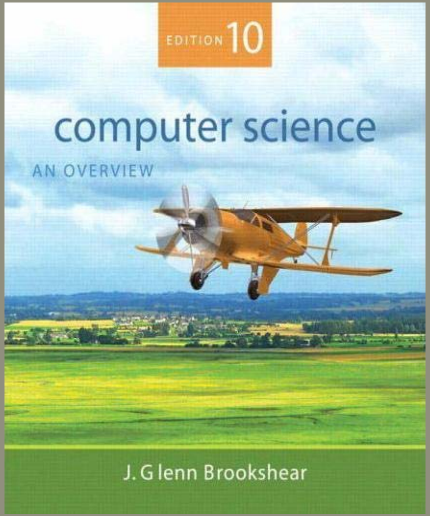
Chapter 6

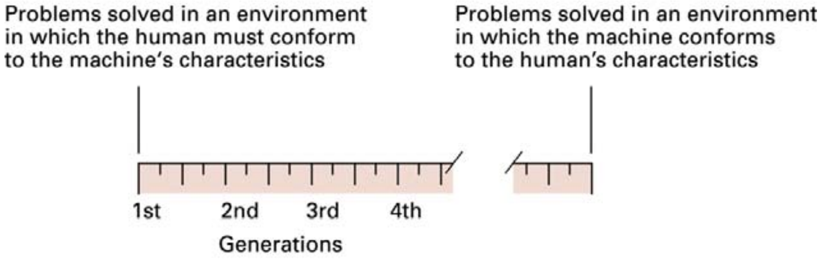
Programming
Languages



Chapter 6: Programming Languages

- 6.1 Historical Perspective
- 6.2 Traditional Programming Concepts
- 6.3 Procedural Units
- 6.4 Language Implementation
- 6.5 Object Oriented Programming
- 6.6 Programming Concurrent Activities
- 6.7 Declarative Programming

Figure 6.1 Generations of programming languages



Second-generation: Assembly language

- A mnemonic system for representing machine instructions
  - Mnemonic names for op-codes
  - Identifiers: Descriptive names for memory locations, chosen by the programmer

Assembly Language Characteristics

- One-to-one correspondence between machine instructions and assembly instructions
  - – Programmer must think like the machine
- Inherently machine-dependent
- Converted to machine language by a program called an **assembler**

Program Example

Machine language	Assembly language
156C	LD R5, Price
166D	LD R6, ShippingCharge
5056	ADDI R0, R5 R6
30CE	ST R0, TotalCost
C000	HLT

Third Generation Language

- Uses high-level primitives
  - – Similar to our pseudocode in Chapter 5
- Machine independent (mostly)
- Examples: FORTRAN, COBOL
- Each primitive corresponds to a sequence of machine language instructions
- Converted to machine language by a program called a **compiler**

