A Complete Java Program

```
public class HelloWorld {
 public static void main(String[] args) {
    System.out.println("Hello World");
    }
}
```

```
– javac    HelloWorld.java
– java     HelloWorld
```


(Non-)Tokens

- Whitespace
  - blank
  - tab
  - newline
- Comment
  - // ...
  - /* ... */
  - /** ... */
- Separators
  - (,), [,], etc
- Keywords (*reserved*)
- Identifiers
- Literals
  - 25, 2.5 (`int/float`)
    - 09 is not an integer.
  - true, false (`boolean`)
  - 'a', \u0061, \n (`char`)
- Operators
  - +, >, &&, etc

Java : Types

- Primitive Types
- Reference Types

Primitive Types and Values

- Numeric Types
  - Integral Types (signed two's complement)
    - `byte`, `short` (2 bytes), `int` (4 bytes), `long` (8 bytes)
    - `char` **(16-bit Unicode)**
  - Floating-point Types (IEEE 754 Standard)
    - `float` (4 bytes), `double` (8 bytes)
- Boolean Type
  - `boolean`
    - `true, false`

Numeric Types

- Explicit range and behavior.
  - Java trades performance for cross-platform portability.
- `byte` : appropriate when parsing a network protocol or file format, to resolve "endianess".
  - BIG endian : SPARC, Power PC : MSB-LSB
  - LITTLE endian : Intel X86 : LSB-MSB
  - Calculations involving `byte/short` done by promoting them to `int`.
  - Internally, Java may even store `byte/short` as `int`, *except in arrays*.

Type Conversions

- Coercion (widening or promotion)
  - `int i = 50;   float f = i;`
- Fractional literals are always `double`.
- Casting (narrowing)
  - `byte b = 128;` // *Error*
  - `byte b = (byte) 258;` // *= 2*
  - `b = (b * 0);` // *Error*
  - `b = (byte) (b * 2);`
  - `char four = (char) ( '1' + 3 );`
  - `float f = (float) 0.0;`

Casting

```
class  PrimCast {
    public static void main(String[]  argv) {
      byte b = 0;
      int  i = b;
      b  =  i;            // *error*
      b  =  (b * 0);      // *error*
      b  = (byte) i;
      b =  (byte) 280;     //  = 24
      b = 128;        // *error* Java 1.1
}}
```


C# : Primitive Type Casting

```
class  PrimCast {
    public static void Main(string[]  argv) {
           int  i = 50;
// *warning* The variable 'i' is assigned but its value is never used
           byte b = 127;
           b = (byte) 258;
// b = 258;
// *error* Constant value '258' cannot be converted to a 'byte'
           unchecked {b = (byte) 258;}
           System.Console.WriteLine("byte b = " + b);
           b =  (byte) (b * 0);
// b = (b * 0);
// *error* Cannot implicitly convert type 'int' to 'byte'
    }
}
// Console Output: byte b = 2
```

Boolean Type

- Distinct from integer type.
  - 0 (1) are *not* `false` (`true`). (Cf. C/C++)
- Let `boolean b,c` and `int i`.
  - `if (b) {} else {};`
  - `if (b == true) { c = false; }`
    `else { c = true; };`
    equivalent to `c = ! b;`
  - `if (i = 0) {};`
    is a type error ("`int` *used* `bool` *expected*").

Operators

- Variety
  - unary, binary, ternary
  - prefix, infix, postfix
  - arithmetic, bitwise, relational, logical
- `var op= expr;` *equivalent to* `var = var op expr;`
- Shift operators:
  - `i >> 5` (sign extension)
  - `i >>> 5` (unsigned)
  - `i << 5`
  - Interaction with promotion (coercion) to `int`

Boolean Operators

- Boolean logical ***and/or*** operator : `&, |`
- Boolean short-circuit ***and/or*** operator : `&&, ||`
  - `false && B == false`
  - `true || B == true`
- De Morgan's laws
  - `! (a & b ) = !a | !b`
  - `! (a | b ) = !a & !b`
- Operator overloading :
  - `& (resp.|):` bitwise/logical ***and*** (resp. ***or***)
  - `+ :` numeric add, string concatenation
    - ***No user defined operator overloads.***

