C++ Basics

What is an Identifier?

- **An identifier** is the **name** to denote **labels, types, variables, constants** or **functions,** in a C++ program.
- C++ is a **case-sensitive** language.
  - **Work** is not **work**
- **Identifiers should be descriptive**
  - Using meaningful identifiers is a good programming practice

Identifier

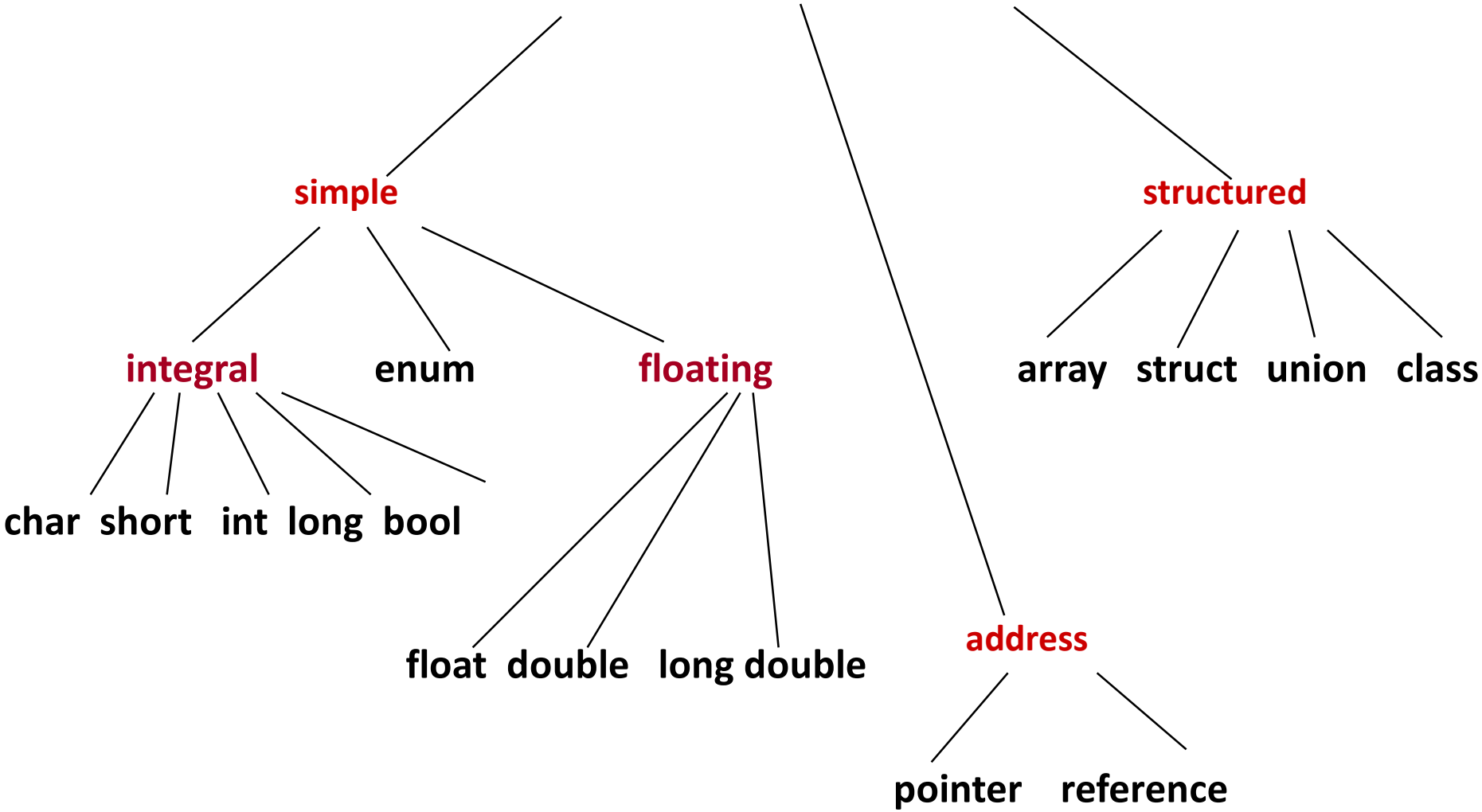
- Identifiers must be unique
- Identifiers cannot be reserved words (keywords)
  - **double main return**
- Identifier must start with a letter or underscore, and be followed by zero or more letters (A-Z, a-z), digits (0-9), or underscores
- **VALID**

