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C++ Basics

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Contents

- C and C++
- A sample C++ program
- Variables, Expressions, Assignments
- Data types
- Console input/output
- Program style

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C and C++

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C Programming Language

- High-level general-purpose language developed in **1972** at **AT&T Bell Lab** by **Dennis Ritchie** from two previous programming `BCPL` and `B`
- Originally developed to write the UNIX operating system.
- Hardware independent (portable).
- By late 1970's `C` had evolved to "Traditional `C`"
- The current standard in `C` is `ANSI C`.
- `C++` is a more advanced version of `C`, incorporating among other things, the object-oriented constructs.

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C Programming Language

- Standardization
  - Many slight variations of C existed, and were incompatible
  - Committee formed to create a "unambiguous, machine-independent" definition
  - Standard created in 1989, updated in 1999
  - C has become a popular language industry due its power and flexibility

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The C Standard Library

- C programs consist of pieces/modules called **functions**
  - A programmer can create his **own** functions
    - Advantage: the programmer knows exactly how it works
    - Disadvantage: time consuming
  - Programmers will often use the C library functions
    - Use these as building blocks
  - Avoid re-inventing the wheel
    - If a pre-made function exists, generally best to use it rather than write your own
    - Library functions carefully written, efficient, and portable

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Origins of the C++ Language

- C is somewhere in between the two extremes of a high-level language and a low-level language.
  - strength
  - weakness
- **Bjarne Stroustrup** (AT&T Bell Labs) developed C++ in early 1980s.
  - the 2018 winner of the **Charles Stark Draper Prize for Engineering**, "for conceptualizing and developing the C++ programming language".
- C++: better C (C with Classes).
- Most of C is subset of C++.

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Origins of the C++ Language

- 1985: first commercial implementation released
- 1989: C++ version 2.0
- 1998: C++98 (standardizing version)
- 2003: C++03 (minor update)
- 2011: C++11 (adding numerous features)
- 2014: C++14 (minor update)
- 2017: C++17
- 2020: C++20

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Reading

- Stroustrup'S FAQ: http://www.stroustrup.com/bs_faq.html#invention

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Introduction to C++

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C++ Terminology

- **Functions**: procedure-like entities
  - procedures, methods, functions, subprograms
- **Program**: a function called `main`.

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A Sample C++ Program

```
//Text-printing program
#include <iostream>
//function main begins program execution
//using namespace std;
int main()
{
      std::cout << "Welcome to C++!\n"; //display message
      return 0; //indicate that program ended successfully

} //end function main
```


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Comments

- Comments are for the reader, not the compiler
- Two types:
  - Single line

```
// This is a C++ program. It prints the sentence:
// Welcome to C++ Programming.
```

  - Multiple lines

```
/*
   You can include comments that can
   occupy several lines.
*/
```


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Another Sample C++ Program

```
#include <iostream>

int main()
{
	int numberofLanguages;

	std::cout << "Hello.\n"
		<< "Welcome to C++.\n";

	std::cout << "How many programming languages have you used? ";
	std::cin >> numberofLanguages;

	if (numberofLanguages < 1)
		std::cout << "Please read the preface carefully.\n";
	else
		std::cout << "Enjoy the book.\n";

	return 0;
}
```


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Layout of a Simple C++ Program

```
#include <iostream>

int main()
{
        Variable_Declarations;

        Statement_1;
        Statement_2;

        ...

        Statement_n;

        return 0;
}
```


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Variables, Expressions, Assignment Statements

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Identifiers

- **Name** of an item be *declared* or *defined* in a program.
- Consist of letters, digits, and the underscore character (_)
- Must begin with a letter or underscore
  - Avoid starting with the underscore for informally being reserved for system,..
- C++ is **case-sensitive**
  - `NUMBER` is not the same as `number`
- Some predefined identifiers are `main`, `cout` and `cin`
- Unlike reserved words, predefined identifiers may be redefined, but it is not a good idea.

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Identifiers

- Legal identifiers in C++:
  - `first`
  - `conversion`
  - `payRate`
- Illegal identifiers in C++:

Illegal Identifier	Description
`employee Salary`	There can be no space between `employee` and `Salary`.
`Hello!`	The exclamation mark cannot be used in an identifier.
`one+two`	The symbol + cannot be used in an identifier.
`2nd`	An identifier cannot begin with a digit.