Figure 6.2 The evolution of programming paradigms

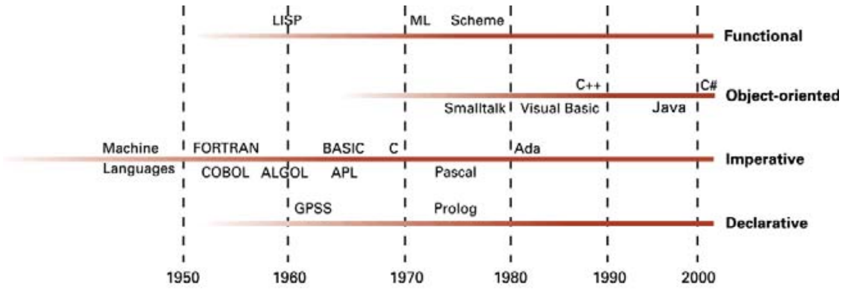


Figure 6.3 A function for checkbook balancing constructed from simpler functions

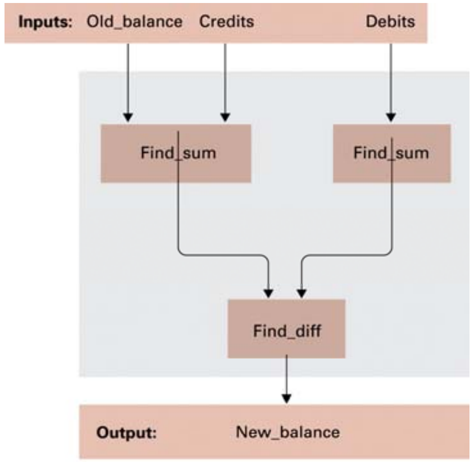
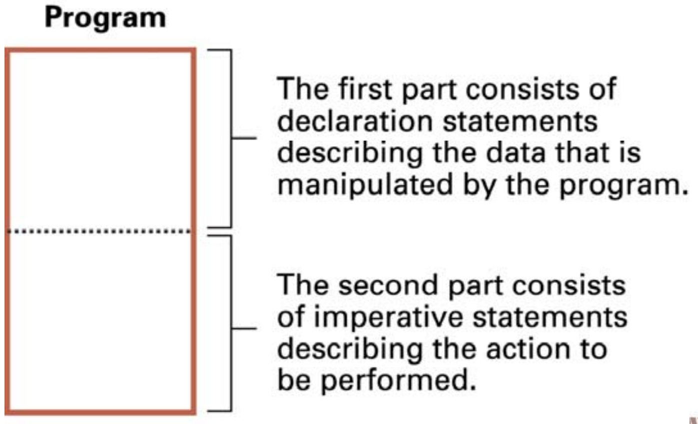


Figure 6.4 The composition of a typical imperative program or program unit



The first part consists of declaration statements describing the data that is manipulated by the program.

The second part consists of imperative statements describing the action to be performed.

Data Types

- Integer: Whole numbers
- Real (float): Numbers with fractions
- Character: Symbols
- Boolean: True/false

Variable Declarations

```
float    Length, Width;
int      Price, Total, Tax;
char     Symbol;
```

Figure 6.5 A two-dimensional array with two rows and nine columns

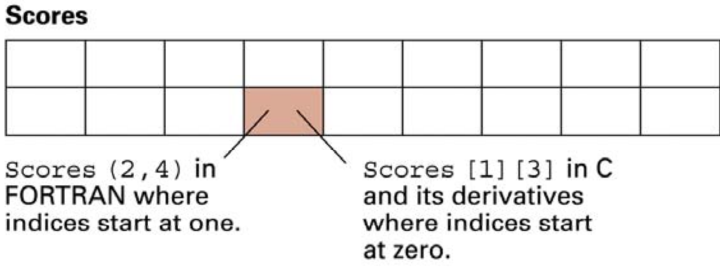


Figure 6.6 The conceptual structure of the heterogeneous array Employee

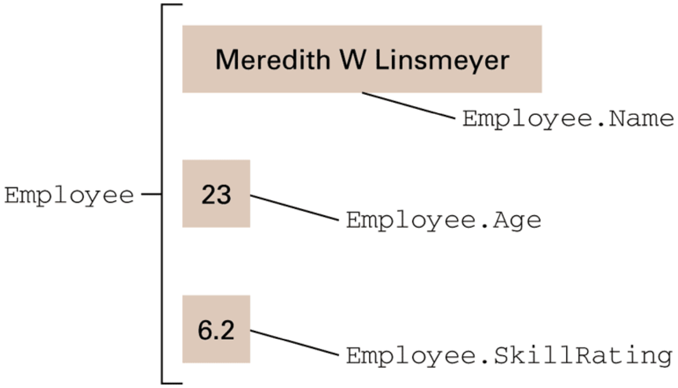
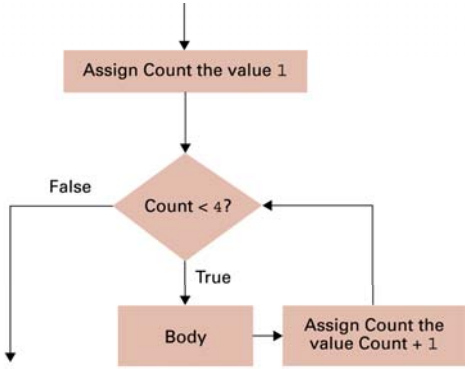