  age_of_dog _taxRateY2K

  PrintHeading ageOfHorse
- **NOT VALID**

  age# 2000TaxRate Age-Of-Dog main

C++ Data Types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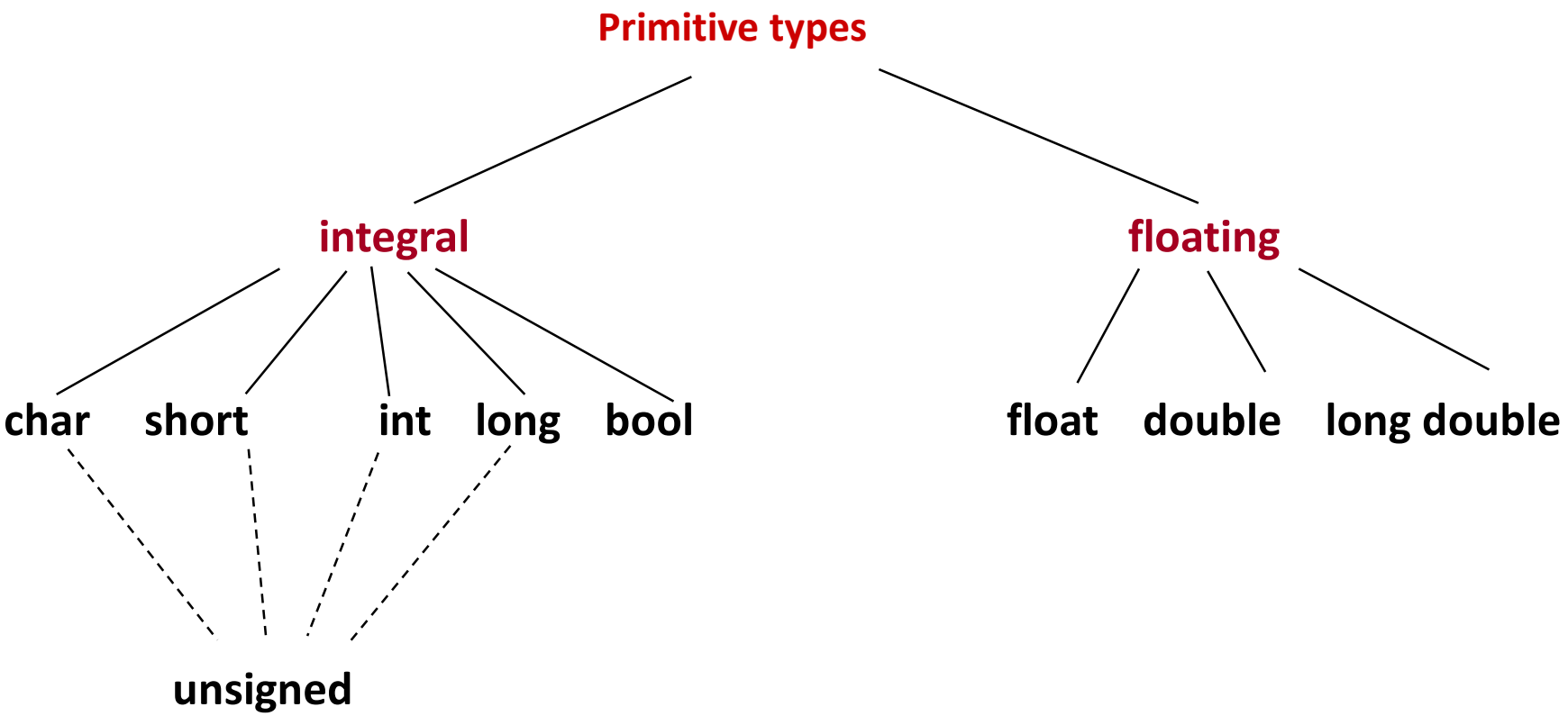
reference

