

Module 5 Guidance Notes

Functions

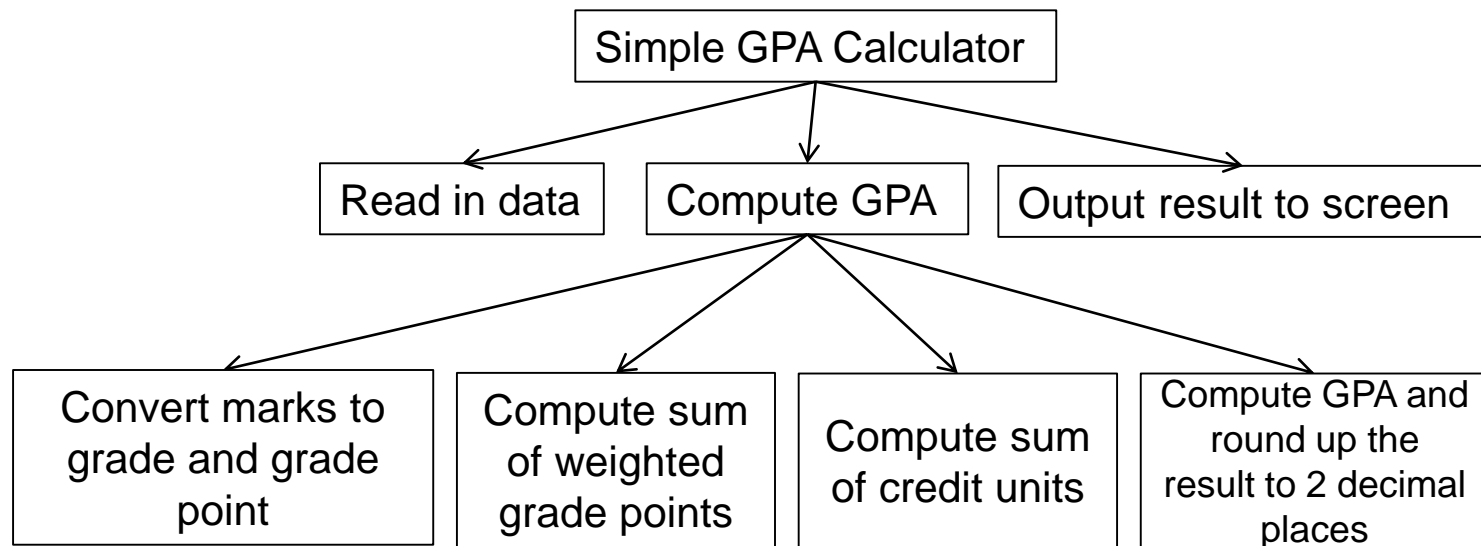
Estimated Time of Completion: 2.5 Hours

Outline

TOP-DOWN DESIGN (DIVIDE AND CONQUER) APPROACH

Top-Down Program Design

Top-Down Design



Each module should perform a single, well-defined task

Functions

```
main()
```

Advantages of Using Functions

```
main()
```

PREDEFINED FUNCTIONS VS. SELF-DEFINED FUNCTIONS


Predefined Functions

```
double x = sqrt(5.29);
```

Here, 5.29 is the function input and the function output 2.3 would be stored to x.

Predefined Functions

Examples



<code>double sqrt(double x)</code>		<code>cmath</code>
<code>double pow(double x, double y)</code>		<code>cmath</code>
<code>double fabs(double x)</code>		<code>cmath</code>
<code>double ceil(double x)</code>		<code>cmath</code>
<code>double floor(double x)</code>		<code>cmath</code>
<code>int abs(int x)</code>		<code>cstdlib</code>
<code>int rand()</code>		<code>cstdlib</code>

Using Predefined Functions

Function Reference Example

Function name

There are different C++ versions. We use C++11.

Header file containing the function declaration of this function

function **sqrt**

`<cmath> <ctgmath>`

C90 C99 C++98 C++11 ?

```
double sqrt (double x);  
float sqrt (float x);  
long double sqrt (long double x);  
double sqrt (T x); // additional overloads for integral types
```

input parameter data type

output data type

Compute square root
Returns the *square root* of *x*.

Describes what the function does and what it outputs

Using Predefined Functions

<...>

```
#include<iostream>  
#include<cstdlib>
```

#include

```
cin cout endl  
rand() srand()
```

Using Predefined Functions

```
#include <iostream>
#include <cmath>
using namespace std;
```

Include `<cmath>` so you can use the `pow()` and `sqrt()` functions from the math library later on in the same program file.

```
int main() {
    // Compute the root mean square of 10 input numbers
    int i;
    double n, sq_sum = 0;

    for(i=0; i<10; i++)
    {
        cout << i+1 << ": ";
        cin >> n;
        sq_sum += pow(n, 2.0);
    }

    cout << "The root mean square is " << sqrt(sq_sum/10) << endl;

    return 0;
}
```

A function may accept one or more input parameters. The order and type of each parameter matter. Check the `pow()` reference page to see what each parameter mean.