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Identifiers

- Special classes of identifiers: **keywords**, **reserved words**.
- Examples:
  - auto, bool, break, case, const
  - ..
- More keywords in Appendix 1
  - Ref: https://en.cppreference.com/w/cpp/keyword
  - Ref: https://www.w3schools.in/cplusplus-tutorial/keywords/

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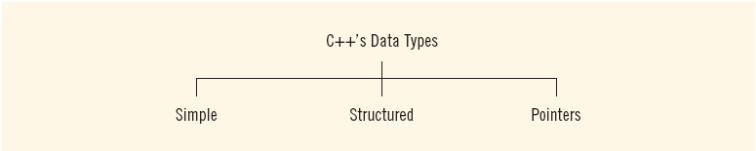
Data Types

- Data type: **set of values** together with a **set of operations**
- C++ data types fall into three categories:
  - Simple
  - Structured
  - Pointer



Simple Data Types

- Three categories of simple data
  - **Integral**: integers (numbers without a decimal)
  - **Floating-point**: decimal numbers
  - **Enumeration type**: user-defined data type

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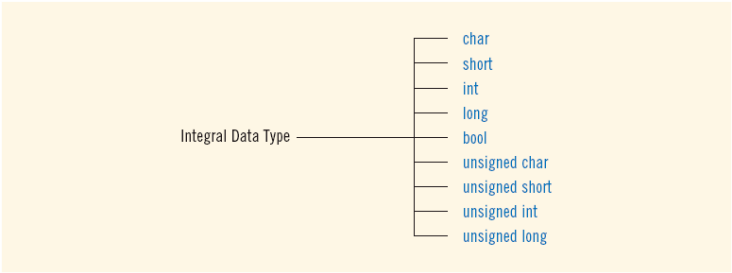
Simple Data Types

- Integral data types
  - char
  - short
  - int
  - long
  - bool
  - ***unsigned*** char
  - ***unsigned*** short
  - ***unsigned*** int
  - ***unsigned*** long



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Simple Data Types

- Floating-point data types: `float`, `double`, `long double`
  - `float`: *single* precision
  - `double`: *double* precision
  - C++ uses scientific notation to represent *real* numbers (floating-point notation)

Real Number	C++ Floating-Point Notation
75.924	7.592400E1
0.18	1.800000E-1
0.0000453	4.530000E-5
-1.482	-1.482000E0
7800.0	7.800000E3

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- Different compilers (systems) may allow **different ranges** of values.

TYPE NAME	MEMORY USED	SIZE RANGE	PRECISION
`short` (also called `short int`)	2 bytes	–32,768 to 32,767	Not applicable
`int`	4 bytes	–2,147,483,648 to 2,147,483,647	Not applicable
`long` (also called `long int`)	4 bytes	–2,147,483,648 to 2,147,483,647	Not applicable
`float`	4 bytes	approximately 10^{-38} to 10^{38}	7 digits
`double`	8 bytes	approximately 10^{-308} to 10^{308}	15 digits
`long double`	10 bytes	approximately 10^{-4932} to 10^{4932}	19 digits
`char`	1 byte	All ASCII characters (Can also be used as an integer type, although we do not recommend doing so.)	Not applicable
`bool`	1 byte	`true`, `false`	Not applicable

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Simple Data Types

- C++11 Fixed-Width Integer Types
- Including <**cstdint**>

TYPE NAME	MEMORY USED	SIZE RANGE
int8_t	1 byte	–128 to 127
uint8_t	1 byte	0 to 255
int16_t	2 bytes	–32,768 to 32,767
uint16_t	2 bytes	0 to 65,535
int32_t	4 bytes	–2,147,483,648 to 2,147,483,647
uint32_t	4 bytes	0 to 4,294,967,295
int64_t	8 bytes	–9,223,372,036,854,775,808 to 9,223,372,036,854,775,807
uint64_t	8 bytes	0 to 18,446,744,073,709,551,615
long long	At least 8 bytes	

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`bool` Data Type

- `bool` type
  - Two values: `true` and `false`
  - Manipulate logical (Boolean) expressions
- `true` and `false` are called logical values
- `bool`, `true`, and `false` are reserved words.

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`char` Data Type

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- The smallest integral data type
- Used for **characters**: letters, digits, and special symbols
- Each character is enclosed in single quotes
  - `'A','a','0','*','+','$','&'`
- A blank space is a character and is written `' '`, with a space left between the single quotes.

