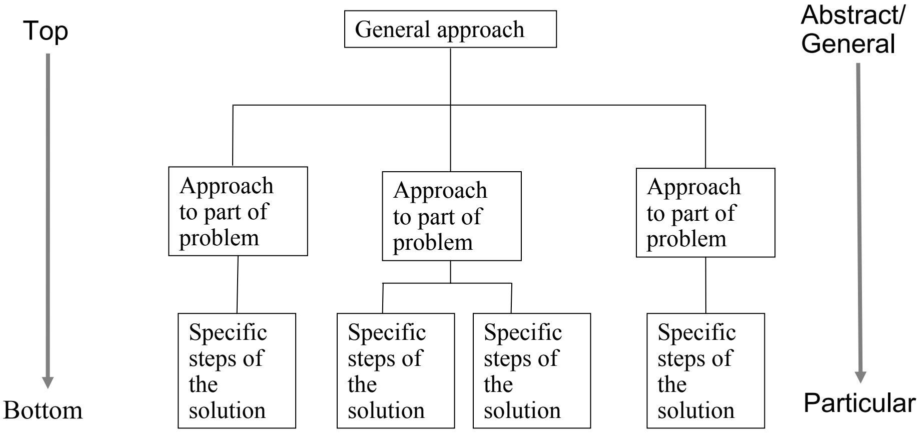
Breaking Problems Down

This section of notes shows you how to break down a large problem into smaller modules that are easier to implement and manage.

Designing A Program: Top-Down Approach



Top

Bottom

General approach

Approach to part of problem

Approach to part of problem

Approach to part of problem

Specific steps of the solution

Specific steps of the solution

Specific steps of the solution

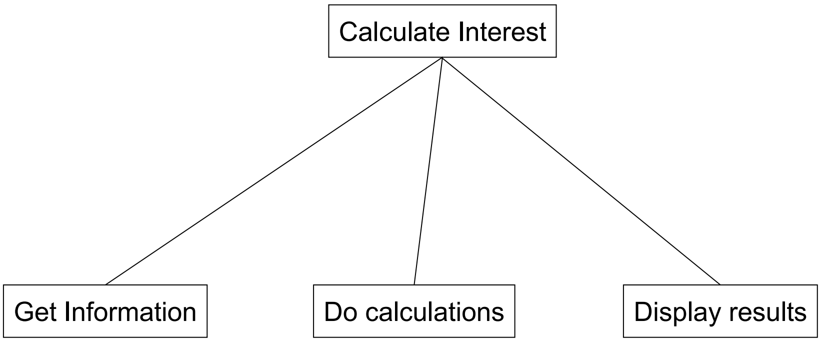
Specific steps of the solution

Abstract/ General

Particular

Figure extracted from Computer Science Illuminated by Dale N. and Lewis J.

Top Down Approach: Programming



Decomposing Problems Via The Top Down Approach

Approach

- Breaking problem into smaller, well defined parts (modules)
- Making modules as independent as possible (loose coupling)

Pascal implementation of program modules

- Procedures
- Functions

Using Functions And Procedures In Pascal

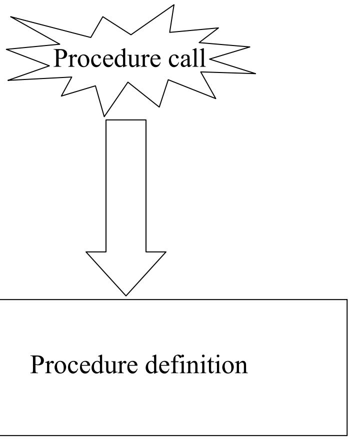
Definition

- Indicating what the function or procedure will do when it runs

Call

- Getting the function or procedure to run

Procedures (Basic Case – No Parameters)



Procedure call

Procedure definition

Defining Procedures (Basic Case – No Parameters)

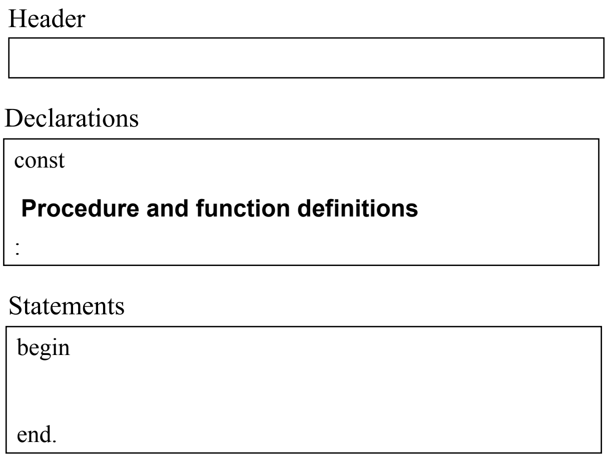
Format:

```
procedure name;
begin
        (* Statements of the procedure go here *)
end;  (* End of procedure name *)
```

Example:

```
procedure displayInstructions;
begin
        writeln ('These statements will typically give a high level');
        writeln('overview of what the program as a whole does');
end;  (* End of procedure displayInstructions *)
```

Where To Define Modules (Procedures)



Header

Declarations

const

Procedure and function definitions

:

Statements

begin

end.