C++ Primitive Data Types



Premitive Data Types in C++

- **Integral Types**
  - represent whole numbers and their negatives
  - declared as int, short, or long
- **Character Types**
  - represent single characters
  - declared as char
  - Stored by ASCII values
- **Boolean Type**
  - declared as bool
  - has only 2 values true/false
  - will not print out directly
- **Floating Types**
  - represent real numbers with a decimal point
  - declared as float, or double
  - Scientific notation where e (or E) stand for “times 10 to the ” (.55-e6)

Samples of C++ Data Values

int sample values

4578 **-4578** **0**

bool values

true **false**

float sample values

95.274 **95.0** **.265**

char sample values

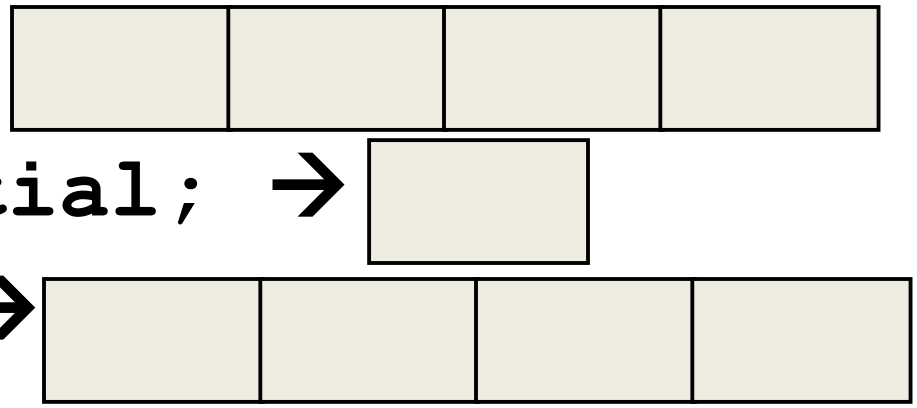
'B' **'d'** **'4'** **'?'** **'*'**

What is a Variable?

- A variable is a memory address where data can be stored and changed.
- Declaring a variable means specifying both its name and its data type.

What Does a Variable Declaration Do?

- **A declaration tells the compiler to allocate enough memory to hold a value of this data type, and to associate the identifier with this location.**
- `int ageOfDog;` →
- `char middleInitial;` →
- `float taxRate;` →



Variable Declaration

- All variables must declared **before** use.
  - At the top of the program
  - Just before use.
- Commas are used to separate identifiers of the same type.

```
int count, age;
```

- Variables can be initialized to a starting value when they are declared

```
int count = 0;
int age, count = 0;
```

What is an Expression in C++?

- An expression is a valid arrangement of variables, constants, and operators.
- In C++, each expression can be evaluated to compute a value of a given type
- In C++, an expression can be:
  - A variable or a constant (count, 100)
  - An operation (a + b, a * 2)
  - Function call (getRectangleArea(2, 4))

Assignment Operator

- An operator to give (assign) a value to a variable.
- Denote as ‘=‘
- Only **variable** can be on the left side.
- An expression is on the right side.
- Variables keep their assigned values until changed by another **assignment statement** or by **reading in** a new value.

Assignment Operator Syntax

- Variable = Expression
  - First, expression on right is **evaluated**.
  - Then the resulting value is **stored** in the memory location of Variable on left.