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Arithmetic Operators

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- C++ arithmetic operators:
  - `+` addition
  - `-` subtraction
  - `*` multiplication
  - `/` division
  - `%` modulus operator
- +, -, *, and / can be used with integral and floating-point data types
- Operators can be unary or binary

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Arithmetic Operators

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C++ operation	C++ arithmetic operator	Algebraic expression	C++ expression
Addition	+	$f + 7$	`f + 7`
Subtraction	-	$p - c$	`p - c`
Multiplication	*	bm or $b \cdot m$	`b * m`
Division	/	x / y or $\frac{x}{y}$ or $x \div y$	`x / y`
Modulus	%	$r \bmod s$	`r % s`

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Arithmetic Operators

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- Rules of operator precedence
  - Same manner as in algebraic expressions
  - Operators in **parentheses** evaluated first
    - Nested/embedded parentheses
      - Operators in innermost pair first
  - Multiplication, division, modulus applied next
    - Operators applied from left to right
  - Addition, subtraction applied last
    - Operators applied from left to right

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Variables

- Location in memory where value can be stored
- **Declare** variables with name and data type **before use.**
  - `int integer1;`
  - `int integer2;`
  - `float sum;`
  - `int numberofBeans;`
- Can declare several variables of same type in one declaration (Comma-separated list)
  - `int num1, num2, count;`
  - `double oneWeight, totalWeight;`

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Variable Declarations

- Syntax:

```
Type_Name Variable_Name_1, Variable_Name_2,..;
```

- Examples:

```
int count, numberofDragons, numberofTrolls;
double distance;
```

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Assignment Statements

- To change the value of a variable.
- Equal sign (=) used as the **assignment operator**.
- Syntax:

```
Variable = Expression;
```

  - Expression can be a variable, a number or a more complicated expression (made up of variables, numbers, operators, function invocations,..)
  - Expression is evaluated and its value is assigned to the variable on the left side.

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Assignment Statements

- Examples:

```
distance = rate * time;
count = count + 2;
```


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Assignment Statements

- More Examples:

```
int num1, num2;
double sale;
char first;
string str;

num1 = 4;
num2 = 4 * 5 - 11;
sale = 0.02 * 1000;
first = 'D';
str = "It is a sunny day.";
```


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Assignment Statements

- More Examples:

```
int num1, num2;
int num3;

num1 = 18;
num2 = num1 + 27;
num2 = num1;
num3 = num2 / 5;
num3 = num3 / 4;
```


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Assignment Statements

- Assignment statements can be used as expressions.
  - DO NOT use (coding errors).
- Examples:
  - n = (m = 2);
  - n = m = 2;

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Named Constant

- **Named constant**: memory location whose content **cannot change** during execution.
- The syntax to declare a named constant is:

```
const dataType identifier = value;
```

- `const` is a reserved word
- Examples:
  - `const double CONVERSION = 2.54;`
  - `const int NO_OF_STUDENTS = 20;`
  - `const char BLANK = ' ';`
  - `const double PAY_RATE = 15.75;`

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Initializing Variables in Declarations

- Syntax:

```
Type_Name     Variable_Name_1 (Expression_for_Value_1),
Variable_Name_2 (Expression_for_Value_2),...;
```

- Examples:

```
int count(0), limit(10);
double distance(999.99);
```


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More Statement Assignments

- Syntax:

```
variable Operator = Expression
variable = variable Operation Expression
```

- Examples:

```
count += 2;
total -= discount;
bonus *= 2;
time /= rushFactor;
change %= 100;
amount *= cnt1 + cnt2;
```


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Assignment Compatibility

- General rule: cannot store a value of one type in a variable of another type.

- Errors?

```
int intVar;
intVar = 2.99; //2.99 is of type double.
```

  - Depends on *compilers*.

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Assignment Compatibility

- `int` to `double`:
  - `double doubleVar;`
  - `doubleVar = 2;`

- integers and Booleans:
  - `int` values can be assigned to `bool` type.
    - nonzero: `true`; zero: `false`
  - `bool` values can be assigned to `int` type.
    - `true`: 1; `false`: 0.

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Type Casting

- ***Type cast**:* changing a value of one type to a value of another type.
- **Implicit type coercion:** when value of one type is automatically changed to another type
  - `double d = 5; //converting 5 to 5.0`
  - `int t = 5/2; //value of t?`
  - `double res = 5.0/2; //value of res?`
- **Cast operator:** provides explicit type conversion

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Type Casting

- ***Type cast**:* changing a value of one type to a value of another type.
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  - `double res = 5.0/2; //value of res?`
- **Cast operator:** provides explicit type conversion

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Type Casting

- Four kinds of type casting:
  - **static_cast**<*Type*> *(Expression)*
  - **const_cast**<*Type*> *(Expression)*
  - **dynamic_cast**<*Type*> *(Expression)*
  - **reinterpret_cast**<*Type*> *(Expression)*