Calling A Procedure (Basic Case – No Parameters)

Format:

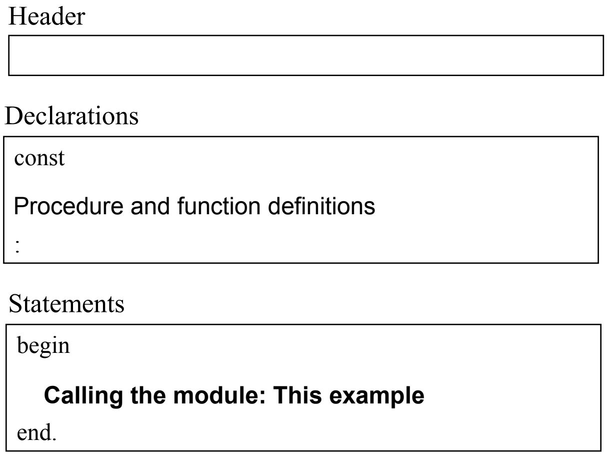
name;

Example:

displayInstructions;

Where To Call Modules (Procedures

It can be done most anywhere in the program



Header

Declarations

const

Procedure and function definitions

:

Statements

begin

Calling the module: This example

end.

Procedures: Putting Together The Basic Case

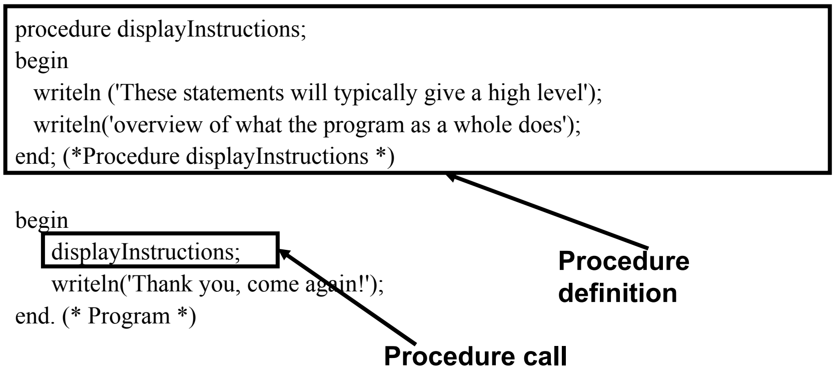
The full version of this example can be found in Unix under /home/231/examples/modules/firstExampleProcedure.p

```
program firstExampleProcedure (output);

procedure displayInstructions;
begin
  writeln ('These statements will typically give a high level');
  writeln('overview of what the program as a whole does');
end; (*Procedure displayInstructions *)

begin
    displayInstructions;
    writeln('Thank you, come again!');
end. (* Program *)
```

Procedures: Putting Together The Basic Case

The full version of this example can be found in Unix under /home/231/examples/modules/firstExampleProcedure.p

```
program firstExampleProcedure (output);
```



```
procedure displayInstructions;
begin
  writeln ('These statements will typically give a high level');
  writeln('overview of what the program as a whole does');
end; (*Procedure displayInstructions *)

begin
    displayInstructions;
    writeln('Thank you, come again!');
end. (* Program *)
```

Defining Local Variables

Exist only for the life the module

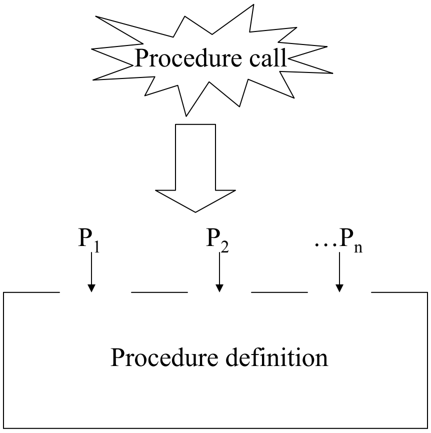
Format:

```
 procedure name;
 var
    (* Local variable declarations go here *)
begin
   :
end;
```

Example:

```
procedure proc;
var
   num  : integer;
   ch     : char;
begin
      :
end; (* Procedure celciusToFahrenheit *)
```

