Arrays

Arrays in Java are objects. They are 0-indexed.

```
int halfsize = 10;
int[] array = new int[2*halfsize];

for (int i=0; i < array.length; i++)
   array[i] = i;


String[] strings1 = { "hi", "there" };

// or

String[] strings2 = new String[2];
strings2[0] = "hi";
strings2[1] = "there";
```


Multidimensional Arrays

Just arrays of arrays:

```
int[][] a = new int[3][];

a[0] = { 1, 2, 3 };
a[1] = null;
a[2] = { 4, 5 };

int[][] b = { { 1, 2, 3 }, null, { 4, 5 } };

System.out.println(a[2][0]);     // prints 3
```


Memory Model

All objects are in heap.

```
Date now = new Date();
Date alsoNow = now;
Date nowAgain = now.clone();

// compare pointers
boolean comp1 = (now == alsoNow);
boolean comp2 = (now == nowAgain);

// compare objects
boolean comp3 = (now.equals(alsoNow));
boolean comp4 = (now.equals(nowAgain));
boolean comp5 = (now.equals(new Date()));
```


Subclasses

Given the following class definitions

```
public class Bird
{
   public String tweet() { return "tweet"; }
}

public class Owl extends Bird
{
   public String tweet() { return "hoot"; }
   public String bob() { return "bob bob"; }
}

public class Dog
{
   public String bark() { return "woof"; }
}
```

Type System

Java is *statically* and *dynamically* typed (C++ is only statically typed).

Consider: `Bird bird = new Owl();`

Static: each variable has a type.

- A variable of type `Bird` can only reference *descendents* (subclasses) of type `Bird`.
- Only methods defined on `Bird`s can be invoked via a `Bird` variable. Legal: `bird.tweet()` Illegal: `bird.bob()`
- Statically, the `bird` variable is of type `Bird`.

Type System (cont)

Consider: `Bird bird = new Owl();`

Dynamic: Each object knows what type it really is.

- So `bird.getClass()` returns the `Class` object for `Owl`.
- Type casts tell compiler that object is really a subclass:
```
Owl owl = (Owl)bird;
owl.bob();
```
- Above cast only works if `bird` is really a reference to an `Owl` or a descendent of `Owl`. It is a *runtime exception* otherwise. E.g. `(Owl)(new Bird())`.
- Dynamically, the value stored in `bird` is of type `Owl`.

Static/Dynamic Type

The *static type* of an expression is the type the compiler associates with the expression.

The *dynamic type* of an expression is actual type of the value of the expression when the program is running.

Assignment is allowed if the *static type* of RHS is a descendent of the *static type* of LHS: `Bird bird = new Owl();`

The *static type* of a type-cast expression is the type of the cast.

A cast succeeds if *dynamic type* of expression is a descendent of the type of the cast. `(Owl)bird;`

Type System, E.g. (cont)

What are the results of each line?
Which lines cause *compile-time* or *run-time* errors?

```
Bird b1 = new Owl();
Bird b2 = new Bird();

b1.tweet();
b2.tweet();
b1.bob();

Owl o0 = b1;
Owl o1 = (Owl)b1;
Owl o2 = (Owl)b2;
Bird b3 = (Bird)(new Dog());
```

Operator `instanceof`

Consider

```
public String animate(Bird b)
{
   String out = b.tweet();
   if (b instanceof Owl)
      out = out + ", " + ((Owl)b).bob();
}
```


Functions, Methods, etc.

Instance variables or *member fields*: Each instance of an object has its own copies.

Member functions or *methods*: Functions invoked on instances of objects. Implicit `this` reference in method body refers to the object that the method was invoked on. `bird.tweet();`

Static variables or *class variables*: One per class. E.g. `System.out` or `Integer.MAX_VALUE` .

Static functions or *class functions*: No implicit `this` reference. Invoked like `<class name>.<function name>`. E.g. `Integer.parseInt("500")`

Static functions and static variables are declared with `static` modifier.