Figure 6.7 The for loop structure and its representation in C++, C#, and Java

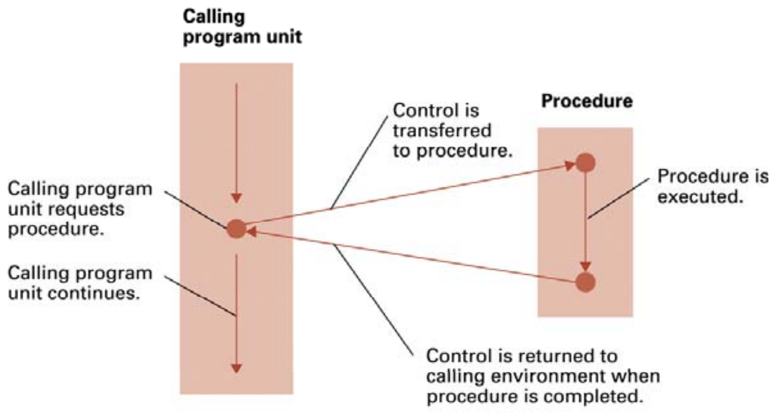


```
for (int Count = 1; Count<4; Count++)
    body ;
```

Procedural Units

- Local versus Global Variables
- Formal versus Actual Parameters
- Passing parameters by value versus reference
- Procedures versus Functions

Figure 6.8 The flow of control involving a procedure



Calling program unit

Procedure

Calling program unit requests procedure.

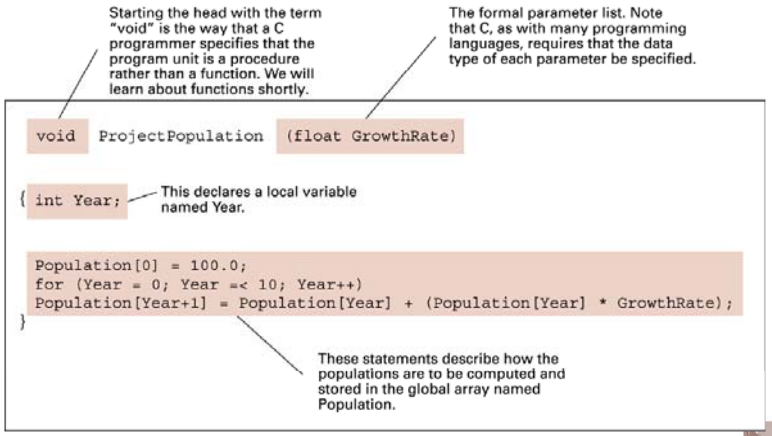
Control is transferred to procedure.

Procedure is executed.

Calling program unit continues.

Control is returned to calling environment when procedure is completed.

Figure 6.9 The procedure ProjectPopulation written in the programming language C



Starting the head with the term "void" is the way that a C programmer specifies that the program unit is a procedure rather than a function. We will learn about functions shortly.

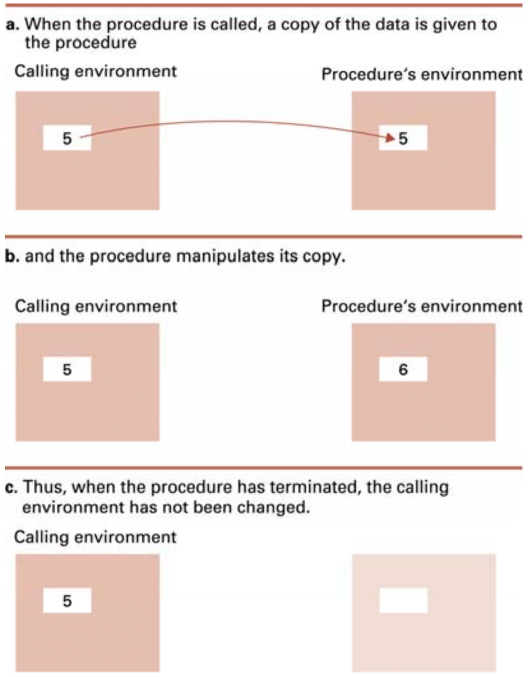
The formal parameter list. Note that C, as with many programming languages, requires that the data type of each parameter be specified.

```
void  ProjectPopulation  (float GrowthRate)

{ int Year;

  Population[0] = 100.0;
  for (Year = 0; Year =< 10; Year++)
  Population[Year+1] = Population[Year] + (Population[Year] * GrowthRate);
}
```