Example: Random Number Generation

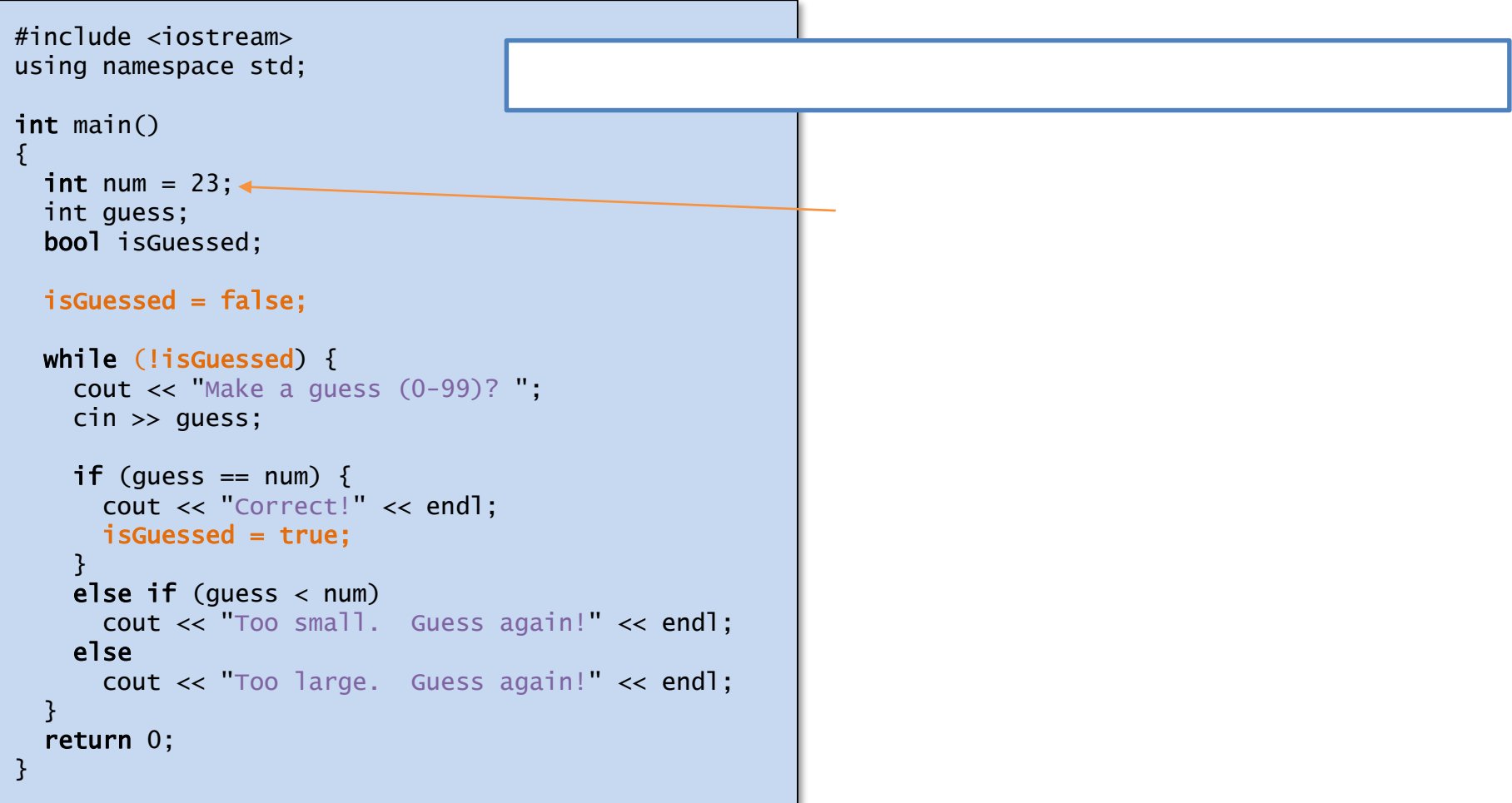
```
#include <iostream>
using namespace std;

int main()
{
    int num = 23;
    int guess;
    bool isGuessed;

    isGuessed = false;

    while (!isGuessed) {
        cout << "Make a guess (0-99)? ";
        cin >> guess;

        if (guess == num) {
            cout << "Correct!" << endl;
            isGuessed = true;
        }
        else if (guess < num)
            cout << "Too small. Guess again!" << endl;
        else
            cout << "Too large. Guess again!" << endl;
    }
    return 0;
}
```



Example: Random Number Generation

function

rand

<stdlib>

```
int rand (void);
```

Generate random number

Returns a pseudo-random integral number in the range between 0 and `RAND_MAX`.

This number is generated by an algorithm that returns a sequence of apparently non-related numbers each time it is called. This algorithm uses a seed to generate the series, which should be initialized to some distinctive value using function `srand`.

`RAND_MAX` is a constant defined in <stdlib>.

Example: Random Number Generation

```
rand() % 10
```

```
rand() % 101
```

```
rand() % 100 + 1
```

Example: Random Number Generation

```
#include <iostream>
#include <cstdlib>      // needed for calling rand()
using namespace std;

int main()
{
    for (int i = 0; i < 10; ++i)
        cout << rand() % 100 + 1 << endl;
    return 0;
}
```

Example: Random Number Generation

function

srand

<stdlib.h>

```
void srand (unsigned int seed);
```

Initialize random number generator

The pseudo-random number generator is initialized using the argument passed as *seed*.

