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

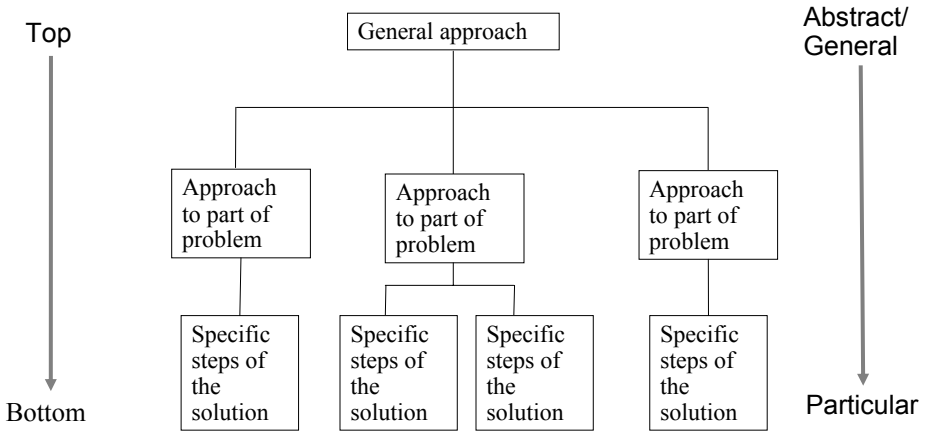
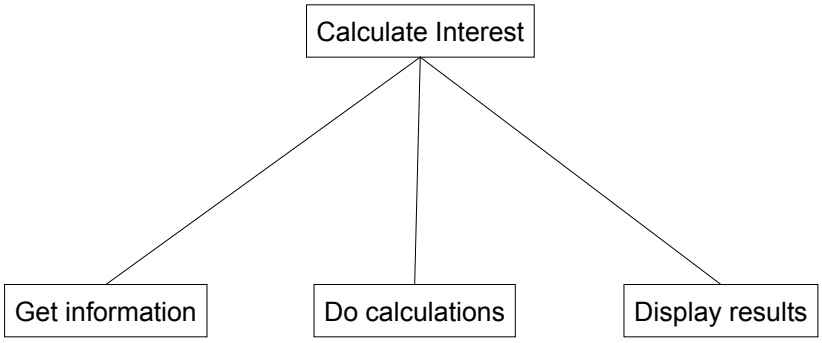


Figure extracted from Computer Science Illuminated by Dale N. and Lewis J.

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

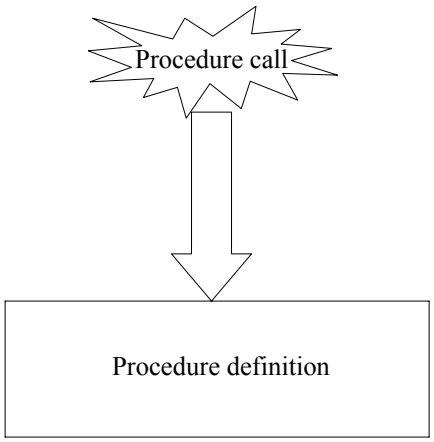
Definition

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

Call

- Getting the function or procedure to run

Procedures (Basic Case – No Parameters)



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 *)
```

Procedure definition

Procedure call

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
   num1 : integer;
begin
   :    :
end;
```


Defining Local Variables: Putting It All Together

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

```
program secondExampleProcedure (output);
procedure proc;
var
  num1 : integer;
begin
  var num2 : integer;
  num1 := 1;
  num2 := 2;
  writeln(num1, ' ', num2);
end;
begin
  var num1 : integer;
  num1 := 10;
  writeln(num1);
  proc;
  writeln(num1);
end.
```

Defining Local Variables: Putting It All Together

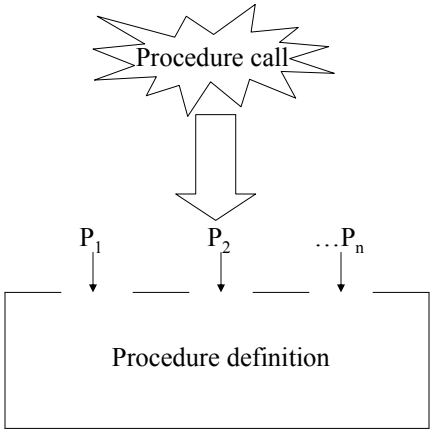
The full version of this example can be found in Unix under /home/231/examples/modules/secondExampleProcedure.p

```
program secondExampleProcedure (output);
procedure proc;
var
  num1 : integer;
begin
  var num2 : integer;
  num1 := 1;
  num2 := 2;
  writeln(num1, ' ', num2);
end;
begin
  var num1 : integer;
  num1 := 10;
  writeln(num1);
  proc;
  writeln(num1);
end.
```