Procedures With Parameters



Defining Modules (Procedures) With Parameters

Format:

```
procedure name (Name of parameter 1 : type of parameter 1;
                Name of parameter 2 : type of parameter 2;
                                  :                     :
                Name of parameter n : type of parameter n);
 begin
     (* Statements of the procedure go here *)
 end;
```

Example:

```
procedure celciusToFahrenheit (celciusValue :  real);
var
   fahrenheitValue : real;
begin
    fahrenheitValue := 9 / 5 * celciusValue + 32;
    writeln(‘temperature in Celsius: ', celciusValue:0:2);
    writeln(‘temperature in Fahrenheit: ', fahrenheitValue:0:2);
end; (* Procedure celciusToFahrenheit *)
```

Calling Modules (Procedures) With Parameters

Format:

name (*Name of parameter 1*, *Name of parameter 2…Name of parameter n*);

Example:

```
celciusToFahrenheit (celciusValue);
```

Procedures: Putting Together The Case Of Procedures With Parameters

The full version of this example can be found in Unix under
/home/231/examples/modules/temperatureConverter.p

```
program temperatureConverter (input, output);

procedure celciusToFahrenheit (celciusValue :  real);
var
  fahrenheitValue : real;
begin
  fahrenheitValue := 9 / 5 * celciusValue + 32;
  writeln('Temperature in Celsius: ', celciusValue:0:2);
  writeln('Temperature in Fahrenheit: ', fahrenheitValue:0:2);
end; (* Procedure celciusToFahrenheit *)
```

Procedures: Putting Together The Case Of Procedures With Parameters

The full version of this example can be found in Unix under
/home/231/examples/modules/temperatureConverter.p

Procedure definition

```
program temperatureConverter (input, output);

procedure celciusToFahrenheit (celciusValue :  real);
var
  fahrenheitValue : real;
begin
  fahrenheitValue := 9 / 5 * celciusValue + 32;
  writeln('Temperature in Celsius: ', celciusValue:0:2);
  writeln('Temperature in Fahrenheit: ', fahrenheitValue:0:2);
end; (* Procedure celciusToFahrenheit *)
```

Procedures: Putting Together The Case Of Procedures With Parameters (2)

```
begin
   var celciusValue :  real;
   writeln;
   writeln('This program will convert a given temperature from a Celsius');
   writeln('value to a Fahrenheit value.');
   write('Enter a  temperature in Celsius: ');
   readln(celciusValue);
   writeln;
   celciusToFahrenheit(celciusValue);
   writeln('Thank you and come again.');
end. (* Program *)
```

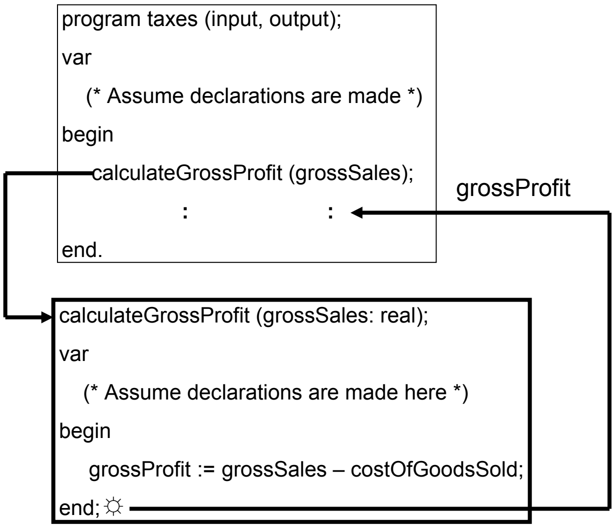
Procedures: Putting Together The Case Of Procedures With Parameters (2)

```
begin
   var celciusValue :  real;
   writeln;
   writeln('This program will convert a given temperature
     from a Celsius');
   writeln('value to a Fahrenheit value.');
   write('Enter a  temperature in Celsius: ');
   readln(celciusValue);
   writeln;
   celciusToFahrenheit(celciusValue);
   writeln('Thank you and come again.');
end. (* Program *)
```

Procedure call

Retaining Information From A Module (Function Or Procedure) After The Module Has Ended