For every different *seed* value used in a call to `srand`, the pseudo-random number generator can be expected to generate a different succession of results in the subsequent calls to `rand`.

Two different initializations with the same *seed* will generate the same succession of results in subsequent calls to `rand`.

Example: Random Number Generation

```
#include <iostream>
#include <cstdlib>          // for calling srand(), rand()
using namespace std;

int main()
{
    srand(???);           // initialize the seed for rand()
    for (int i = 0; i < 10; ++i)
        cout << rand() % 100 + 1 << endl;
    return 0;
}
```

Example: Random Number Generation

function

time

time_t is a special data type for integral values representing
time

<ctime>

```
time_t time (time_t* timer);
```

Get current time

~~Get the current calendar time as a value of type time_t.~~

time(NULL)

```
// initialize random seed  
srand(time(NULL));
```

Example: Random Number Generation

```
#include <iostream>
#include <cstdlib>      // for calling srand(), rand()
#include <ctime>        // for calling time()
using namespace std;

int main()
{
    srand(time(NULL)); // initialize the seed for rand()
    for (int i = 0; i < 10; ++i)
        cout << rand() % 100 + 1 << endl;
    return 0;
}
```

Example: Random Number Generation

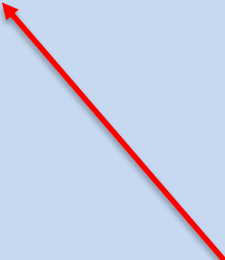
`srand(0)`

`srand()`

Defining Your Own Functions

Defining Your Own Functions

```
double larger(double x, double y)
```



input parameters with data
type

Defining Your Own Functions

```
double larger(double x, double y)
{
    double max;
    if (x >= y)
        max = x;
    else
        max = y;

    return max;
}
```

function body
embraced by {}

function parameters x and y
are used in the calculation

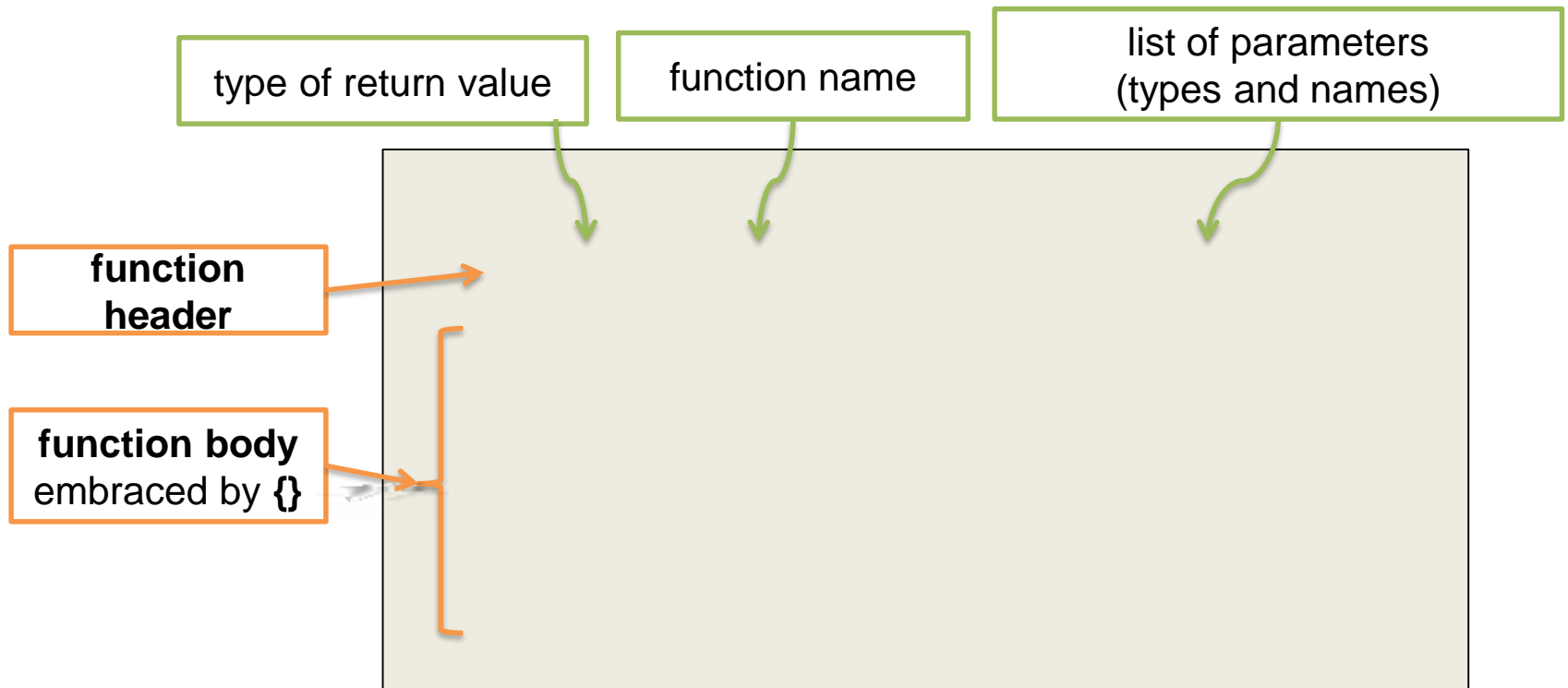
max is the return value, and its
data type must agree with that
specified in the function header
(i.e., **double**)

return statement

returns the specified value to the
caller
terminates the execution of the
function