Methods: Scoping

Scoping:

- A method's formal parameter variable names shadow instance variable names. Use `this` to access instance variables. E.g. the `Point` constructor:
  `public Point(int x, int y) { this.x = x; this.y = y; }`
- Superclass instance variables (and methods) are shadowed by subclass instance variables (and methods). Use `super` to access superclass variables.

Methods: Overloading

Overloading:

- Operators cannot be overloaded. I.e. `*` can only multiply numbers.
- Methods and static functions can be overloaded. The *signature* of a function is a combination of its name and its argument types.
- Overloading uses static types not dynamic types of arguments.

Methods: Overriding

Overriding:

- In C++ terms, all Java methods are *virtual*: All method invocations are *dynamically dispatched*.
- A method in a subclass *overrides* same-signature method in superclass.
- Dangerous to combine overloading with overriding.

Overriding & Overloading (E.g.)

```
public class Bird
{
   public String tweet() { return "tweet"; }
   public String peck(Bird b)
      { return "A bird pecks a bird"; }
   public String peck(Owl o)
      { return "A bird pecks an owl"; }
}

public class Owl extends Bird
{
   public String tweet() { return "hoot"; }
   public String bob() { return "bob bob"; }
   public String peck(Bird b)
      { return "An owl pecks a bird"; }
   public String peck(Owl o)
      { return "An owl pecks an owl"; }
}
```


Overriding & Overloading (cont)

What are the results of?

```
Bird b1 = new Bird();
Bird b2 = new Bird();
Bird bo1 = new Owl();
Bird bo2 = new Owl();
Owl o1 = new Owl();
Owl o2 = new Owl();
```

```
b1.peck(b2);
b1.peck(bo2);
b1.peck(o2);

o1.peck(b2);
o1.peck(bo2);
o1.peck(o2);
```

```
bo1.peck(b2);
bo1.peck(bo2);
bo1.peck(o2);
```


Subclassing

Use `extends` keyword.

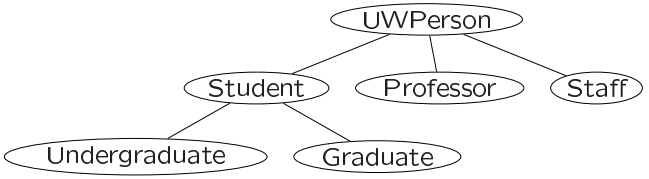
Subclasses must define their own constructors. If not, a default one will be used. If any constructor is defined, the default constructor will not be used.

A class can have only one parent class – no *multiple inheritance*.

What might be bad about multiple inheritance?

Multiple Inheritance?

Consider the U.W. people database:



Who teaches classes/sections? Graduates and Professors do:

```
public class Graduate extends Student
{  ...
   public void teach(Course c) {...}
}
public class Professor extends UWPerson
{  ...
   public void teach(Course c) {...}
}
```


Multiple Inheritance (cont)

How can we register teachers to teach courses?

```
public class Course
{
   ...
   public void registerTeacher(UWPerson p)
   {
      p.teach(this);
   }
}
```

What's wrong?

Multiple Inheritance (cont)

Second try:

```
public void registerTeacher(UWPerson p)
{
   if (p instanceof Professor)
   {
      Professor prof = (Professor)p;
      prof.teach(this);
   }
   else if (p instanceof Graduate)
      ((Graduate)p).teach(this);
}
```

Works, but clunky.

Interfaces

While multiple-inheritance might be a bad idea, the idea of having variable for objects that have the `teach(Course)` method is useful.

Solution: *interfaces*

A java class can implement any number of interfaces.

```
public interface Teacher
{
   public void teach(Course c);
}
```

Any class that *implements* this interface can be put in a `Teacher` variable.

Any class that implements `Teacher` must define its own `teach(Course)` function.