For example: producing an income statement



```
program taxes (input, output);
var
   (* Assume declarations are made *)
begin
   calculateGrossProfit (grossSales);
               :                  :
end.
```

grossProfit

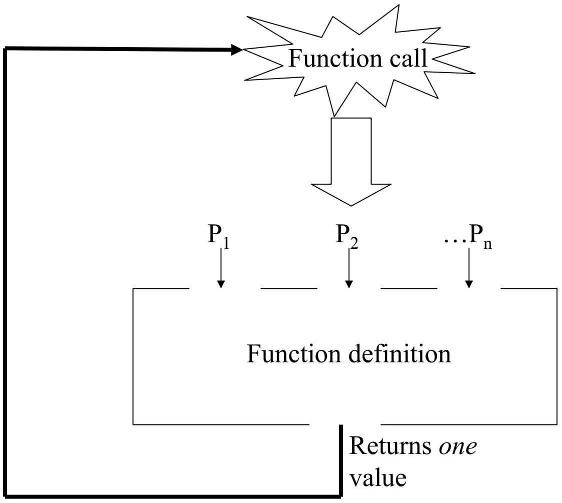
```
calculateGrossProfit (grossSales: real);
var
   (* Assume declarations are made here *)
begin
    grossProfit := grossSales – costOfGoodsSold;
end; ☼
```

Retaining Information From A Module (Function Or Procedure) After The Module Has Ended (2)

Methods:

- **Return a value with a function**
- Pass parameters into the procedure as variable parameters (rather than as value parameters)

Functions



Function call

P_1 P_2 $\ldots P_n$

Function definition

Returns *one* value

Defining Functions

Format:

```
function name (Name of parameter 1 : type of parameter 1;
                       Name of parameter 2 : type of parameter 2;
                                   :                              :
                       Name of parameter n : type of parameter n):
                       return type;
 begin
      (* Statements of the function go here *)
                  :                     :
      name := expression; (* Return value *)
 end;
```

Example:

```
function calculateGrossIncome (grossSales, costOfGoodsSold : real) : real;
begin
     calculateGrossIncome := grossSales - costOfGoodsSold;
end;
```

Defining Functions

Format:

```
function name (Name of parameter 1 : type of parameter 1;
               Name of parameter 2 : type of parameter 2;
                       :                    :
               Name of parameter n : type of parameter n):
               return type;
 begin
     (* Statements of the function go here *)
             :                    :
    name := expression; (* Return value *)
 end;
```

Return: Often the last statement in the function

Example:

```
function calculateGrossIncome (grossSales, costOfGoodsSold : real) : real;
begin
   calculateGrossIncome := grossSales - costOfGoodsSold;
end;
```

Calling Functions

Format:

name;

name (*name of parameter 1*, *name of parameter 2…name of parameter n*);

Example:

```
grossIncome := calculateGrossIncome (grossSales, costOfGoodsSold);
```

Functions: Putting It All Together

The full version of this example can be found in Unix under /home/231/examples/modules/financialStatements.p

```
program financialStatments (input, output);

function calculateGrossIncome (grossSales, costOfGoodsSold : real) : real;
begin
   calculateGrossIncome := grossSales - costOfGoodsSold
end;

function calculateNetIncome (grossIncome, expenses : real) : real;
begin
   calculateNetIncome := grossIncome - expenses;
end;
```

Functions: Putting It All Together

The full version of this example can be found in Unix under /home/231/examples/modules/financialStatements.p

```
program financialStatments (input, output);

function calculateGrossIncome (grossSales, costOfGoodsSold
: real) : real;
begin
   calculateGrossIncome := grossSales - costOfGoodsSold
end;
```

Function definitions

```
function calculateNetIncome (grossIncome, expenses : real) :
```

Functions: Putting It All Together (2)

```
procedure produceIncomeStatement;
var
  grossSales       : real;
  costOfGoodsSold : real;
  grossIncome      : real;
  expenses         : real;
  netIncome        : real;
begin
  write('Enter gross sales $');
  readln(grossSales);
  write('Enter cost of the goods that were sold $');
  readln(costOfGoodsSold);
  write('Enter corporate expenses $');
  readln(expenses);

  grossIncome := calculateGrossIncome (grossSales, costOfGoodsSold);

  netIncome := calculateNetIncome (grossIncome, expenses);
```

Functions: Putting It All Together (2)

```
procedure produceIncomeStatement;
var
  grossSales       : real;
  costOfGoodsSold : real;
  grossIncome      : real;
  expenses         : real;
  netIncome        : real;
begin
  write('Enter gross sales $');
  readln(grossSales);
  write('Enter cost of the goods that were sold $');
  readln(costOfGoodsSold);
  write('Enter corporate expenses $');
  readln(expenses);

  grossIncome := calculateGrossIncome (grossSales, costOfGoodsSold);

  netIncome := calculateNetIncome (grossIncome, expenses);
```

Function calls

Functions: Putting It All Together (3)

```
(* Procedure produceIncomeStatement continued *)
   writeln;
   writeln('Gross sales $':26, grossSales:0:2);
   writeln('Less: cost of goods sold $':26, costOfGoodsSold:0:2);
   writeln('Gross income $':26, grossIncome:0:2);
   writeln('Less: expenses $':26, expenses:0:2);
   writeln('Net income $':26, netIncome:0:2);
   writeln;
end; (* End of procedure produceIncomeStatement *)
```