Reference Types and Values

- **Class Types**
  - String is a class.
- **Interface Types**
- **Array Types**

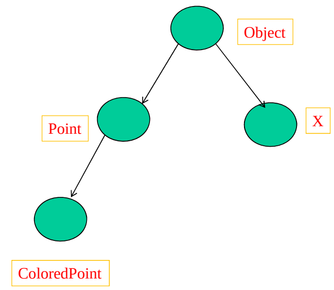
An *object* (resp. *array object*) is an instance of a class (resp. an array).

A *reference* is a pointer to (or the address of) an object or an array object.

Variables and Values

- A variable of a primitive type always holds a value of that *exact primitive type*.
- A variable of a reference type can hold either *a null reference* or *a reference to any object whose class is assignment compatible with the type of the variable*.

Example Class Hierarchy




```
class Point { }
class ColoredPoint extends Point { }
class RefCast {
  public static void main (String [] args) {
        Object oR;
        Point pR = null;
        ColoredPoint cpR = null;
              oR  = pR;
              pR  = cpR;
              cpR = pR;     // *error*
              cpR = (ColoredPoint) pR;
                    // *run-time exception*
        X xR = null;
              cpR = (ColoredPoint) xR;
              // *error*
}}
class X {}
```


Notes on Type Checking

- Coercion, Widening: pR = cpR;
- Casting, Narrowing:

  cpR = (ColoredPoint) pR;

  - Sound because a Point-type variable can potentially hold a ColoredPoint reference.
  - However, to guarantee type safety, Java compiler emits type checking code which can, at runtime, throw ClassCastException if the type constraint is not met.

(cont'd)

- Casting, Narrowing:

  xR = (X) pR;

  - This is unsound because a Point-type variable can never hold an X-reference. So, compiler generates a type error.
- Initialization:
  - Java requires that local variables be explicitly initialized before their first use. So, assignments of null to pR and cpR, in the example, are mandatory.

C# : Reference Type Casting

```
class Point { }
class ColoredPoint : Point { }
class X { }
class RefCast {
  public static void Main () {
       System.Object oR;
       Point pR = null;
       ColoredPoint cpR = null;
       oR = pR;
       pR = cpR;
       //cpR = pR;
      // *error* Cannot implicitly convert type 'Point' to 'ColoredPoint'
       cpR = (ColoredPoint) pR;
       X xR;
      // *warning* The variable 'xR' is declared but never used
      // xR = (X) pR;      // *error* Cannot convert type 'Point' to 'X'
  }
}
```


Type Compatibility Examples

- class variable - subclass instance

```
import java.awt.*;          import java.applet.*;
   Panel  p = new Applet();
   Applet a = (Applet) p;
   p = a;
import java.io.*;
   BufferedReader bin = new BufferedReader
        (new InputStreamReader (System.in));
```

- interface variable - class instance

```
   Runnable  p = new Thread();
```


Subtle Differences

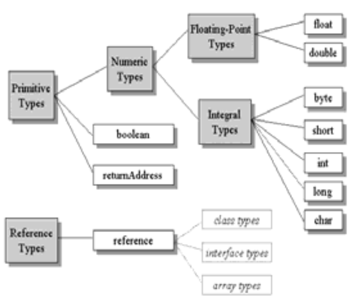
- Assignment (x = y)
  - Primitive type : copying a value
    - Parameter passing: *call by value*
  - Reference type: sharing an object
    - Parameter passing: *copying reference*
- *final* variable modifier
  - Primitive type : constant value
  - Reference type: constant object
    - Mutable : state of the object changeable
    - Immutable : state of the object constant
      - E.g., *class* String