NOTE: An automatic type coercion occurs after evaluation but before the value is stored if the types differ for Expression and Variable

Assignment Operator Mechanism

- Example:

```
int count = 0;
int starting;
starting = count + 5;
```

- Expression evaluation:
  - Get value of **`count`**: 0
  - Add 5 to it.
  - Assign to **`starting`**

Input and Output

- C++ treats input and output as a **stream** of characters.
- **stream** : sequence of characters (printable or nonprintable)
- The functions to allow standard I/O are in **iostream** header file or **iostream.h**.
- Thus, we start every program with

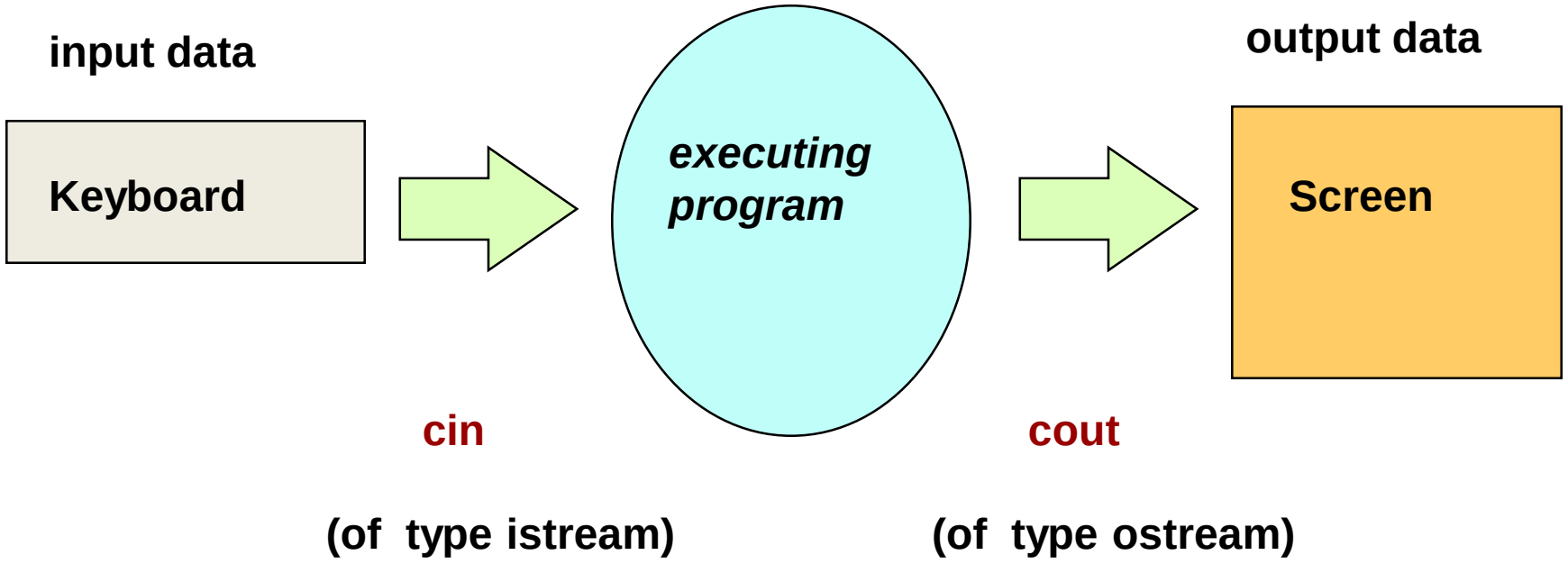
```
#include <iostream>
using namespace std;
```

Include Directives and Namespaces

- **include:** directive copies that file into your program
- **namespace:** a collection of names and their definitions. Allows different namespaces to use the same names without confusion

Keyboard and Screen I/O

```
#include <iostream>
```



Insertion Operator (<<)

- Variable **cout** is predefined to denote an output stream that goes to the standard output device (display screen).
- The insertion operator **<<** called "put to" takes 2 operands.
- The left operand is a stream expression, such as **cout**. The right operand is an **expression** of simple type or a **string constant**.

Output Statements

SYNTAX

```
cout << Expression << Expression . . . ;
```

cout statements can be linked together using **<<** operator.