Functions: Putting It All Together (4)

```
(* Start of main program *)
begin
   writeln;
   writeln('This program will produce an income statement based upon your');
   writeln('gross sales figures, the cost of the goods that you sold and
   writeln('your expenses.');
   writeln;
   produceIncomeStatement;
   writeln('Thank you, come again!');
end.  (* End of entire program. *)
```

Retaining Information From A Module (Function Or Procedure) After The Module Has Ended

Methods:

- Return a value with a function
- **Pass parameters into the procedure as variable parameters (rather than as value parameters)**

Passing Parameters As Value Parameters

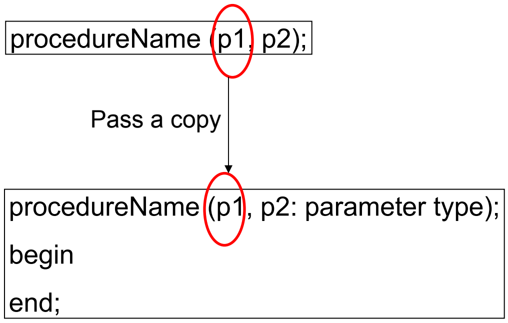
Previous examples

```
procedureName (p1, p2);
```

```
procedureName (p1, p2: parameter type);
begin
end;
```

Passing Parameters As Value Parameters

Previous examples



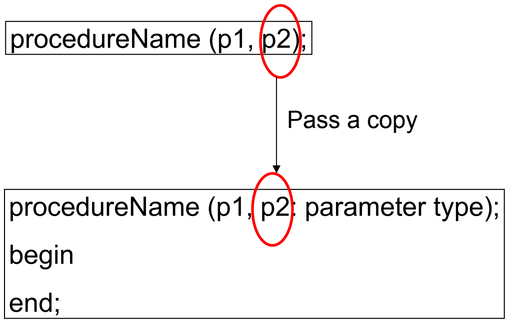
```
procedureName (p1, p2);
```

Pass a copy

```
procedureName (p1, p2: parameter type);
begin
end;
```

Passing Parameters As Value Parameters

Previous examples



```
procedureName (p1, p2);
```

Pass a copy

```
procedureName (p1, p2: parameter type);
begin
end;
```

Passing Parameters As Variable Parameters

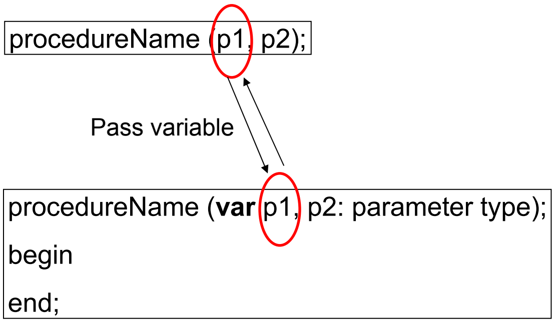
Example coming up

```
procedureName (p1, p2);
```

```
procedureName (var p1, p2: parameter type);
begin
end;
```

Passing Parameters As Variable Parameters

Example coming up



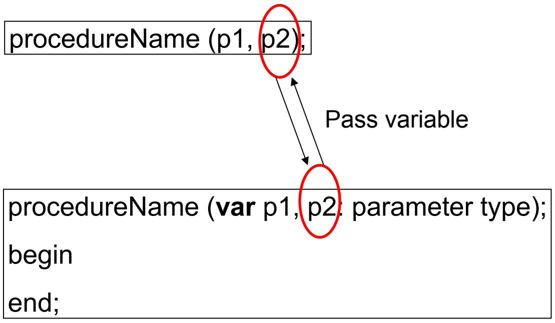
```
procedureName (p1, p2);
```

Pass variable

```
procedureName (var p1, p2: parameter type);
begin
end;
```

Passing Parameters As Variable Parameters

Example coming up



procedureName (p1, p2);

Pass variable

procedureName (**var** p1, p2: parameter type);

begin

end;

Procedure Definitions When Passing Parameters As Variable Parameters

Format:

```
procedure name (var Name of parameter 1 : type of parameter 1;
                var Name of parameter 2 : type of parameter 2;
                                 :                           :
                var Name of parameter n : type of parameter n);
begin
    (* Statements of the function go here *)
end;
```

Example:

```
procedure tabulateIncome (    grossSales      : real;
                              costOfGoodsSold : real;
                          var grossIncome     : real;
                              expenses        : real;
                          var netIncome       : real);
begin
  grossIncome := grossSales - costOfGoodsSold;
  netIncome := grossIncome - expenses;
end;
```

Calling Procedures With Variable Parameters

It’s the same as calling procedures with value parameters!

