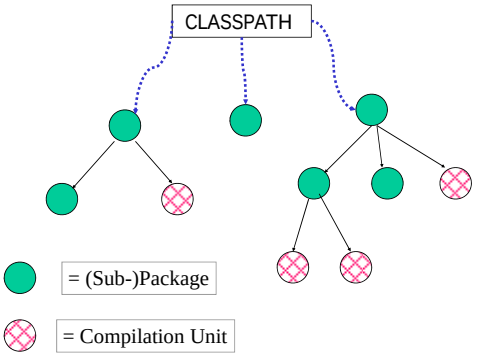
Packages

Partitioning class name space

Access control of names

Organization of a Java Program

- Java Program
  - *Forest* of packages
    - E.g., $PWD, java, javax, etc.
- Package (Tree)
  - *Directory* of sub-packages and compilation units
    - E.g., java.io, java.util, java.lang.Thread, java.applet.Applet;
- Compilation Unit (Leaf)
  - *File* containing *class* and *interface* definitions with at most one *public class*
- CLASSPATH environment variable
  - Set to full-path names of *roots of trees in the forest*



`package` statement

- Omitted : *anonymous* package
  - For ***.class** byte code files to be accessible to the JVM, ensure "**.**" ($PWD) is contained in the environment variable CLASSPATH.
- `package Pk;`
  - If a class is declared inside package `Pk` (or subpackage `Pk.Sk`), then the ***.java** source files must be stored in the directory **Pk** (or **Pk/Sk**), and the CLASSPATH must contain at least **.../Pk.**

`import` statement (*for programmer convenience*)

- importing a type explicitly
  - `import java.util.StringTokenizer;`
- importing type-on-demand
  - `import java.io.*;`

Access Control

- `private` : inaccessible from outside the class
- *default* : accessible in the package
- `protected` : accessible in the subclasses and the package
- `public` : no restriction on accessibility

	`private`	*default*	`protected`	`public`
same class	Y	Y	Y	Y
same package subclass	N	Y	Y	Y
same package non-subclass	N	Y	Y	Y
different package subclass	N	N	Y	Y
different package non-subclass	N	N	N	Y

Access Control : `C` and `S` in different packages

```
class C {
  public    int x;
  protected int y;
  private   int z;
  int p(C c) {
     return c.x + c.y +
            c.z   ;
  }
  int q(S s) {
     return s.x + s.y
  +((C) s).y +((C) s).z
     // + s.z
            + s.i ;
     // + s.j + s.k ;
}}
```

```
class S extends C {
  public    int i;
  protected int j;
  private   int k;
  int p(C c) {
     return c.x ;
    // + c.y + c.z ;
  }
  int q(S s) {
     return s.x + s.y +
            // s.z +
            s.i + s.j +
            s.k   ;
}}
```


Notes

- Public, protected and private fields of a direct instance (e.g., `c.x, c.y, c.z`) of a class are accessible in the class (C's text), while the private fields of a subclass instance (e.g., `s.z`) are accessible in the class (C's text) *only via a static cast* (e.g., `(C) s.z`).
- **The inherited protected field due to parent class (C) of a direct instance of a subclass (e.g., `s.y`) is available in subclass (S's text).**
  - Note that the protected field of a direct class instance (e.g., `c.y`) is not available in the subclass (S's text) and the protected field of a subclass instance is not available in the parent class (C's text) (e.g., `s.j`).

Other Constraints

- *Access modifier* of a hiding/overriding method must provide *at least as much access as* the hidden/overridden method.
  - Otherwise, access barrier beaten by *casting*.

```
class C {
   public void p() {}
}
class S extends C {
   private void p() {}
}
C x = new S();
   x.p();
```

Illegal Code

Hiding and Overriding : Static and Dynamic Binding

```
class C {
       int a = 84;
   static int q() {}
      int p() {...}
}
class S extends C {
  int a = 77;
  static int q() {
      super.q() + 1;
  ...}
  int p() {...
      super.p() + 1;
  ...}
}
```

```
S x = new S();
C y = x;

    (x.a == 77)
    (y.a == 84)
(((C) x).a == 84)

(x.p() == y.p())

(x.q() != y. q())
(((C) x).q() == y.q())
```


Notes

- Static methods, static fields and instance fields are *statically* bound, while instance methods are *dynamically* bound.
- Static methods, static fields, and instance fields can be *hidden*, while instance methods can be *overridden*.
- Hidden members of a subclass instance can be accessed outside the class (text) using *static cast* and within the subclass (text) using `super` prefix.