FUNCTION DEFINITION, FUNCTION CALL & FUNCTION DECLARATION

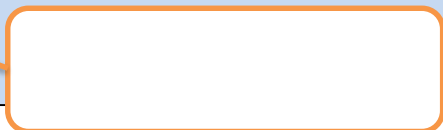
Function Definition



Void Functions


Void Functions

```
void print_msg(int x)
{
    cout << "This is a void function " << x << endl;
    return;
}
```



A diagram consisting of a white rounded rectangle with an orange border. An orange arrow points from the bottom-left corner of this rectangle to the `return;` statement in the code block above.

```
void print_msg(int x)
{
    cout << "This is a void function " << x << endl;
}
```



A diagram consisting of a white rounded rectangle with an orange border. An orange arrow points from the bottom-left corner of this rectangle to the closing curly brace `}` of the function in the code block above.

Both are OK!

Function Call

```
double z = larger(2.5, 5.0);
```

Return value from
larger() after function
call is assigned to the
variable z

Function name

Parameters as input
to function

Function Call

```
double larger(double x, double y)
{
    ...
}
```

parameters

```
c = larger ( 2.5, 5.0 );
```

arguments

Function Call

```
double z1 = larger (2.5, 5.0);           // constants
double z2 = larger (one, two);           // variables
double z3 = larger (one - 2, two);       // expressions
double z4 = larger (2.5, larger (3, 5.0) ); // a function
```

Function Declaration

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    ...
    c = larger(a, b);
    ...
}
```

One way to do this is to place the **function definition** before the **function call** in the source file.

```
#include <iostream>
using namespace std;
```

```
double larger(double x, double y);
```

```
int main()
{
```

```
    ...
    c = larger(a, b);
```

```
    ...
}
```

```
double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}
```

Note the ; here. It is needed since this function declaration is a statement. Compare this with the function header in the example on the left.

Alternatively, the function definition can be placed anywhere in the source file by including a **function declaration** before the **function call**.

Function Declaration



Function Declaration

```
#include <iostream>
using namespace std;

→ double larger(double p, double q) ;

int main()
{
    ...
    c= larger(a, b);
    ...
}

double larger(double x, double y)
{
    return (x >= y)? x : y;
}
```

```
#include <iostream>
using namespace std;

→ double larger(double, double) ;

int main()
{
    ...
    c = larger(a, b);
    ...
}

double larger(double x, double y)
{
    return (x >= y)? x : y;
}
```

(x >= y)? x : y

FLOW OF CONTROL

Flow of Control

Flow of Control

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;

    c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```


Flow of Control

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

→ int main()
{
    double a = 2.5, b = 5.0, c;

    c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```


Flow of Control

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;
    c = larger(a, b);
    cout << c << " is larger." << endl;


    return 0;
}
```



Flow of Control

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;
     c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```

Flow of Control

```
#include <iostream>
using namespace std;

→ double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;

    ⇨ c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```

The diagram illustrates the flow of control in the provided C++ code. A yellow arrow points to the function signature `double larger(double x, double y)`, indicating the start of the function call. Two blue arrows originate from the arguments `a` and `b` in the function call `c = larger(a, b);` within the `main` function. These arrows point to the parameters `x` and `y` in the `larger` function, representing the passing of control and data. Two white rectangular boxes are placed on these arrows. A third blue arrow points from the closing brace of the `larger` function back to the line `c = larger(a, b);` in the `main` function, representing the return of control to the caller. A small orange icon with a right-pointing arrow is located next to the function call line in the `main` function.

Flow of Control

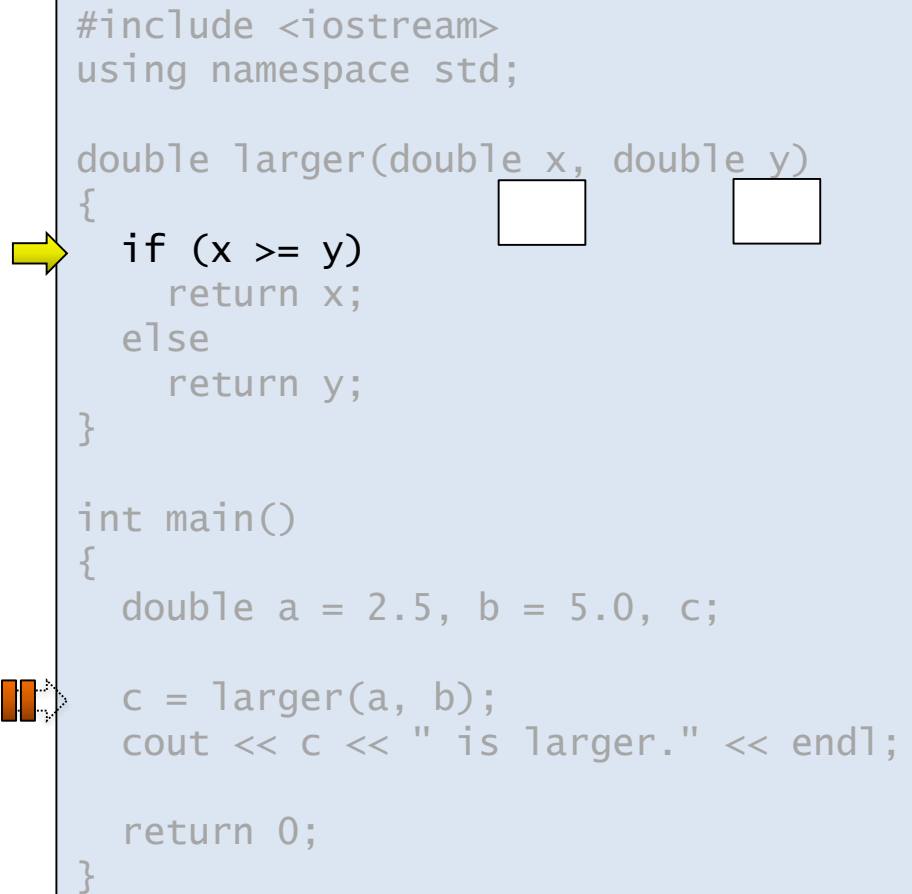
```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;

