // code to turn Robot left goes here
}
```


Review: Parameters and Arguments

- **Define** methods that take in generic **parameters** (input) and have **return** values (output); e.g., this `Calculator`'s method:

```
public int add(int x, int y) {
    return x + y; // x, y are dummy (symbolic) variables
}
```

- **Call** such methods on instances of a class by providing specific **arguments** (actual values for symbolic parameters)

```
myCalculator.add(5, 8);
```

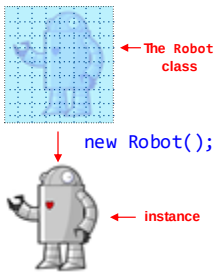
- Remember the one-to-one correspondence rule: list of arguments must match list of parameters in number, order, and types
  - thus, Java can substitute each argument for its corresponding parameters

Review: Classes

- Recall that classes are just blueprints
- A class gives a basic definition of an **object** we want to model (one or more instances of that class)
- It tells the **properties** and **capabilities** of that **object**
- You can create any class you want and invent any methods and properties you choose for it!

Review: Instantiation

- **Instantiation** means building an instance from its class
  - the capabilities of the instance are defined through the class's methods
- Ex: `new Robot();` creates an instance of Robot by calling the `Robot` class' **constructor** (see next slide)



Review: Constructors (1/2)

- A **constructor** is a method that is called to create a new instance
- Let's define one for the `Dog` class
- Let's also add methods for actions all `Dog`s know how to do like bark, eat, and wag their tails

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

  public void bark(int numTimes) {
        // code for barking goes here
  }

  public void eat() {
        // code for eating goes here
  }

  public void wagTail() {
        // code for wagging tail goes here
  }
}
```

Review: Constructors (2/2)

- Note constructors do not specify a return type
- Name of constructor must exactly match name of class
- Now we can instantiate a Dog in some method using the `new` keyword:

```
new Dog();
```

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

  public void bark(int numTimes) {
        // code for barking goes here
  }

  public void eat() {
        // code for eating goes here
  }

  public void wagTail() {
        // code for wagging tail goes here
  }
}
```

79/85