Local variable: procedure 'proc'

Local variable: main module

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


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

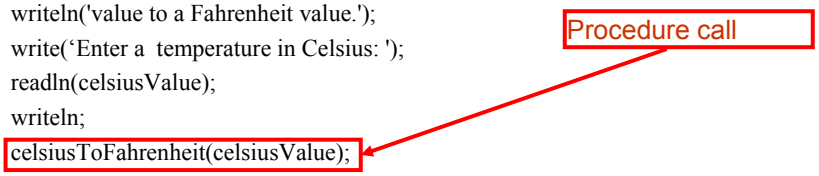
James Tam

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

```
begin
  var celsiusValue :  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(celsiusValue);
  writeln;
  celsiusToFahrenheit(celsiusValue);
  writeln('Thank you and come again.');
end. (* Program *)
```


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

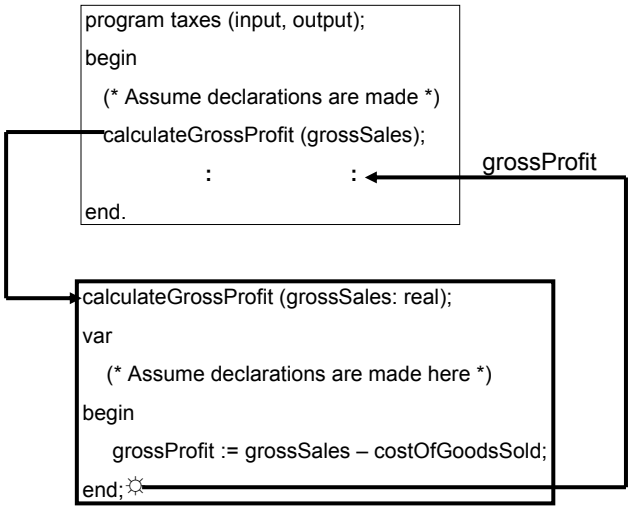
```
begin
  var celsiusValue :  real;
  writeln;
  writeln('This program will convert a given temperature from a Celsius');
  writeln('value to a Fahrenheit value.');
  write('Enter a  temperature in Celsius: ');
  readln(celsiusValue);
  writeln;
  celsiusToFahrenheit(celsiusValue);
  writeln('Thank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



James Tam

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

For example: producing an income statement

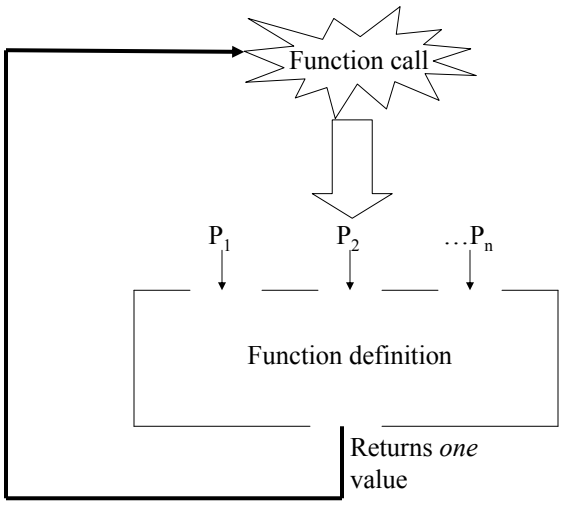


Retaining Information From A Module (Function Or Procedure) After The Module Has Ended (2)

Methods:

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

Functions



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


Calling Functions

Format:

variable := *name of function*;

variable := *name* of function (*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

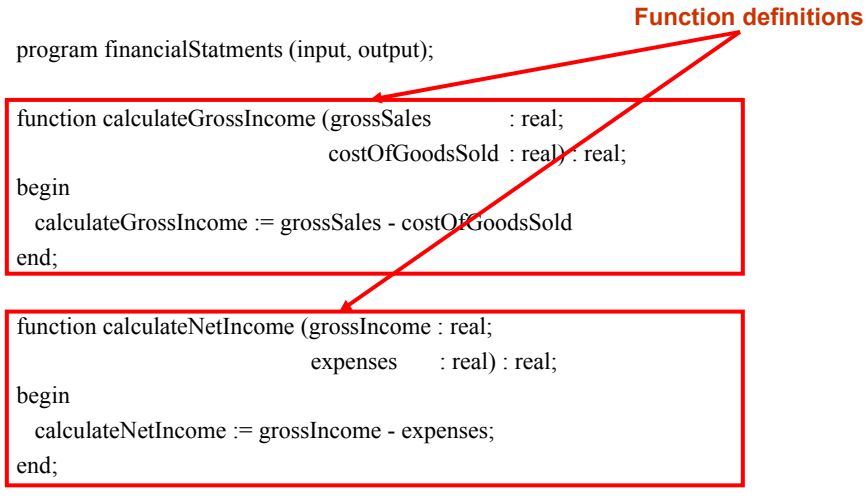
```
program financialStatments (input, output);

