**Scope vs. Lifetime**

It is usually required that the lifetime of a run-time object at least cover the scope of the identifier. That is, whenever you can access an identifier, the run-time object it denotes better exist.

But, it is possible to have a run-time object’s lifetime exceed the scope of its identifier. An example of this is static or own variables.

**In C:**

```c
void p() {
  static int i = 0;
  print(i++);
}
```

Each call to `p` prints a different value of `i` (0, 1, ...) Variable `i` retains its value across calls.

Some languages allow an explicit binding of an identifier for a fixed scope:

```plaintext
Let
  id = val in statements
end;
```

A declaration may appear wherever a statement or expression is allowed. Limited scopes enhance readability.

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**Structs vs. Blocks**

Many programming languages, including C, C++, C#, Pascal and Ada, have a notion of grouping data together into structs or records.

For example:

```c
struct complex { float re, im; }
```

There is also the notion of grouping statements and declarations into blocks:

```c
{ float re, im;
  re = 0.0; im = 1.0;
}
```

Blocks and structs look similar, but there are significant differences:

- **Structs are data,**
  - As originally designed, structs contain only data (no functions or methods).
  - Structs can be dynamically created, in any number, and included in other data structures (e.g., in an array of structs).
  - All fields in a struct are visible outside the struct.
Blocks are code,
- They can contain both code and data.
- Blocks can’t be dynamically created during execution; they are “built into” a program.
- Locals in a block aren’t visible outside the block.

By adding functions and initialization code to structs, we get classes—a nice blend of structs and blocks.

For example:
```java
class complex{
    float re, im;
    complex (float v1, float v2){
        re = v1; im = v2; }
}
```

Classes
- Class objects can be created as needed, in any number, and included in other data structure.
- They include both data (fields) and functions (methods).
- They include mechanisms to initialize themselves (constructors) and to finalize themselves (destructors).
- They allow controlled access to members (private and public declarations).

Type Equivalence in Classes

In C, C++ and Java, instances of the same struct or class are type-equivalent, and mutually assignable.

For example:
```java
class MyClass { ... }
MyClass v1, v2;
v1 = v2; // Assignment is OK
```

We expect to be able to assign values of the same type, including class objects.

However, sometimes a class models a data object whose size or shape is set upon creation (in a constructor). Then we may not want assignment to be allowed.

```java
class Point {
    int dimensions;
    float coordinates[];
    Point () {
        dimensions = 2;
        coordinates = new float[2];
    }
    Point (int d) {
        dimensions = d;
        coordinates = new float[d];
    }
}
Point plane = new Point();
Point solid = new Point(3);
plane = solid; //OK in Java
```

This assignment is allowed, even though the two objects represent points in different dimensions.
Subtypes

In C++, C# and Java we can create subclasses—new classes derived from an existing class.
We can use subclasses to create new data objects that are similar (since they are based on a common parent), but still type-inequivalent.

Example:

```java
class Point2 extends Point {
    Point2() {super(2); }
}
class Point3 extends Point {
    Point3() {super(3); }
}
Point2 plane = new Point2();
Point3 solid = new Point3();
plane = solid; //Illegal in Java
```

Parametric Polymorphism

We can create distinct subclasses based on the values passed to constructors. But sometimes we want to create subclasses based on distinct types, and types can’t be passed as parameters. (Types are not values, but rather a property of values.)

We see this problem in Java, which tries to create general purpose data structures by basing them on the class `Object`. Since any object can be assigned to `Object` (all classes must be a subclass of `Object`), this works—at least partially.

```java
class LinkedList {
    Object value;
    LinkedList next;
    Object head() {return value;}
    LinkedList tail(){return next;}
    LinkedList(Object O) {
        value = O; next = null;
    }
    LinkedList(Object O, LinkedList L){
        value = O; next = L;
    }
}
```

Using this class, we can create a linked list of any subtype of `Object`.
But,

- We can't guarantee that linked lists are type homogeneous (contain only a single type).
- We must cast `Object` types back into their “real” types when we extract list values.

```java
class LinkedList {
    Object value;
    LinkedList next;
    Object head() {return value;}
    LinkedList tail(){return next;}
    LinkedList(Object O) {
        value = O; next = null;
    }
    LinkedList(Object O, LinkedList L){
        value = O; next = L;
    }
}
```

- We must use wrapper classes like `Integer` rather than `int` (because primitive types like `int` aren't objects, and aren't subclass of `Object`).

For example, to use `LinkedList` to build a linked list of `ints` we do the following:

```java
LinkedList l =
    new LinkedList(new Integer(123));
int i =
    ((Integer) l.head()).intValue();
```

This is pretty clumsy code. We’d prefer a mechanism that allows us to create a “custom version” of `LinkedList`, based on the type we want the list to contain.
We can’t just call something like

```
LinkedList(int)
LinkedList(Integer)
```

because types can’t be passed as parameters. Parametric polymorphism is the solution. Using this mechanism, we can use type parameters to build a “custom version” of a class from a general purpose class. C++ allows this using its template mechanism. Tiger Java, the newest version of Java, also allows type parameters.

In both languages, type parameters are enclosed in “angle brackets” (e.g., `LinkedList<T>` passes `T`, a type, to the `LinkedList` class).

Thus we have

```
class LinkedList<T> {
    T value; LinkedList<T> next;
    T head() {return value;}
    LinkedList<T> tail() {
        return next;
    }
    LinkedList(T O) {
        value = O; next = null;
    }
    LinkedList(T O, LinkedList<T> L) {
        value = O; next = L;
    }
}
```

```java
LinkedList<int> l = new LinkedList(123);
int i = l.head();
```