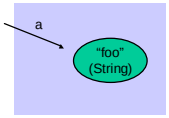
Review of objects and variables in Java

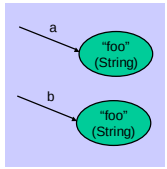
variables & objects

- what happens when you run this?
  String a = "foo";
  System.out.println (a);
- *it prints*
  foo
- what is "foo"?
- *a string literal that evaluates to a String object*
- what is a?
- *a variable whose value is an object reference*
- what is String a = "foo"?
- *a declaration and an assignment in one*



method calls

- what happens when you run this?
  String a = "foo";
  String b = a.toUpperCase ();
  System.out.println (b);
- *it prints*
  foo
- what is toUpperCase?
  a method of class String
  - *type is* String -> String
  - *declared as* public String toUpperCase ()
- what is a.toUpperCase ()?
  a method call on the object a
- does it change a?
  no, it creates a new string



null references

- what happens when you run this?
  String a = null;
  System.out.println (a);
- *it prints*
  null
- what happens when you run this?
  String a = null;
  String b = a.toUpperCase ();
  System.out.println (b);
  it throws a NullPointerException
- why?
  because a method call must have a subject

sharing & equality

– what happens when you run this?

```
String a = "foo";
String b = "foo";
System.out.println (b);
```

– *it prints*

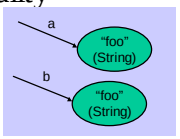
```
foo
```

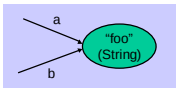
– is that the same as this?

```
String a = "foo";
String b = a;
System.out.println (b);
```

– *yes, because String is immutable.*

– *There is no way to distinguish these cases and, in fact, Java virtual machine may produce upper or lower state in this case.*





mutable containers

–what happens when you run this?

```
Vector v = new Vector ();
String a = "foo";
v.addElement (a);
System.out.println (v.lastElement ());
```

–*it prints*

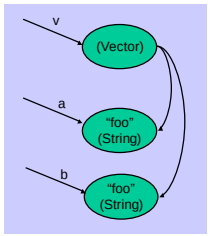
```
foo
```

–what happens when you run this?

```
Vector v = new Vector ();
String a = "foo";
String b = "foo";
v.addElement (a);
System.out.println (v.lastElement ());
v.addElement (b);
System.out.println (v.lastElement ());
```

–*it prints*

```
foo
foo
```



aliasing

–what about this?

```
Vector v = new Vector ();
Vector q = v;
String a = "foo";
v.addElement (a);
System.out.println (q.lastElement ());
```

–*it prints*

```
foo
```

–why?

–*because v and q are aliased: they are names for the same object*

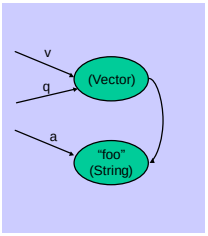
–what if we now do this?

```
if (v == q) System.out.println ("same object");
if (v.equals (q)) System.out.println ("same value");
```

–*it prints*

```
same object
same value
```

Aliasing *occurs when several different identifiers refer to the same object. The term is very general and is used in many contexts.*



aliasing & immutables

– what does this do?

```
String a = "foo";
String b = a;
a.toUpperCase ();
System.out.println (b);
```

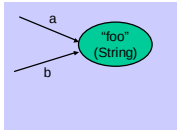
it prints

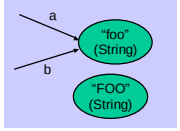
```
foo
```

– why?

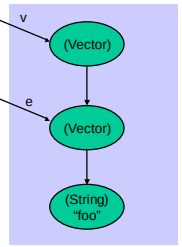
because strings are immutable

– The objects created by the toUpperCase method is eventually GCed (garbage collected.)





polymorphism



- what does this do?

```
Vector v = new Vector ();
Vector e = new Vector ()
v.addElement (e);
e.addElement ("foo");
System.out.println (
  ((Vector) v.lastElement ()).lastElement ());
```

- *it prints*

```
foo
```

- what kind of method is addElement?
  - *a polymorphic one*
    - *type is* Vector, Object -> void
    - *declared as* public void addElement (Object o)

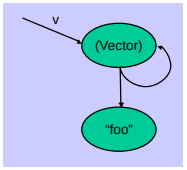
On polymorphism

- First identified by Christopher Strachey (1967) and developed by Hindley and Milner, allowing types such as *a list of anything*.
- E.g. in Haskell we can define a function which operates on a list of objects of any type *a* (*a* is a type variable).

```
length :: [a] -> Int
```

- Polymorphic typing allows strong type checking as well as generic functions. ML in 1976 was the first language with polymorphic typing.
- Ad-hoc polymorphism (aka overloading) is the ability to use the same syntax for objects of different types, e.g. "+" for addition of reals and integers.
- In OOP, the term is used to describe variables which may refer at run-time to objects of different classes.

reference loops



- can i even add v to itself?

```
Vector v = new Vector ();
v.addElement (v);
System.out.println (v.lastElement ())
```

- *yes, try it!*
- and this?

```
v.addElement (5);
```

- *no, 5 is a primitive value, not an object*

a pair of methods

- some types
  - what are the types of *addElement*, *lastElement*?
    - *addElement : Vector, Object -> void*
    - *lastElement : Vector -> Object*
- a puzzle
  - how are x and e related after this?

```
v.addElement (e);
x = v.lastElement ();
```

  - *they denote the same object*
  - can the compiler infer that?
  - *no! not even that x and e have the same class*

downcasts

– what does this do?

```
Vector v = new Vector ();
String a = "foo";
v.addElement (a);
String  b = v.lastElement ();
System.out.println (b);
```

– *compiler rejects it: v.lastElement doesn't return a String!*

– what does this do?

```
Vector v = new Vector ();
String a = "foo";
v.addElement (a);
String  b = (String) v.lastElement ();
System.out.println (b);
```

– *it prints*

```
foo
```


upcasting and downcasting

- Suppose we have object O of class C1 with superclass C2
- In Java, upcasting is automatic but downcasting must be explicit.
- Upcasting: treating O as a C2
- Downcasting: treating O as a C1

variable & object classes

– what does this do?

```
Vector v = new Vector ();
String a = "foo";
v.addElement (a);
Object  o = v.lastElement ();
System.out.println (o.getClass ());
```

– *it prints*

```
java.lang.String
```

– what's going on here?

- *getClass returns an object representing a class*
- *o.getClass () is the class o has at runtime*
- *System.out.println prints a string representation, ie, the name*

Some key concepts

- variables & objects
  - variables hold *object references* (or primitive values like 5)
  - null is a special object reference
- sharing, equality & mutability
  - distinct objects can have the same value
  - state is held in value of *instance variables*
  - an object can be *mutable* (state may change) or *immutable*
  - two variables can point to the same object; changing one affects the other
- methods
  - a method has a 'subject' or 'target' object
  - may be *polymorphic*, ie. work on several types of object
- compile-time & runtime types
  - an object has a type at runtime: the class of its constructor
  - a variable has a declared, compile-time type or class
  - runtime class is subclass of compile-time class