    c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```



Flow of Control

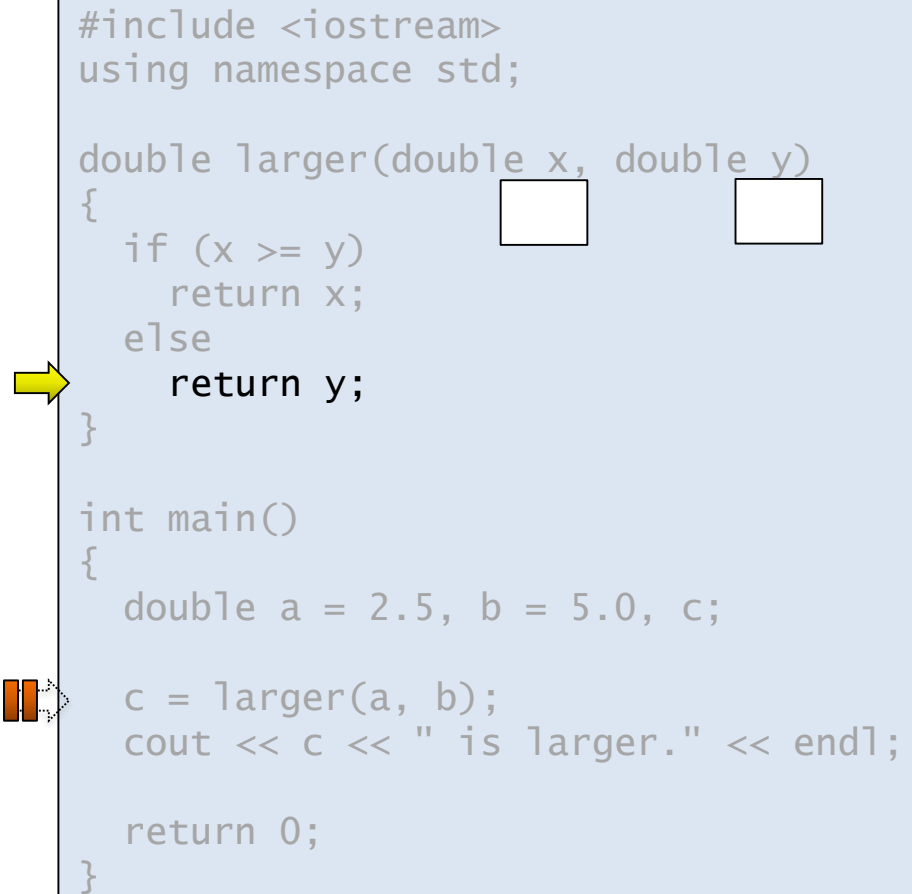
```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

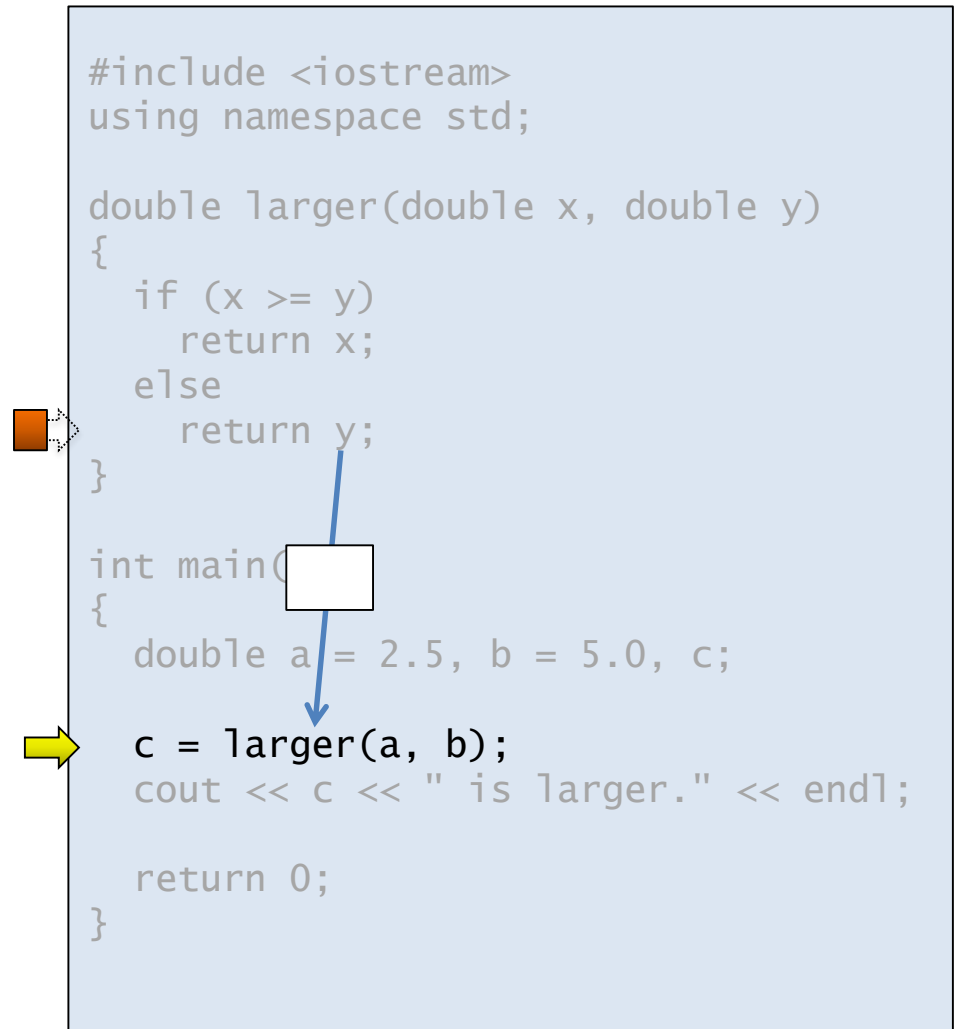
int main()
{
    double a = 2.5, b = 5.0, c;

    c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```




Flow of Control



Flow of Control

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;
     c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```


Flow of Control

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;
    c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```



c takes the value 5.0
which is the return value
of larger()

Flow of Control