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Type Casting

Expression	Evaluates to
`static_cast<int>(7.9)`	`7`
`static_cast<int>(3.3)`	`3`
`static_cast<double>(25)`	`25.0`
`static_cast<double>(5+3)`	`= static_cast<double>(8) = 8.0`
`static_cast<double>(15) / 2`	`= 15.0 / 2` (because `static_cast<double>(15) = 15.0`) `= 15.0 / 2.0 = 7.5`
`static_cast<double>(15 / 2)`	`= static_cast<double>(7)` (because `15 / 2 = 7`) `= 7.0`
`static_cast<int>(7.8 + static_cast<double>(15) / 2)`	`= static_cast<int>(7.8+7.5)` `= static_cast<int>(15.3)` `= 15`
`static_cast<int>(7.8 + static_cast<double>(15 / 2))`	`= static_cast<int>(7.8 + 7.0)` `= static_cast<int>(14.8)` `= 14`

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Type Casting

Example 01:

```
int i1 = 4, i2 = 8;
std::cout << i1 / i2 << std::endl;
std::cout << (double)i1 / i2 << std::endl;
std::cout << i1 / (double)i2 << std::endl;
std::cout << (double)(i1 / i2) << std::endl;
```

Example 02:

```
double d1 = 5.5, d2 = 6.6;
std::cout << (int)d1 / i2 << std::endl;
std::cout << (int)(d1 / i2) << std::endl;
d1 = i1;
std::cout << d1 << std::endl;
i2 = d2;
std::cout << i2 << std::endl;
```


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Increment and Decrement Operators

- Increment operator: increment variable by 1
  - Pre-increment: `++variable`
  - Post-increment: `variable++`
- Decrement operator: decrement variable by 1
  - Pre-decrement: `--variable`
  - Post-decrement: `variable--`
- What is the difference between the following?

```
x = 5;
y = ++x;
```

```
x = 5;
y = x++;
```


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Increment and Decrement Operators

- `n++`: first returns the value of `n`; then the value of `n` is increased by 1.
- `++n`: first the value of `n` is increased by 1; the returns the value of increased `n`.
- `n--`: first returns the value of `n`; then the value of `n` is decreased by 1.
- `--n`: first the value of `n` is decreased by 1; the returns the value of decreased `n`.
- Only applied to a single variable. Others (e.g, `(x + y)++, 5++,..`) are illegal.

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Console Input/Output

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Console Input/Output

- Using these objects: `std::cin`, `std::cout`, `std::cerr` of `iostream`
- Declaring before use:

```
#include <iostream>
```


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Input

- Data must be loaded into main memory before it can be manipulated
- Storing data in memory is a two-step process:
  - Instruct computer to allocate memory
  - Include statements to put data into memory

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Input Using `std::cin`

- `std::cin` is used with >> to gather input
- The stream **extraction operator** is >>
- Using more than one variable in `std::cin` allows more than one value to be read at a time
- Examples:
  - `std::cin >> miles;`
  - `std::cin >> numberofLanguages;`
  - `std::cin >> dragrons >> trolls;`
  - `std::cin >> dragrons >> trolls;`

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Input Using `std::cin`

- `std::in` stops when getting white spaces.
- Try to use function `getline` of `std::cin`.

Input Using `std::cin`

```
#include <iostream>
#include <cstring>
int main()
{
      char name[80];
      std::cout << "Input your name: ";
      std::cin.getline(name, 80);
      std::cout << "Your name is " << name << "\n";
      return 0;
}
```


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Output Using `std::cout`

- Any combinations of variables and strings can be output.
- `std::cout` is used with << to output.
- The stream **insertion operator** is <<
- Expression evaluated and its value is printed at the current cursor position on the screen.

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Output Using `std::cout`

- The new line character is '`\n`' . May appear anywhere in the string.
- `std::endl` causes insertion point to move to beginning of next line.

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Output Using `std::cout`

- Commonly used escape sequences:

	Escape Sequence	Description
`\n`	Newline	Cursor moves to the beginning of the next line
`\t`	Tab	Cursor moves to the next tab stop
`\b`	Backspace	Cursor moves one space to the left
`\r`	Return	Cursor moves to the beginning of the current line (not the next line)
`\\`	Backslash	Backslash is printed
`\'`	Single quotation	Single quotation mark is printed
`\"`	Double quotation	Double quotation mark is printed

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Output Using `std::cout`

- Formatting for Numbers:

```
std::cout.setf(std::ios::fixed);
std::cout.setf(std::ios::showpoint);
std::cout.precision(2);
```

```
std::cout.setf(std::ios::fixed);
std::cout.setf(std::ios::showpoint);
std::cout.precision(2);

std::cout << 7.9999 << " " << 10.5 << std::endl;
```

```
8.00 10.50
```