Format:

name (*name of parameter 1*, *name of parameter 2…name of parameter n*);

Example:

```
tabulateIncome(grossSales,costOfGoodsSold,grossIncome,expenses,
netIncome);
```

Passing Variable Parameters: Putting It All Together

The full version of this example can be found in Unix under /home/231/examples/modules/financialStatements2.p

```
program financialStatments (input, output);

procedure getIncomeInformation (var grossSales       : real;
                                var costOfGoodsSold : real;
                                var expenses         : real);
begin
  write(‘Enter gross sales $');
  readln(grossSales);
  write(‘Enter the cost of the goods that were sold $');
  readln(costOfGoodsSold);
  write(‘Enter business expenses $');
  readln(expenses);
end;   (* End of procedure getIncomeInformation *)
```

Passing Variable Parameters: Putting It All Together (2)

```
procedure tabulateIncome (     grossSales          : real;
                               costOfGoodsSold : real;
                           var grossIncome        : real;
                               expenses             : real;
                           var netIncome          : real);
begin
   grossIncome := grossSales - costOfGoodsSold;
   netIncome := grossIncome - expenses;
end;   (* End of procedure tabulateIncome *)
```

Passing Variable Parameters: Putting It All Together (3)

```
procedure displayIncomeStatement (grossSales          : real;
                                  costOfGoodsSold : real;
                                  grossIncome        : real;
                                  expenses             : real;
                                  netIncome          : real);
begin
   writeln;
   writeln('INCOME STATEMENT':40);
   writeln('Gross sales $':40, grossSales:0:2);
   writeln('Less: Cost of the goods that were sold $':40, costOfGoodsSold:0:2);
   writeln('Equals: Gross Income $':40, grossIncome:0:2);
   writeln('Less: Business Operating Expenses $':40, expenses:0:2);
   writeln('Equals: Net income $':40, netIncome:0:2);
   writeln;
end;   (*  End of displayIncomeStatement *)
```

Passing Variable Parameters: Putting It All Together (4)

```
procedure produceIncomeStatement;
var
  grossSales         : real;
  grossIncome        : real;
  costOfGoodsSold : real;
  expenses           : real;
  netIncome          : real;
begin
  getIncomeInformation(grossSales, costOfGoodsSold, expenses);
  tabulateIncome(grossSales,costOfGoodsSold,grossIncome,expenses,netIncome);
  displayIncomeStatement
    (grossSales,costOfGoodsSold,grossIncome,expenses,netIncome);
end;   (* End of procedure produceIncomeStatement *)
```

Passing Variable Parameters: Putting It All Together (5)

```
(* Begin main program *)
begin
  writeln;
  writeln('This program will produce an income statement based upon your');
  writeln('gross sales figures, the cost of the goods that you sold and');
  writeln('your expenses.');
  writeln;
  produceIncomeStatement;
  writeln('Thank you, come again!');
end.   (* End of main program *)
```

Scope

It determines when a part of a program (Constant, variable, function, procedure) is available for use in that program.

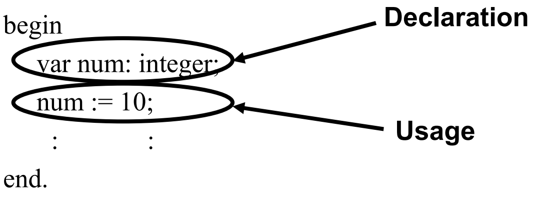
e.g., variables or constants must first be declared before they can be referred to or used.

```
begin
    var num: integer;
    num := 10;
      :          :
end.
```

Scope

It determines when a part of a program (Constant, variable, function, procedure) is available for use in that program.

e.g., variables or constants must first be declared before they can be referred to or used.



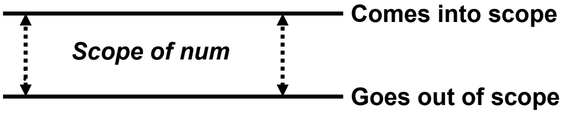
```
begin
    var num: integer;
    num := 10;
      :          :
end.
```

Scope

It determines when a part of a program (Constant, variable, function, procedure) is available for use in that program.

e.g., variables or constants must first be declared before they can be referred to or used.

```
begin
   var num: integer;
   num := 10;
            :
end.
```



Global Scope

Global scope: After declaration, the item (constant, variable, function or procedure) can be accessed anywhere in the program.

