Suppose we have the Dog and Corgi classes which are defined below with a few methods but no implementation shown. (modified from Spring '16, MT1)

```java
public class Dog {
    public Dog() { /* D1 */ }
    public void bark(Dog d) { /* Method A */ }
}

public class Corgi extends Dog {
    public Corgi() { /* C1 */ }
    public void bark(Corgi c) { /* Method B */ }
    @Override
    public void bark(Dog d) { /* Method C */ }
    public void play(Dog d) { /* Method D */ }
    public void play(Corgi c) { /* Method E */ }
}
```

For the following main method at each call to play or bark, circle the options corresponding to the methods that will be executed at runtime. If there will be a compiler error or runtime error, circle that instead.

```java
public static void main(String[] args) {
    Corgi c = new Corgi();
    C1 D1
    Dog d = new Corgi();
    C1 D1
    There is always an implicit call to the superclass’s constructor.

    Dog d2 = new Dog();
    D1
    Corgi c2 = new Dog();
    Compiler-Error
    Corgi c3 = (Corgi) new Dog();
    Runtime-Error D1
    During compile time, we can cast an object along a class’s heirarchy with no problem. At runtime, java is upset that the Dog instance "is not" a Corgi. That is, a Dog does not extend from Corgi. However, the dog is instantiated before java attempts to assign it.

    d.play(d);
    Compiler-Error
d.play(c);
    Compiler-Error
d’s static type Dog does not have a play method.

    c.play(d);
    D
    At compile time, we check c’s static type, Corgi, does have a play method that takes in a Dog. At runtime, we look at c’s dynamic type, Corgi,
for a play method. Here we see play is overloaded, so we pick the method with the "more specific" parameters relative to our arguments, which is method D.

c.play(c);
E
Same as previous.

c.bark(d);
C
c.bark(c);
B
d.bark(d);
C

We notice that bark is overloaded and overridden. As a reminder, dynamic method selection applies to overridden methods. Method C overrides Method A, and method B overloads C. For c.bark(c), the compiler had bound caller c’s static type’s bark to argument c’s most specific static type, Corgi, thus binding method B.

d.bark(c);
C
d.bark((int) c);
Compiler-Error

During compile time, the compiler will complain that a Corgi "is not" an int. You can only cast up or down the heirarchy.

c.bark((Corgi) d2);
Runtime-Error

During compile time, we check c’s static type, Corgi, for a bark method that takes in a Corgi, which exists, so there is no compile time error. At runtime, java is upset that d2 "is not" a Corgi. Note that the cast only temporarily changes the static type for this SPECIFIC line.

((Corgi)d).bark(c);
B
((Dog) c).bark(c);
C
c.bark((Dog) c);
C
}

We encourage you to try inheritance problems here: [link] Please post on piazza if you have questions!
General flow for one argument methods, suppose we have \texttt{a.call(b)} \texttt{[ST = Static type, DT = dynamic type]}. 

1. During compile time, java only cares about static types. First, check if a’s ST, or its superclasses, has a method that takes in the ST of b. 
   
   (a) If not, check a’s superclasses for a method that takes in ST of b.
   
   (b) If not, check if any of the methods take in supertype of ST of b, as we are looking for b’s "is-a" relationships. Start from a’s ST methods and move up from its superclass. 
   
   (c) If still not, Compiler-Error! 

2. Take a snapshot of the method found. 
   
   (a) The method \textbf{signature} that is chosen at runtime will try to exactly match with our snapshot. The signature consists of the method name, and the number and type of its paramaters. 

3. During runtime, if \texttt{call} is an overridden method, then run a’s dynamic type’s \texttt{call} method. 

4. Runtime errors can consist of downcasting (as seen in \texttt{Corgi c3 = (Corgi) new Dog();}), but also many that are not related to inheritance (NullPointerException, IndexOutOfBoundsException, etc). 

Notes:
- If a method is overloaded and overridden, as bark is above, the compiler will bind the method first. 
- Dynamic method selection has no interaction with assignment.
2 Dynamic Method Selection

Modify the code below so that the max method of DMSList works properly. Assume all numbers inserted into DMSList are positive, and we only insert between sentinel and sentinel.tail. You may not change anything in the given code. You may only fill in blanks. You may not need all blanks. (Adapted from Spring ’17, MT1)

```java
public class DMSList {
    private IntList sentinel;
    public DMSList() {
        sentinel = new IntList(-1000, new LastIntList());
    }
    public class IntList {
        public int head;
        public IntList tail;
        IntList(int h, IntList t) {
            head = h;
            tail = t;
        }
        public int max() {
            return Math.max(head, tail.max());
        }
    }
    public class LastIntList extends IntList {
        LastIntList() {
            super(0, null);
        }
        @Override
        public int max() {
            return 0;
        }
    }
    /* Returns 0 if list is empty. Otherwise, returns the max element. */
    public int max() {
        return sentinel.tail.max();
    }
}
```
Consider the declarations below. Assume that Falcon extends Bird. (Spring ’17, MT1)

Bird bird = new Falcon();
Falcon falcon = (Falcon) bird;

Consider the following possible features for the Bird and Falcon classes. Assume that all methods are instance methods (not static!). The notation Bird::gulgate(Bird) specifies a method called gulgate with parameter of type Bird from the Bird class.

F1. The Bird::gulgate(Bird) method exists.
F2. The Bird::gulgate(Falcon) method exists.
F3. The Falcon::gulgate(Bird) method exists.
F4. The Falcon::gulgate(Falcon) method exists.

(a) Suppose we make a call to bird.gulgate(bird);

Which features are sufficient ALONE for this call to compile? For example if feature F3 or feature F4 alone will allow this call to compile, select F3 and F4.

☒ F1 ☐ F2 ☐ F3 ☐ F4 ☐ Impossible

Select a set of features such that this call executes the Bird::gulgate(Bird) method. For example, if having features F2 and F4 only (and not F1 and F3) would result in Bird::gulgate(Bird) being executed, only select F2 and F4.

☒ F1 ☐ F2 ☐ F3 ☐ F4 ☐ Impossible

Select a set of features such that this call executes the Falcon::gulgate(Bird) method.

☒ F1 ☐ F2 ☒ F3 ☐ F4 ☐ Impossible

(b) Suppose we make a call to falcon.gulgate(falcon);

Which features are sufficient ALONE for this call to compile?

☒ F1 ☒ F2 ☒ F3 ☒ F4 ☒ Impossible

Select a set of features such that this call executes the Bird::gulgate(Bird) method.

☒ F1 ☐ F2 ☒ F3 ☒ F4 ☒ Impossible

Select a set of features such that this call executes the Bird::gulgate(Falcon) method.

☐ F1 ☒ F2 ☐ F3 ☐ F4 ☒ Impossible

Select a set of features such that this call executes the Falcon::gulgate(Bird) method.

☐ F1 ☐ F2 ☒ F3 ☐ F4 ☒ Impossible

Select a set of features such that this call executes the Falcon::gulgate(Falcon) method.

☐ F1 ☐ F2 ☐ F3 ☒ F4 ☒ Impossible