This declares a local variable named Year.

These statements describe how the populations are to be computed and stored in the global array named Population.

Figure 6.10 Executing the procedure Demo and passing parameters by value



a. When the procedure is called, a copy of the data is given to the procedure

Calling environment

Procedure's environment

5

5

b. and the procedure manipulates its copy.

Calling environment

Procedure's environment

5

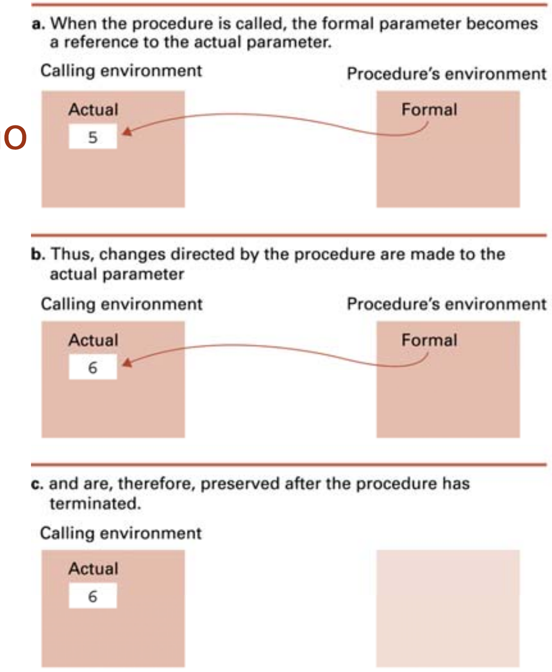
6

c. Thus, when the procedure has terminated, the calling environment has not been changed.

Calling environment

5

Figure 6.11 Executing the procedure Demo and passing parameters by reference



a. When the procedure is called, the formal parameter becomes a reference to the actual parameter.

Calling environment

Procedure's environment

Actual

5

Formal

b. Thus, changes directed by the procedure are made to the actual parameter

Calling environment

Procedure's environment

Actual

6

Formal

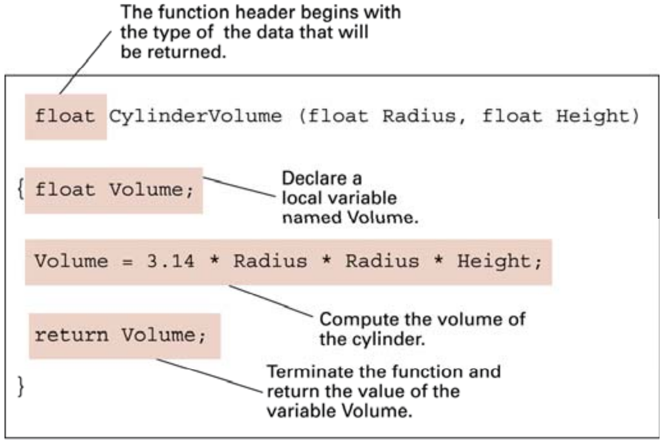
c. and are, therefore, preserved after the procedure has terminated.

Calling environment

Actual

6

Figure 6.12 The function CylinderVolume written in the programming language C



The function header begins with the type of the data that will be returned.