Meaning of assignment

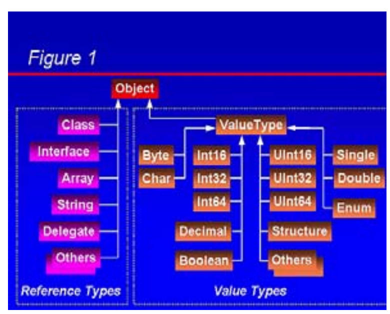
```
class  ToAssign {
   public static void main(String[]  argv) {
     int  ip = 5;    Pair  ir  =  new Pair (15,25);
     int  jp = ip;   Pair  jr  = ir;

   System.out.println( "jp = "  + jp  + "\t" +  "jr = "  + jr);
       ip = 9;            ir.x    = 19;
   System.out.println("ip = "  + ip  + "\t" +  "ir = "  + ir);
   System.out.println("jp = "  + jp  + "\t" +  "jr = "  + jr);
}}
```


- The uniform abstraction of "*everything is an object*" traded for efficiency.
  - No composite types such as *structures* or *unions.*
- Every expression has a type deducible at compile-time.
- All assignments of expressions to variables are checked for type compatibility.

Data Types supported by JVM



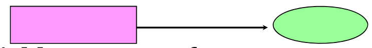
Data Types supported by C#



Motivation for Strong Typing

- Type declarations provide extra information associated with an identifier. This redundant info. enables mechanical detection of errors.
- In practice, a number of logical and typographical errors *manifest* themselves as type errors. Thus, strongly typed languages allow construction of reliable programs.
- In OOPLs, the type tags associated with objects aid in the impl. of dynamic binding, polymorphism, and safe conversions.

Typing



variable **reference** **object**

(*text*) (*pointer*) (*memory*)

- Static Typing (e.g., Ada)
  - *type*(variable) = *type*(object)
  - compile-time checking : *efficient*
- Dynamic Typing (e.g., Scheme)
  - variables type-less; objects carry type tags
  - run-time type-checking : *flexible*

- **Typing in OOPL** (*E.g., Java, Eiffel, C#, …*)
  - *type*(object/reference) **is-a-subtype-of** *type*(variable).
  - In Java, a variable of class Cl, can hold a reference to an instance (object) of a subclass of Cl.

– Type correctness guaranteed at compile-time.
  - Efficient and secure.

– Dynamic binding dispatches each call to the appropriate code, at run-time.
  - Flexible handling of heterogeneous data.

Arrays

Arrays

- Declaration
  - `int[]  intArray; String[] args;`
- Creation
  - `intArray = new int[5];`
  - `intArray = { 0, 2, 4, 3*2, 4+4 };`
- Array of arrays (cf. multi-dimensional array)
  - `double [][] iA = { { 1, 0 }, null };`
- Java runtime verifies that array indices are in the correct range.

An Example Program

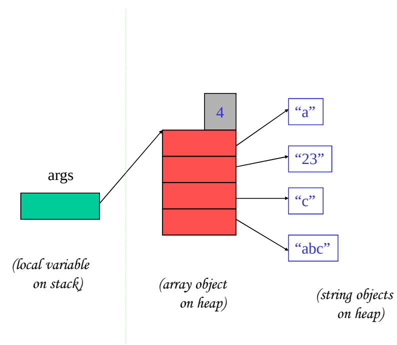
```
class  EchoArgs {
 public static void main(String[] args){
   for (int i = 0; i < args.length; i++)
       System.out.print( args[i] );
   };
   System.out.println("");
}
```

- `javac   EchoArgs.java`
- `java    EchoArgs a 23 c abc`
- `java    EchoArgs`

Java 5 version

```
class  EchoArgs {
 public static void main(String[] args){
   System.out.print("Command line arguments: ");
   for (String s : args)
       System.out.printf( " %s ", s );
   System.out.println(".");
 }
}
```