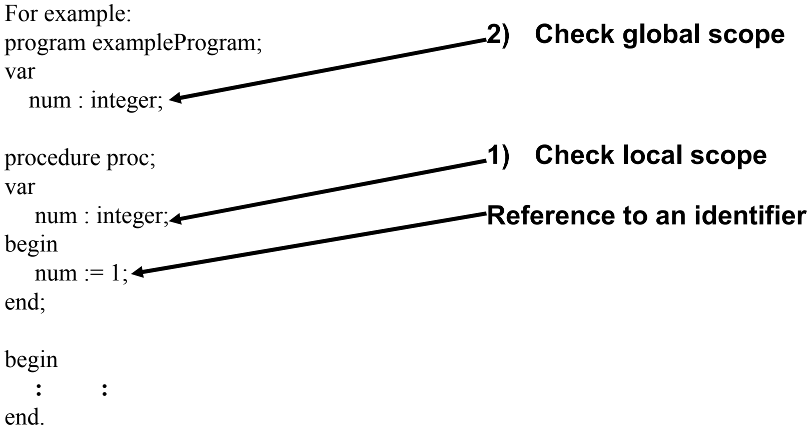
```
program exampleProgram;

Declarations here have global scope

procedure proc;
var
   Declarations with local scope
begin

end;

begin
   Declarations with local scope
end.
```

Global Scope (2)

When an identifier (constant, variable, function or procedure) is encountered the compiler will:

- First check in the local scope
- Check the global scope if no matches can be found locally

For example:



```
program exampleProgram;
var
   num : integer;

procedure proc;
var
    num : integer;
begin
    num := 1;
end;

begin
    :        :
end.
```

2) Check global scope

1) Check local scope

Reference to an identifier

A Scoping Example

The full version of this program can be found in Unix under: /home/231/examples/modules/scope1.p

```
program scope1 (output);
const
  SIZE =  10;
var
  num  : integer;
  ch     : char;
procedure proc1;
var
  x : real;
  y : real;
begin
  writeln('In proc1');
end;
begin

end.
```

Second Scoping Example

The full version of this program can be found in Unix under:
/home/231/examples/functions/scope2.p

```
program scope2 (output);
var
  num : integer;
  ch    : char;
procedure proc1;
var
  ch : char;
begin
  ch := 'b';
  writeln('In proc1');
  writeln ('num=', num, ' ch=', ch);
  writeln;
end;
```

Second Scoping Example (2)

```
procedure proc2(numProc2: integer);
var
  num : integer;
begin
  writeln(‘In proc2’);
  num := 2;
  numProc2 := 20;
  writeln ('num=', num, ' ch=', ch, ' numProc2=', numProc2);
  writeln;
  proc1;
end;
```

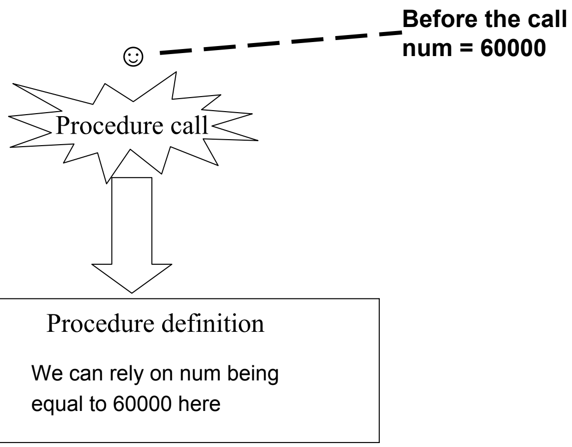
Second Scoping Example (3)

```
begin
   var numLocal : integer;
   num := 1;
   ch := 'a';
   numLocal := 10;
   writeln;
   proc2(numLocal);
   writeln('In main program');
   writeln('num=', num, ' char=', ch, ' numLocal=', numLocal);
end.
```

Preconditions

Describe what should be true before a statement is executed

e.g., What will be the value of a variable before a procedure call.



☺

Before the call
num = 60000

Procedure call

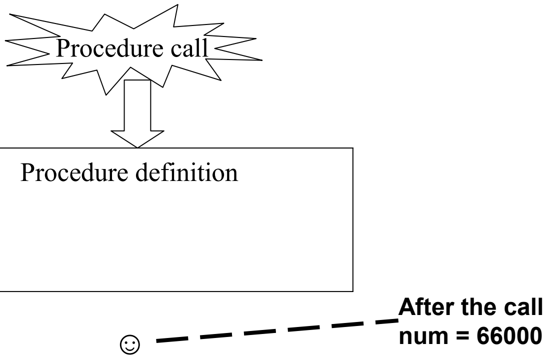
Procedure definition

We can rely on num being equal to 60000 here

Postconditions

Describe what should be true after a statement is executed

e.g., What will be the value of a variable after a procedure call.