```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;

    c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```



Flow of Control

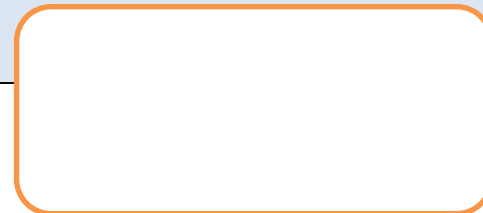

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    if (x >= y)
        return x;
    else
        return y;
}

int main()
{
    double a = 2.5, b = 5.0, c;

    c = larger(a, b);
    cout << c << " is larger." << endl;

    return 0;
}
```



SCOPE OF VARIABLES

Local Variables

Local Variables

```
#include <iostream>
using namespace std;

double larger(double, double)
{
    double ym;
    max = (x >= y)? x : y;

    return max;
}

int main()
{
    double m = 2.5, n = 5.0, ym;

    max = larger(a, b);
    cout << max << " is larger." << endl;

    return 0;
}
```

local variables of **larger()**:

x, y, max

i.e., these variables are input parameters or variables defined in the function `larger()`, and therefore can only be seen or used in `larger()`

local variables of **main()**:

a, b, max

i.e., these variables are defined in the function `main()`, and therefore can only be seen or used in `main()`

The local variables **max** of **larger()** and **max** of **main()** are **unrelated**.

Local Variables

```
#include <iostream>
using namespace std;

double larger(double x, double y)
{
    nxq ym
    max = (x >= y)? x : y;

    return max;
}

int main()
{
    double a = 2.5, b = 5.0, max;

    max = larger(a, b);
    cout << max << " is larger." << endl;

    return 0;
}
```

There will be a compilation error if we comment out the declaration of **max** in **larger()** because **max** in **main()** is a local variable of **main()** and cannot be seen or used in **larger()**.

Global Variables

Global Variables

```
#include <iostream>
using namespace std;

double m, n;
const double PI = 3.1415;

double larger()
{
    return (a >= b)? a : b;
}

int main()
{
    cout << "Input two integers: ";
    cin >> a >> b;
    cout << larger() << " is larger." << endl;

    double r;
    cout << "Input radius of a circle: ";
    cin >> r;
    cout << "Area of circle = " << PI * r * r << endl;
    return 0;
}
```

global variables:
a, b, PI

The global constant **PI** can be used throughout the file after its declaration.

Avoid using global variables to communicate data between functions

The variables **a, b** should best be changed into input parameters for the function `larger()`. *Can you do that?*

Scopes of Variables

Scopes of Variables

```
double m;  
int func(int , int )  
{  
    ...  
    if (x > y)  
    {  
        int ;  
        ...  
    }  
    int ;  
    ...  
}
```