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

function calculateNetIncome (grossIncome : real;
                             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



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)

```
procedure intro;
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;
end;
```

Functions: Putting It All Together (5)

```
(* Start of main program *)
begin
  intro;
  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: parameter type);
```

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


Passing Parameters As Value Parameters

Previous examples

```
procedureName (p1: parameter type);
```

Pass a copy

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

Passing Parameters As Variable Parameters

Example coming up

```
procedureName (p1: parameter type);
```

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


Passing Parameters As Variable Parameters

Example coming up

```
procedureName (p1: parameter type);
```

Pass a variable

```
procedureName (var p1 : 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 procedure 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)

```
procedure intro;
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;
end.;
```


Passing Variable Parameters: Putting It All Together (6)

```
(* Begin main program *)
begin
  intro;
  produceIncomeStatement;
  writeln('Thank you, come again!');
end.   (* End of main program *)
```

Functions Vs. Variable Parameters

Functions: *Exactly one value is returned by the function.*

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

Variable parameters: *One or parameters may be modified in the module*

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

Declaration

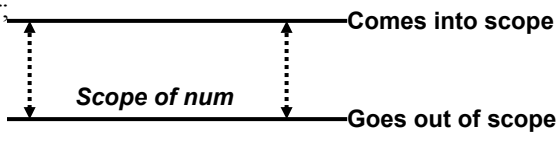
Usage

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

First 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
  num1  : integer;
  ch    : char;
procedure proc1;
var
  num2 : real;
  num3 : 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/modules/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;
```

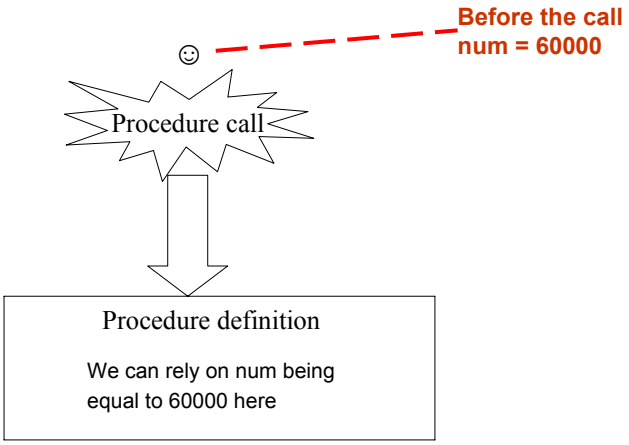

Second Scoping Example (3)

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

Preconditions

Describe what should be true before a statement is executed

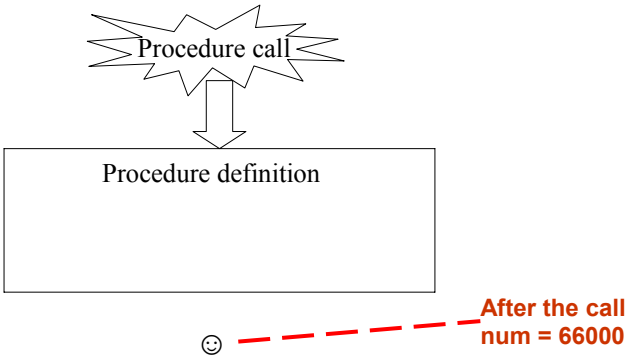
e.g., What will be the value of a variable before a procedure call.



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.

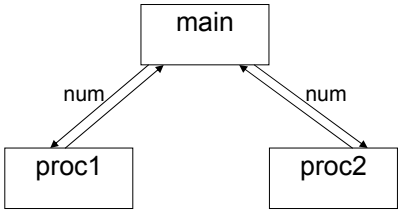


Preconditions And PostConditions

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

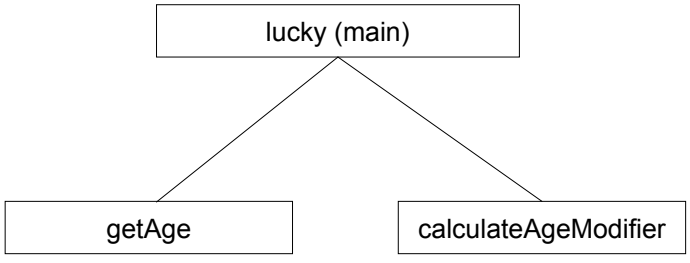
☺ — Precondition: 'age' is 1 - 113

```
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