Defining a Method with the Same Signature as a Superclass's Method

	Superclass Instance Method	Superclass Static Method
Subclass Instance Method	Overrides	Generates a compile-time error
Subclass Static Method	Generates a compile-time error	Hides

Accessibility and Overriding

A method can be *overridden* in a subclass only if the method in the superclass is accessible.

If a method in the superclass is *not accessible* then method in the subclass *does not override* it *even if they have the same signature.*


```
package P1;
public abstract class AbstractBase {
  private void pri() {        System.out.print("AbstractBase.pri()"); }
  void pac() {      System.out.("AbstractBase.pac()"); }
  protected void pro() {     System.out.("AbstractBase.pro()"); }
  public void pub() {        System.out.("AbstractBase.pub()"); }
 public final void show() {
                    pri();
                    pac();
                    pro();
                    pub();
 }}
```



```
package P2;     // Different package from AbstractBase
import P1.AbstractBase;
public class Concrete1 extends AbstractBase {
        public void pri() { print("Concrete1.pri()"); }
        public void pac() { print("Concrete1.pac()"); }
        public void pro() { print("Concrete1.pro()"); }
        public void pub() { print("Concrete1.pub()"); }
}
new Concrete1().show();
// only protected and public can be overridden
OUTPUT:
                AbstractBase.pri()
                AbstractBase.pac()
                Concrete1.pro()
                Concrete1.pub()
```



```
package P1; // Same package as AbstractBase
import P2.Concrete1;
public class Concrete2 extends Concrete1 {
        public void pri() { print("Concrete2.pri()"); }
        public void pac() { print("Concrete2.pac()"); }
        public void pro() { print("Concrete2.pro()"); }
        public void pub() { print("Concrete2.pub()"); }
}
new Concrete2().show();
// default (package), protected and public can be overridden
OUTPUT:
                AbstractBase.pri()
                Concrete2.pac()
                Concrete2.pro()
                Concrete2.pub()
```

```
package P3; // Different package from AbstractBase
import P1.Concrete2;
public class Concrete3 extends Concrete2 {
        public void pri() { print("Concrete3.pri()"); }
        public void pac() { print("Concrete3.pac()"); }
        public void pro() { print("Concrete3.pro()"); }
        public void pub() { print("Concrete3.pub()"); }
}
new Concrete3().show();
//  Concrete3.pac() overriddes Concrete2.pac()
//   which in turn overrides AbstractBase.pac()
OUTPUT:
                AbstractBase.pri()
                Concrete3.pac()
                Concrete3.pro()
                Concrete3.pub()
```


Java Development Kit

- `java.lang` (contains `Threads`)
- `java.io` (contains `StreamTokenizer`)
- `java.awt` (Abstract Windowing ToolKit)
- `java.net` (Support for TCP/IP, HTTP)
- `java.applet` (To run code via Browser)
- `java.util` (Standard Utilities)
- *javac*, *java*, *javadoc*

Scope and Lifetime

- The ***scope*** of an identifier declaration is *the region of text* in which the declaration is effective.
  - E.g., class scope, block scope, global, etc.
- The ***lifetime*** of a variable (or an object) bound to an identifier is the period during which it exists in the memory.
  - E.g., Static variables and objects allocated via `new` on *heap* have "infinite" lifetime. (garbage collection)
  - E.g., Formal parameters and local variables of a method are allocated on *stack*. (LIFO discipline)


```
Enumeration myEnumerate(final Object[] arr) {

    class E implements Enumeration {
      int count = 0;
      public boolean hasMoreElements()
           { return count < arr.length; }
      public Object nextElement()
           { return arr[count++]; }
    }
   return new E();
}
```

- *Scope* of `arr` is the body of `myEnumerate` function.
- *Lifetime* of the array instance referenced by `arr` is "infinite". It survives as long as the `Enumeration` object returned is "alive".