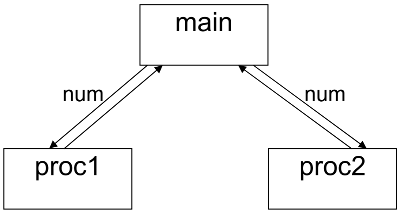


Preconditions And PostConditions

Relative: One procedure’s postcondition can be another procedure’s precondition

e.g.,

```
begin
   var num: integer;
   proc1(num);
   proc2(num);
end.
```



Preconditions And PostConditions

Assertions: Making assumptions about what is the state of (a part of) the program at a certain point.

☺ **No precondition on 'age'**

```
procedure getAge (var age : integer);
begin
     write('How old are you (1-113 years)? ');
     readln(age);
end;
```

☺ **Post condition: 'age' is 1 - 113**

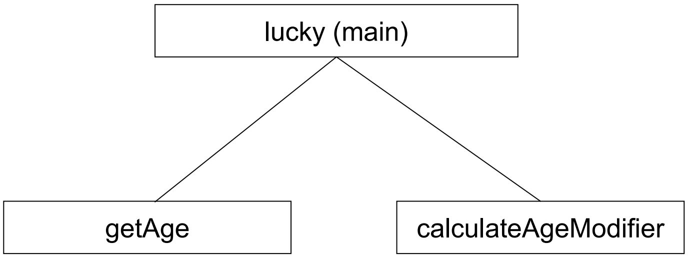
☺ **Precondition: 'age' is 1 - 113**

```
function calculateAgeModifier (age : integer): integer;
begin
    if (age >= 1) AND (age <= 25) then
        calculateAgeModifier := age * 2;
   else  if (age >= 26) AND (age <= 65) then
        calculateAgeModifier := age * 3;
   else  if (age >= 66) AND (age <= 113) then
        calculateAgeModifier := age * 4;
   else
        calculateAgeModifier := 0;
end;
```

Testing Modules

- Making sure the function or procedure does what it is supposed to do e.g., checking if calculations are correct.
- Ties into the top-down approach to design
  1) Outline the structure of the program (empty modules)
  2) As modules are implemented test each one as appropriate
  3) Fix and bugs and add the working module to the program.

Outline Of The Lucky Number Program



Code Skeleton For The Lucky Number Generator

```
program Lucky (input, output);

procedure getAge (var age :  integer);
begin

end;

function calculateAgeModifier (age :  integer): integer;
begin
    calculateAgeModifier := 0;
end;

begin
   var age              : integer;
   var ageModifier : integer;
   getAge (age);
   ageModifier := calculateAgeModifier(age);
end.
```

Implementation Of Procedure “getAge”

```
procedure getAge (var age :  integer);
begin
   write('How old are you (1-113 years)? ');
   readln(age);
end;
```

Testing Procedure “getAge”

Testing simply involves checking the input:

```
(* In the main procedure *)
   getAge(age);
   writeln('After getAge, age=', age);
```

Implementing Function “calculateAgeModifier”

```
function calculateAgeModifier (age :  integer): integer;
begin
   if (age >= 1) AND (age <= 25) then
      calculateAgeModifier := age * 2
   else  if (age >= 26) AND (age <= 65) then
      calculateAgeModifier := age * 3
   else  if (age >= 66) AND (age <= 113) then
      calculateAgeModifier := age * 4
   else
      calculateAgeModifier := 0;
end;
```

Testing Function “calculateAgeModifier”

```
 (* Testing in the main procedure calculateAgeModifier*)
   ageModifier := calculateAgeModifier(0);
   if (ageModifier <> 0) then
        writeln('Error if age < 1');

   ageModifier := calculateAgeModifier(114);
   if (ageModifier <> 0) then
        writeln('Error if age > 113');

   ageModifier := calculateAgeModifier(20);
   if (ageModifier <> 40) then
        writeln('Error if age 1 - 25');

   ageModifier := calculateAgeModifier(40);
   if (ageModifier <> 120) then
        writeln('Error if age 26 - 65');
```

Testing Function “calculateAgeModifier” (2)

```
ageModifier := calculateAgeModifier(70);
if (ageModifier <> 280) then
    writeln('Error if age 66 - 113');
```

Why Use Modular Design

Drawback

- Complexity – understanding and setting up inter-module communication may appear daunting at first
- Tracing the program may appear harder as execution appears to “jump” around between modules.

Benefit

- Solution is easier to visualize
- Easier to test the program
- Easier to maintain (if modules are independent)

You Should Now Know

How to break a programming problem down into modules

What is the difference between a procedure and a function

What is the difference between a value parameter and variable parameter

How to define and call program modules (procedures and functions)

Variables and scope

- What is a local variable
- What is a global variable
- What is the scope of a procedure or function

What are preconditions and post-conditions

How to test functions and procedures