```
double n;  
int main()  
{  
    int , , ;  
    ...  
    if (...)  
    {  
        int ;  
        ...  
    }  
    ...  
}
```

Scope of global variable **a**:
from declaration to end of block
(in this case, end of file; hence
scope of **a** is the entire file)

Scope of formal parameters **x, y**:
entire function

Scope of local variable **k**:
from declaration to end of block
(in this case, end of if statement)

Scope of local variable **z**:
from declaration to end of block
(in this case, end of func)

Scopes of Variables

```
double m;  
int func(int , int )  
{  
    ...  
    if (x > y)  
    {  
        int ;  
        ...  
    }  
    int ;  
    ...  
}
```

```
double n;  
int main()  
{  
    int , , ;  
    ...  
    if (...)  
    {  
        int ;  
        ...  
    }  
    ...  
}
```

Scope of global variable **b**:
from declaration to end of block
(in this case, end of file)

Scope of local variables **x, y, z**:
from declaration to end of block
(in this case, end of main
function)

Scope of local variable **x** in the
inner block:
from declaration to end of block
(in this case, end of if
statement)

**the outer x is hidden
within this block**

Scopes of Variables

```
#include <iostream>
using namespace std;

int main()
{
    int i = 0;
    cout << "Outer block: i = " << i << endl;

    {
        int i = 100;
        cout << "Inner block: i = " << i << endl;
    }

    cout << "Outer block: i = " << i << endl;
    return 0;
}
```

Outer block: i = 0
Inner block: i = 100
Outer block: i = 0

PARAMETER PASSING MECHANISM

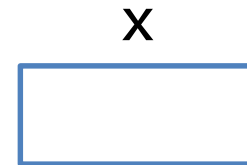

Pass-by-Value

Pass-by-Value

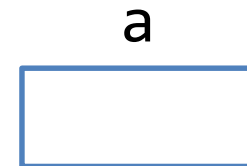
```
#include <iostream>
using namespace std;

// computes the square of an integer
void square( int x )
{
    x *= x;
}


int main()
{
    int a = 10;
    cout << a << " squared: ";
    square( a );
    cout << a << endl;
    return 0; }
```



x is a
parameter
and also a
local
variable of
the square
function



Copying of
value of
actual
argument to
formal
parameter



Pass-by-Value

```
#include <iostream>
using namespace std;

// computes the square of an integer
void square( int x )
{
    x *= x;
}

int main()
{
    int a = 10;
    cout << a << " squared: ";
    square( a );
    cout << a << endl;
    return 0; }
```

x



a




Pass-by-Value

```
#include <iostream>
using namespace std;

// computes the square of an integer
void square( int x )
{
    x *= x;
}

int main()
{
    int a = 10;
    cout << a << " squared: ";
    square( a );
    cout << a << endl;
    return 0; }
```



Variable **x** disappears
(more precisely, the
memory location it
occupies is released
back to the system)
upon function
completion.

a



Pass-by-Value

```
#include <iostream>
using namespace std;

void swap(int a, int b)
{
    cout << "a = " << a << ", b = " << b << endl;
    int temp = a;
    a = b;
    b = temp;
    cout << "a = " << a << ", b = " << b << endl;
}

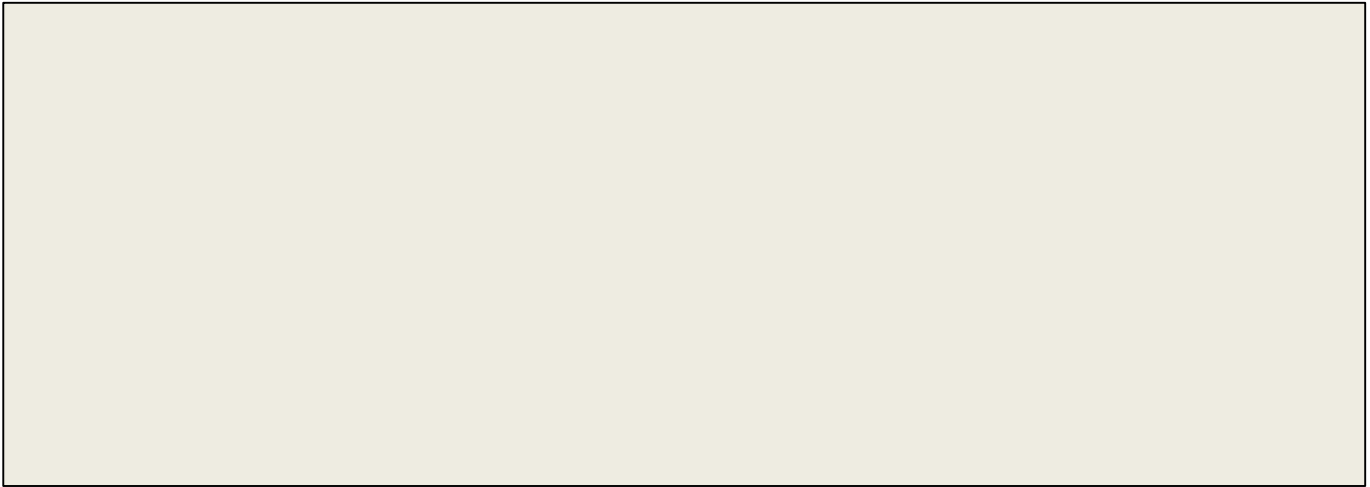
int main()
{
    int x = 0, y = 100;
    cout << "x = " << x << ", y = " << y << endl;
    swap(x, y);
    cout << "x = " << x << ", y = " << y << endl;
    return 0;
}
```