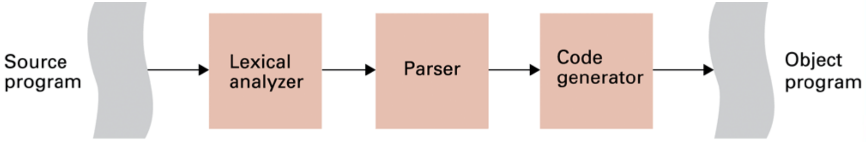
```
float CylinderVolume (float Radius, float Height)
{ float Volume;
  Volume = 3.14 * Radius * Radius * Height;
  return Volume;
}
```

Declare a local variable named Volume.

Compute the volume of the cylinder.

Terminate the function and return the value of the variable Volume.

Figure 6.13 The translation process



Source program

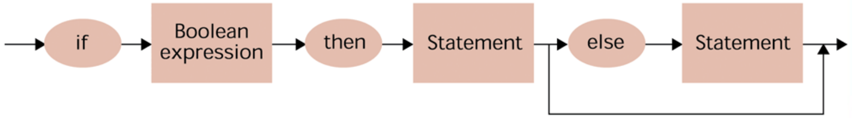
Lexical analyzer

Parser

Code generator

Object program

Figure 6.14 A syntax diagram of our if-then-else pseudocode statement



if

Boolean expression

then

Statement

else

Statement

Figure 6.15 Syntax diagrams describing the structure of a simple algebraic expression

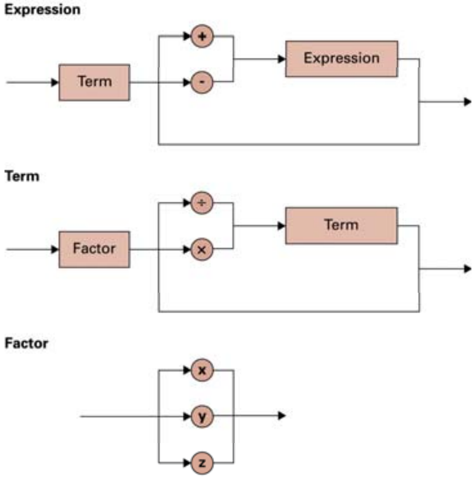


Figure 6.16 The parse tree for the string x + y x z based on the syntax diagrams in Figure 6.17

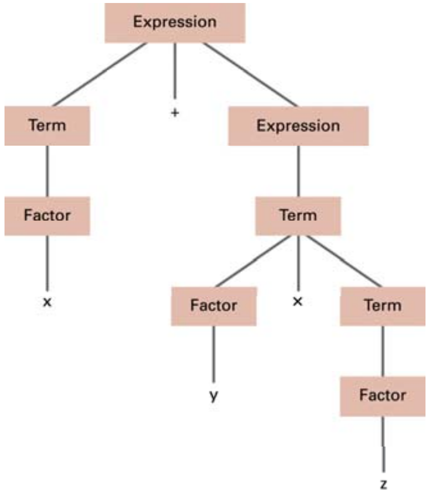


Figure 6.17 Two distinct parse trees for the statement if B1 then if B2 then S1 else S2