These examples yield the same output:

```
cout << "The answer is " ;
cout << 3 * 4 ;
```

```
cout << "The answer is " << 3 * 4 ;
```

Output Statements (String constant)

- String constants (in double quotes) are to be printed as is, without the quotes.

  cout<<"Enter the number of candy bars ";

  OUTPUT: Enter the number of candy bars

- **"Enter the number of candy bars "** is called a **prompt**.
- All user inputs must be preceded by a **prompt** to tell the user what is expected.
- You must insert **spaces** inside the quotes if you want them in the output.
- Do not put a string in quotes on multiple lines.

Output Statements (Expression)

- All expressions are computed and then outputted.

  cout << "The answer is " << 3 * 4 ;

  OUTPUT: The answer is 12

Escape Sequences

- The backslash is called the escape character.
- It tells the compiler that the next character is “escaping” it’s typical definition and is using its secondary definition.
- Examples:
  - new line: **\n**
  - horizontal tab: **\t**
  - backslash: ****
  - double quote **\”**

Newline

- **cout<<"\n"** and **cout<<endl** both are used to insert a blank line.
- Advances the cursor to the start of the next line rather than to the next space.
- Always end the output of all programs with this statement.

Formatting for Decimal Point Numbers

- Typed float, or double
- Use the three format statements (magic formula) to format to fixed decimal notation.

  cout.setf(ios::fixed);

  cout.setf(ios::showpoint);

  cout.precision(2);
- **setf** "set flag" means that all real output will be formatted according to the function, until changed by either unsetting the flag or a new **setf** command.
- **ios::** means the functions from the **iostream** library

Extraction Operator (>>)

- Variable **cin** is predefined to denote an input stream from the standard input device (the keyboard)
- The extraction operator **>>** called "get from" takes 2 operands. The left operand is a **stream expression**, such as **cin**--the right operand is a variable of simple type.
- Operator **>>** attempts to extract the next item from the input stream and store its value in the right operand variable.

Input Statements

SYNTAX

```
cin >> Variable >> Variable . . . ;
```

cin statements can be linked together using **>>** operator.

These examples yield the same output:

```
cin >> x;
cin >> y;
```

```
cin >> x >> y;
```

How Extraction Operator works?

- Input is not entered until user presses <ENTER> key.
- Allows backspacing to correct.
- Skips whitespaces (space, tabs, etc.)
- Multiple inputs are stored in the order entered:

```
cin>>num1>>num2;
```

User inputs: **3 4**

Assigns num1 = 3 and num2 = 4

Numeric Input

- Leading blanks for numbers are ignored.
- If the type is double, it will convert integer to double.
- Keeps reading until blank or <ENTER>.
- Remember to **prompt** for inputs

C++ Data Type String

- **A string is a sequence of characters enclosed in double quotes**

- **string sample values**

  "Hello" "Year 2000" "1234"

- **The empty string (null string) contains no displayed characters and is written as ""**

C++ Data Type String (cont.)

- **string is not a built-in (standard) type**
  - it is a programmer-defined data type
  - it is provided in the C++ standard library
- Need to include the following two lines:

  #include <string>

  using namespace std;
- **string operations** include
  - comparing 2 string values
  - searching a string for a particular character
  - joining one string to another (concatenation)
  - etc...

Type compatibilities

- **<u>Warning:</u>** If you store values of one type in variable of another type the results can be inconsistent:
  - Can store integers in floating point or in char (assumes ASCII value)
  - bool can be stored as int: (true = nonzero, false = 0)
- Implicit promotion: integers are promoted to doubles

  double var = 2; // results in var = 2.0
- On integer and doubles together:
  - Mixed type expressions: Both must be **int** to return **int**, otherwise **float**.