```
x = 0, y = 100
a = 0, b = 100
a = 100, b = 0
x = 0, y = 100
```

Because the variables x and y are passed to swap() using pass-by-value, only the values are transferred to swap(), and swap() can only deal with its local variables a and b.

Pass-by-Reference

Pass-by-Reference



Pass-by-Reference

```
#include <iostream>
using namespace std;

// computes the square of an integer
void square( int &x )
{
    x *= x;
}

int main()
{
    int a = 10;
    cout << a << " squared: ";
    square( a );
    cout << a << endl;
    return 0;
}
```

Note the **&** to indicate that the formal parameter x is pass-by-reference.

x



Formal parameter refers to the same memory location as the argument

a

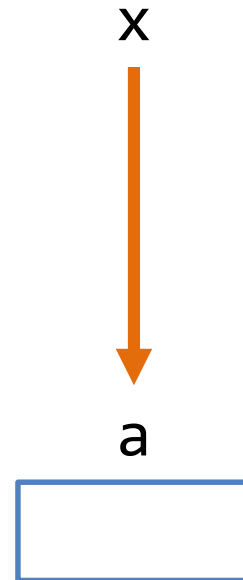


Pass-by-Reference

```
#include <iostream>
using namespace std;

// computes the square of an integer
void square( int &x )
{
    x *= x;
}

int main()
{
    int a = 10;
    cout << a << " squared: ";
    square( a );
    cout << a << endl;
    return 0;
}
```



Pass-by-Reference

```
#include <iostream>
using namespace std;

// computes the square of an integer
void square( int &x )
{
    x *= x;
}

int main()
{
    int a = 10;
    cout << a << " squared: ";
    square( a );
    cout << a << endl;
    return 0;
}
```



a



Pass-by-Reference

```
#include <iostream>
using namespace std;

void swap(int &a, int &b)
{
    cout << "a = " << a << ", b = " << b << endl;
    int temp = a;
    a = b;
    b = temp;
    cout << "a = " << a << ", b = " << b << endl;
}

int main()
{
    int x = 0, y = 100;
    cout << "x = " << x << ", y = " << y << endl;
    swap(x, y);
    cout << "x = " << x << ", y = " << y << endl;
    return 0;
}
```

x = 0, y = 100
a = 0, b = 100
a = 100, b = 0
x = 100, y = 0

The formal parameters a and b in swap() refer to the memory locations of the arguments x and y, respectively.

Pass-by-Reference vs. Value-Returning Function

```
uz squareByValue( uz z yna )  
{  
    return number *= number;  
}
```

```
u squareByReference( uz z yna )  
{  
    number *= number;  
}
```

Pass-by-Reference vs. Value-Returning Function

```
int squareByValue( int );  
void squareByReference( int & );
```

```
int main()  
{
```

```
    int x = 2;  
    int z = 4;
```

```
    cout << "x = " << x << " before squareByValue\n";  
    cout << "Value returned by squareByValue: "  
        << m q mx q << endl;  
    cout << "x = " << x << " after squareByValue\n" << endl;
```

```
    cout << "z = " << z << " before squareByReference" << endl;  
    m q qr q qzoq  
    cout << "z = " << z << " after squareByReference" << endl;
```

```
    return 0;
```

```
}
```

x = 2 before squareByValue
Value returned by squareByValue: 4
x = 2 after squareByValue

z = 4 before squareByReference
z = 16 after squareByReference

Return value of squareByValue() is used by the cout expression.

Result of computation by squareByReference() is updated in z.

Pass-by-Reference vs. Value-Returning Function

```
const double CONVERSION = 2.54;
const int INCHES_IN_FOOT = 12;
const int CENTIMETERS_IN_METER = 100;

u metersAndCentTofeetAndInches(int mt, int ct, uz r, uz uz)
{
    int centimeters;
    centimeters = mt * CENTIMETERS_IN_METER + ct;
    in = (int) (centimeters / CONVERSION);
    r = in / INCHES_IN_FOOT;
    uz = in % INCHES_IN_FOOT;
}
```

f and in are the computation results.
Think about how the calling functions can call this function and access the results through the arguments after function call.

Quick Exercise 1

```
#include <iostream>
using namespace std;

void figureMeOut(int &x, int y, int &z) {
    cout << x << ' ' << y << ' ' << z << endl;
    x = 1;
    y = 2;
    z = 3;
    cout << x << ' ' << y << ' ' << z << endl;
}

int main() {
    int a=10, b=20, c=30;
    figureMeOut(a, b, c);
    cout << a << ' ' << b << ' ' << c << endl;
}
```

Answer to Quick Exercise 1

```
10 20 30  
1 2 3  
1 20 3
```

We are happy to help you!



“If you face any problems in understanding the materials,

.

We wish you enjoy learning programming in this class 😊.”