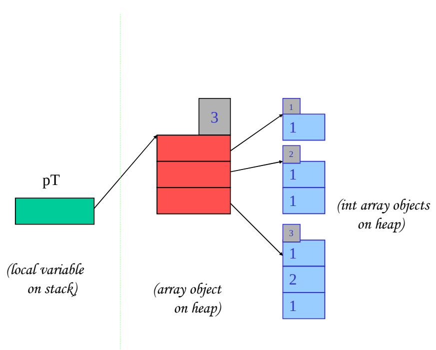
- `javac   EchoArgs.java`
- `java    EchoArgs a 23 c ab`



Pascal Triangle

1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1
…


```
class PascalTriangle {
  public static void main( String[] args ) {
   n = Integer.parseInt( args[0] );
   int [] [] pT = new int [n + 1] [];
   pT[0] = new int[1];            // first row
   pT[0][0] = 1;
   for (int i = 1; i <= n; i++) {// rows 2 to n+1
         pT[i] = new int [i + 1];
         pT[i][0] = 1;
         pT[i][i] = 1;
         for (int j = 1; j < i ; j++ ) {
           pT[i][j] = pT[i-1][j-1] + pT[i-1][j];
   }
  }
}
```

C# Equivalent

```
using System;
class PascalTriangleInCSharp {
    public static void Main( string[] args ) {
      int n = 7;
      if (args.Length > 0)
             n = int.Parse( args[0] );
      int [] [] pT = new int [n + 1] [];
      pT[0] = new int[1]; pT[0][0] = 1;
      for (int i = 1; i <= n; i++) {
         pT[i] = new int [i + 1];
         pT[i][0] = 1;
         pT[i][i] = 1;
         for (int j = 1; j < i ; j++ ) {
            pT[i][j] = pT[i-1][j-1] + pT[i-1][j];
         }
      }
   }
```

C# Alternative

```
using System;

class RectArrayInCSharp {
    public static void Main( string[] args ) {
       const int n = 7;
       int [,] pT = new int [n,n];

      for (int i = 0;  i < n; i++) {
       for (int j = 0; j < n; j++) {
           pT[i,j] = i + j;
          }
       }
       System.Console.WriteLine(pT);
    }
}
```


Array type : "*unconstrained*"

- Define matrix operations in terms of structure of the array (dimensionality); size is implicit.
  - *Vector dot-product* that works for two equal length single-dimension array with same type elements.
  - *Matrix multiplication* : Dimension compatibility checked at run-time.
- `length` field of an array object used :
  - to control loops.
  - to allocate storage for local variables.
- Type is *unconstrained*, but each object/instance has a *fixed* size. (E.g., String type *vs* String object)
- Cf. Ada Unconstrained array types.

Java Generics


```
import java.util.*;
public class OldList {
  public static void main(String args[]) {
    List list = new ArrayList();
    //  (Potentially heterogeneous collection)
    list.add("one");
    list.add("two");
    list.add("three");
    list.add("four");
    Iterator itr = list.iterator();
    while(itr.hasNext()) {
      // Explicit type cast needed
      String str = (String) itr.next();
      System.out.println(str + " is " +
                  str.length + " chars long.");
    }
  }
}
```

```
import java.util.*;
public class NewList {
  public static void main(String[] args) {
    List <String>  list =
            new LinkedList <String>();
    // Instantiating generic type.
    // (Homogeneous collection)
    list.add("one");
    list.add("two");
    list.add("three");
    list.add("four");
    for (String str : list) {
      System.out.printf("%s is %d chars long.\n",
                        str, str.length);
    };
  }
}
```



```
using System;
using System.Collections.Generic;

public class NewList {
  public static void Main(string [] args) {
    // List class supports method Add
    LinkedList <String> list =
              new LinkedList <String>();
    // Instantiating generic type.
    // (Homogeneous collection)
    list.AddFirst("one");
    list.AddLast("two");
    list.AddLast("three");
    list.AddLast("four");
    foreach (string str in list) {
      System.Console.WriteLine(str + " is " +
                      str.Length + " chars long.");
    };
  }
}
```