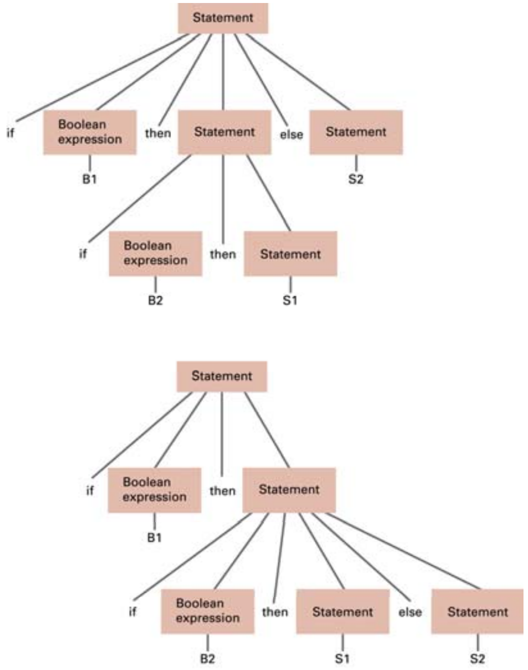
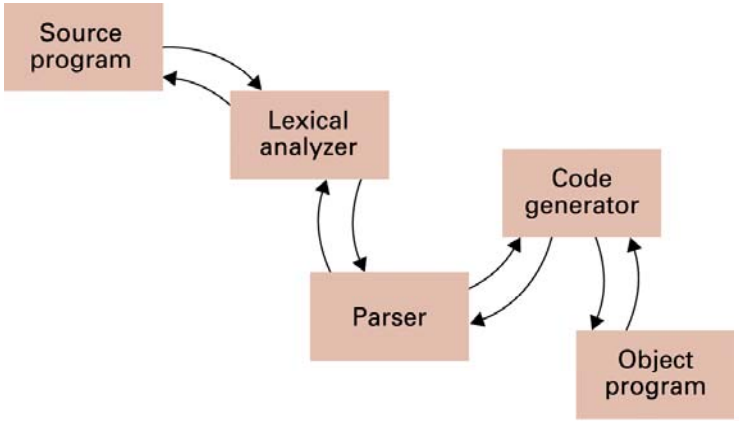


Figure 6.18 An object-oriented approach to the translation process

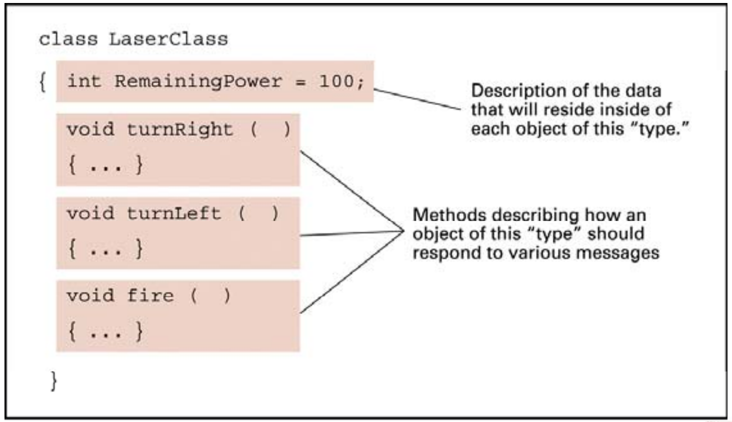


Objects and Classes

- **Object:** Active program unit containing both data and procedures
- **Class:** A template from which objects are constructed

An object is called an **instance** of the class.

Figure 6.19 The structure of a class describing a laser weapon in a computer game



```
class LaserClass
{  int RemainingPower = 100;

   void turnRight (  )
   { ... }

   void turnLeft (  )
   { ... }

   void fire (  )
   { ... }

 }
```

Description of the data that will reside inside of each object of this "type."

Methods describing how an object of this "type" should respond to various messages

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Components of an Object

- **Instance Variable:** Variable within an object
  - – Holds information within the object
- **Method:** Procedure within an object
  - – Describes the actions that the object can perform
- **Constructor:** Special method used to initialize a new object when it is first constructed

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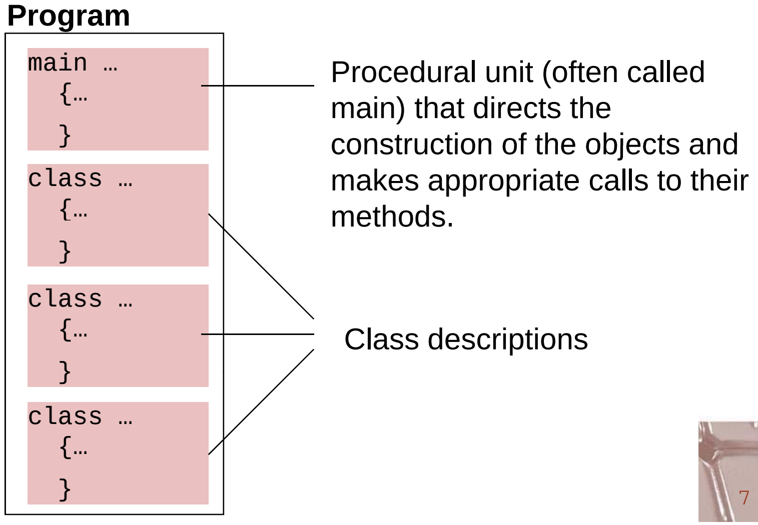
Figure 6.20 The Structure of a typical object-oriented program