Interfaces (E.g.)

```
public class Graduate extends Student implements Teacher
{
   ...
   public void teach(Course c) {...}
}

public class Professor extends UWPerson implements Teacher
{
   ...
   public void teach(Course c) {...}
}
```


registerTeacher

Now we can define `registerTeacher` as:

```
public class Course
{
   ...
   public void registerTeacher(Teacher t)
   {
      t.teach(this);
   }
}
```

It can be called as:

```
Course c1 = ...;
Course c2 = ...;
Professor p = ...;
Graduate g = ...;

c1.registerTeacher(p);
c2.registerTeacher(g);
```


Enumeration Interface

Consider `java.util.Enumeration`:

```
public interface Enumeration
{
   public boolean hasMoreElements();
   public Object nextElement();
}
```


Polymorphism

Interfaces provide means of *polymorphism*.

A *polymorphic* function is one that can by applied to arguments of different types:

```
public static void printEnumeration(Enumeration e)
{
   while (e.hasMoreElements())
      System.out.println(e.nextElement());
}
```

`java.util.StringTokenizer` implements `Enumeration`:

```
StringTokenizer st = new StringTokenizer("this is a test");
printEnumeration(st);
```

You can get an `Enumeration` from a `java.util.Vector`:

```
Vector v = ...;
printEnumeration(v.elements());
```

IntegerRange Class

```
public class IntegerRange implements Enumeration
{
   int min; int max;
   public IntegerRange(int minIn, int maxIn)
   {
      min = minIn;
      max = maxIn;
   }
   public boolean hasMoreElements()
   {
       return min <= max;
   }
   public Object nextElement()
   {
       return new Integer(min++);
   }
}
```


Subclasses and Interfaces

Subclassing:

- *Inheritance* of code
- Polymorphism

Interfaces:

- Polymorphism

Abstract Classes

Sometimes it does not make sense ever instantiate a class, E.g. `UWPerson`.

Sometimes we want to specify part of an implementation but not all of it.

Classes declared `abstract` can not be instantiated.

Abstract classes may declare abstract methods that non-abstract subclasses must implement (Like *pure virtual* methods in C++).

InputStream

```
public abstract class InputStream
{
   // simple default implementations.
   public int available() { return 0; }
   public void close() {}
   public boolean markSupported() { return false; }
   public void reset() {}

   // abstract read() method, overridden by subclass
   // depending on its input source.
   public abstract int read() throws IOExcption;

   // default implementations that use read()
   public int read(byte[] b, int off, int len)
      { ...  b = read();  ... }

   public int read(byte[] b) throws IOException
      { return read(b, 0, b.length); }
   public long skip(long n)
      { ... }
}
```

StringInputStream

```
public class StringInputStream extends InputStream
{
   private byte[] data;
   private int length;
   private int cursor;

   public StringInputStream(String in)
   {
      data = in.getBytes();
      length = in.length();
      cursor=0;
   }

   public int read()
   {
      if (cursor >= length)
        return -1;

      return (int)data[cursor++];
   }
}
```


Abstract Classes – Summary

Abstract `InputStream` class made `StringInputStream` easy to create.

`StringInputStream` only had to implement `int read()` method.

`StringInputStream` inherited `read(byte[])` and `read(byte[], int, int)`.

Inherited `read(byte[],int,int)` used `StringInputStream`'s `int read()` method.

Generic Collections

All classes are subclasses of `Object`.

To make a collection of any type use `Object` as type.

E.g. `java.util.Vector` and `java.util.Hashtable`.

It is easy to insert elements:

```
Vector v = new Vector();
v.add(new Bird());
```

But, cast is required to remove elements:

```
Bird b = (Bird)v.elementAt(0);
```

Java does not provide generic support like C++'s *templates* (only arrays).

Primitive Wrappers

Any `Object` can be put in a `Vector`.

Java primitive `int`s are not `Objects`.

Can not have a `Vector` of `int`.

Can *wrap* `int` in `Integer` class:

```
Vector v = new Vector();
v.add(new Integer(5));

int i = ((Integer)(v.lastElement())).intValue();
```

Wrapper classes also have useful class functions and class variables: E.g. `Integer.parseInt(String)` and `Integer.MAX_VALUE`.