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File Input

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Reading From a Text File

- using `std::ifstream`.
  - Open file for reading: `open`
  - Close file after reading: `close`
  - Take input (same as `cin`, extractor operator): `>>`
- including `fstream`

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Examples

```cpp
#include <iostream>
#include <fstream>

int main()
{
	std::ifstream fIn;

	fIn.open("Data01.txt");
	if (fIn.is_open() == false)
	{
		std::cout << "File does not exist" << std::endl;
		return 1;
	}

	int N, i;
	int A[100];

	fIn >> N;
	for (i = 0; i < N; i++)
		fIn >> A[i];

	for (i = 0; i < N; i++)
		std::cout << A[i] << "\t";
	std::cout << "\n";

	fIn.close();
	std::cout << "Done\n";
	return 0;
}
```


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Program Style

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Program Style

- Every C++ program has a function `main`
- All C++ statements end with a **semicolon**
- `{` and `}` are not C++ statements
- Follow the syntax rules
- Commas separate items in a list

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Program Style

- Identifiers can be self-documenting:
  - `CENTIMETERS_PER_INCH`
- Avoid run-together words :
  - `annualsale`
  - Solution:
    - Capitalize the beginning of each new word
      - `annualSale`
    - Inserting an underscore just before a new word
      - `annual_sale`

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Use of Blanks

- Use one or more blanks to separate numbers when data is input.
- Used to separate reserved words and identifiers from each other and from other symbols.
- Must never appear within a reserved word or identifier.

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Prompt Lines

- Prompt lines: executable statements that inform the user what to do.

```
std::cout << "Please enter a number between 1 and 10 and "
     << "press the return key" << std::endl;
std::cin >> num;
```


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Documentation

- A well-documented program is easier to understand and modify
- You use comments to document programs
- Comments should appear in a program to:
  - Explain the purpose of the program
  - Identify who wrote it
  - Explain the purpose of particular statements

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Syntax Errors

- Errors in syntax are found in compilation

```
int x;        //Line 1
int y         //Line 2: error
double z;     //Line 3

y = w + x;    //Line 4: error
```


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Reading

- Programming Convention

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Libraries and Namespaces

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Libraries

- C++ has a small number of operations
- Many functions and symbols needed to run a C++ program are provided as collection of libraries.
- Every **library** has a name and is referred to by a **header file**.
- **Preprocessor directives** are commands supplied to the preprocessor
- All preprocessor commands begin with **#**
- **No semicolon** at the end of these commands.

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Libraries

- C++ includes a number of standard libraries.
  - Ref: Appendix 4
- Using preprocessor directive `include`:
  - `#include <Library_Name>`
  - `#include <Header_File>`

```
#include <iostream>
#include <cmath>
#include <string>
```


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Namespaces

- A **namespace** is a collection of name definitions.
- In modern C++, all of the functionality in the C++ standard library is defined inside namespace `std`.
- Using the definitions, insert the `using` directive.

```
using namespace std;
using std::cin;
using std::endl;
```


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Namespaces

- `cin` and `cout` are declared in the header file `iostream`, but within `std` namespace.
- To use `cin` and `cout` in a program, use the following two statements:

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


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Namespaces

- Best practice:
  - Use **explicit** namespace prefixes to access identifiers defined in a namespace.
- Warning:
  - Many texts, tutorials, and even some compilers recommend or use a *using directive* at the top of the program. However, used in this way, this is a **bad practice**, and highly discouraged.

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Namespaces

- An error example:

```
#include <iostream> // imports the declaration of std::cout

using namespace std; // makes std::cout accessible as "cout"
int cout() // declares our own "cout" function
{
    return 5;
}
int main()
{
    cout << "Hello, world!"; // Compile error!
    return 0;
}
```


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Namespaces

- A good example:

```
#include <iostream> // imports the declaration of std::cout

//using namespace std; // makes std::cout accessible as "cout"
int cout() // declares our own "cout" function
{
    return 5;
}
int main()
{
    std::cout << "Hello, world!" << std::endl;
    return 0;
}
```


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Namespaces

```
#include <iostream>
namespace test{
    void cout()
    {
        std::cout << "inside test::cout" << std::endl;
    }
}
int main()
{
    std::cout << "Hello World" << std::endl;
    test::cout();
    return 0;
}
```


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Programming Example

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Programming Example

- Write a program that takes as input a given length expressed in feet and inches
  - Convert and output the length in centimeters
- **Input**: length in feet and inches
- **Output:** equivalent length in centimeters
- Lengths are given in feet and inches
- Program computes the equivalent length in centimeters
- One foot is equal to `12` inches.
- One inch is equal to `2.54` centimeters.

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Questions and Answers

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