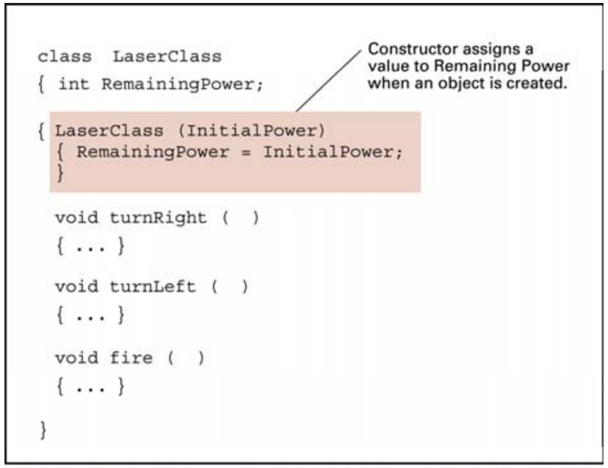
Program

```
main …
  {…
  }
class …
  {…
  }
class …
  {…
  }
class …
  {…
  }
```

Procedural unit (often called main) that directs the construction of the objects and makes appropriate calls to their methods.

Class descriptions

Figure 6.21 A class with a constructor



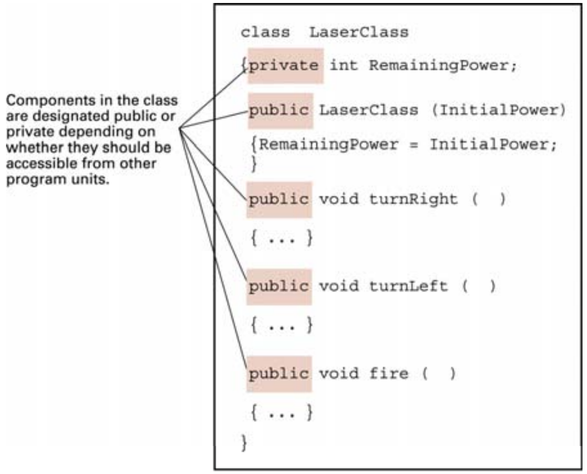
```
class  LaserClass
{ int RemainingPower;

{ LaserClass (InitialPower)
  { RemainingPower = InitialPower;
  }

  void turnRight (  )
  { ... }

  void turnLeft (  )
  { ... }

  void fire (  )
  { ... }

}
```

Constructor assigns a value to Remaining Power when an object is created.

Object Integrity

- **Encapsulation:** A way of restricting access to the internal components of an object
  - Private versus public

Figure 6.22 Our LaserClass definition using encapsulation



Components in the class are designated public or private depending on whether they should be accessible from other program units.

```
class  LaserClass
{private int RemainingPower;
 public LaserClass (InitialPower)
 {RemainingPower = InitialPower;
 }
 public void turnRight ( )
 { ... }
 public void turnLeft ( )
 { ... }
 public void fire ( )
 { ... }
}
```

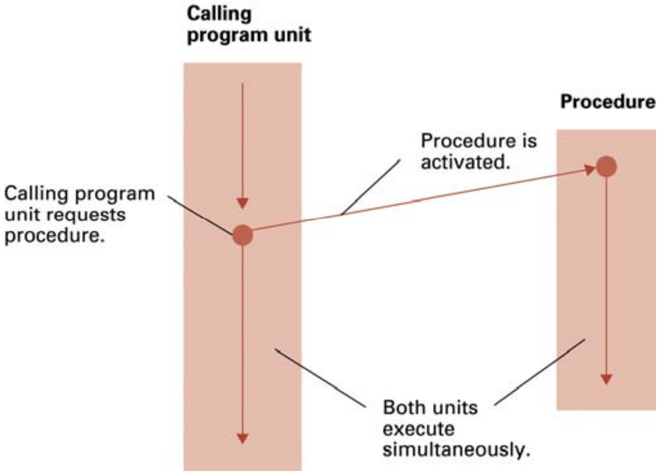
Additional Object-oriented Concepts

- **Inheritance:** Allows new classes to be defined in terms of previously defined classes
- **Polymorphism:** Allows method calls to be interpreted by the object that receives the call

Programming Concurrent Activities

- **Parallel** (or **concurrent**) **processing:** simultaneous execution of multiple processes
  - True concurrent processing requires multiple CPUs
  - Can be simulated using time-sharing with a single CPU

Figure 6.23 Spawning threads



Controlling Access to Data

- **Mutual Exclusion:** A method for ensuring that data can be accessed by only one process at a time
- **Monitor:** A data item augmented with the ability to control access to itself

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Declarative Programming

- **Resolution:** Combining two or more statements to produce a new statement (that is a logical consequence of the originals).
  - Example: (P OR Q) AND (R OR ¬Q) resolves to (P OR R)
  - **Resolvent:** A new statement deduced by resolution
  - **Clause form:** A statement whose elementary components are connected by the Boolean operation OR
- **Unification:** Assigning a value to a variable so that two statements become "compatible."

Figure 6.24 Resolving the statements (*P* OR *Q*) and (*R* OR ¬*Q*) to produce (*P* OR *R*)

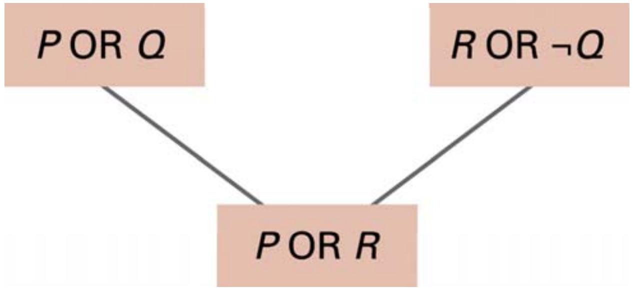
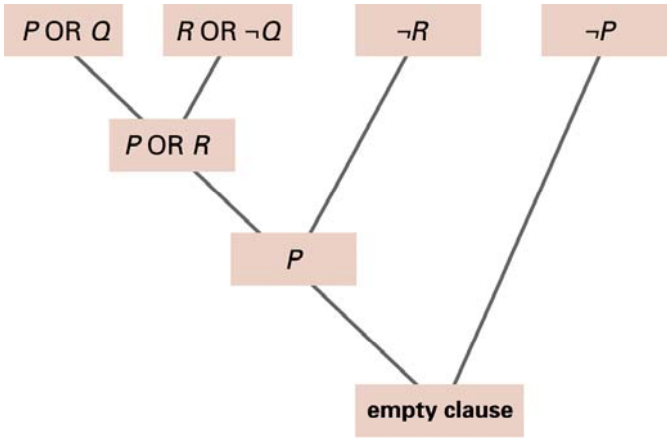


Figure 6.25 Resolving the statements (*P* OR *Q*), (*R* OR ¬*Q*), ¬R, and ¬*P*



P OR *Q*

R OR ¬*Q*

¬*R*

¬*P*

P OR *R*

P

empty clause

Prolog

- **Fact:** A Prolog statement establishing a fact
  - Consists of a single predicate
  - Form: *predicateName*(*arguments*).
    - Example: `parent(bill, mary).`
- **Rule:** A Prolog statement establishing a general rule
  - Form: *conclusion* :- *premise.*
    - :- means “if”
  - Example: `wise(X) :- old(X).`
  - Example: `faster(X,Z) :- faster(X,Y), faster(Y,Z).`