Type compatibilities (Implicit Conversion)

- The compiler tries to be value-preserving.
- General rule: promote up to the first type that can contain the value of the expression.
- Note that representation doesn't change but values can be altered .
- Promotes to the smallest type that can hold both values.
- If assign **float** to **int** will truncate

  int_variable = 2.99; // results in 2 being stored in int_variable
- If assign **int** to **float** will promote to double:

  double dvar = 2; // results in 2.0 being stored in dvar

Type compatibilities (Explicit Conversion)

- Casting - forcing conversion by putting (type) in front of variable or expression. Used to insure that result is of desired type.
- Example: If you want to divide two integers and get a real result you must **cast** one to double so that a real divide occurs and store the result in a double.

```
int x=5, y=2; double z;   z = static_cast <double>(x)/y;   // 2.5
int x=5, y=2; double z;   z = (double)x/y;                 // 2.5
int x=5, y=2; double z;   z = static_cast <double>(x/y) ; // 2.0
```

- converts x to double and then does mixed division, not integer divide
- **static_cast<int> (z)** - will truncate z
- **static_cast <int> (x + 0.5**) - will round positive x {use () to cast complete expression)
- Cast division of integers to give real result:

```
int x=5, y=2; double z;   z = static_cast <double>(x/y) ; // 2.0
```

Arithmetic Operators

- Operators: **+, -, * /**
- For **floating numbers**, the result as same as Math operations.
- Note on **integer** division: the result is an integer. **7/2 is 3**.
- **%** (remainder or modulo) is the special operator just for integer. It yields an integer as the result. **7%2 is 1**.
- Both / and % can only be used for positive integers.
- Precedence rule is similar to Math.

Arithmetic Expressions

- Arithmetic operations can be used to express the mathematic expression in C++:

$b^2 - 4ac$	$b*b-4*a*c$
$x(y+z)$	$x*(y+z)$
$\frac{1}{x^2+x+3}$	$1/(x*x+x+3)$
$\frac{a+b}{c-d}$	$(a+b)/(c+d)$

Simple Flow of Control

- Three processes a computer can do:
  - Sequential

    expressions, **insertion** and **extraction** operations
  - Selection (Branching)

    if statement, **switch** statement
  - Repetition/Iteration (Loop)

    while loop, **do-while** loop, **for** loop

`bool` Data Type

- Type **`bool`** is a built-in type consisting of just 2 values, the constants true and false
- We can declare variables of type **bool**

```
bool   hasFever;    // true if has high temperature
bool   isSenior;    // true if age is at least 55
```

- The value 0 represents false
- ANY non-zero value represents true

Boolean Expression

- **Expression that yields bool result**
- **Include:**

  6 Relational Operators

  < <= > >= == !=

  3 Logical Operators

  ! && ||

Relational Operators

are used in boolean expressions of form:

ExpressionA	*Operator*	*ExpressionB*
temperature	**>**	**humidity**
B * B - 4.0 * A * C	**>**	**0.0**
abs (number)	**==**	**35**
initial	**!=**	**'Q'**

- **Notes:**
  - == (equivalency) is **NOT** = (assignment)
  - characters are compared alphabetically. However, lowercase letters are higher ASCII value.
  - An integer variable can be assigned the result of a logical expression
  - You cannot string inequalities together:

    Bad Code: **4<x<6** Good Code: **(x > 4) &&(x < 6)**

Relational Operators

```
int  x, y ;
x = 4;
y = 6;
```

EXPRESSION	VALUE
x < y	true
x + 2 < y	false
x != y	true
x + 3 >= y	true
y == x	false
y == x+2	true
y = x + 3	7
y = x < 3	0
y = x > 3	1

Logical Operators

are used in boolean expressions of form:

ExpressionA Operator ExpressionB

A || B (true if either A or B or both are true. It is false otherwise)

A && B (true if both A and B are true. It is false otherwise)

or

Operator Expression

!A (true if A is false. It is false if A is true)

Notes:

Highest precedence for NOT, AND and OR are low precedence.

Associate left to right with low precedence. Use parenthesis to override priority or for clarification

- x && y || z will evaluate "x && y " first
- x && (y || z) will evaluate "y || z" first

Logical Operators

```
int     age ;
bool   isSenior,  hasFever ;
float   temperature ;
age = 20;
temperature = 102.0 ;
isSenior = (age >=  55) ;                    // isSenior is  false
hasFever =  (temperature > 98.6) ;           // hasFever is  true
```

EXPRESSION	VALUE
isSenior && hasFever	false
isSenior || hasFever	true
!isSenior	true
!hasFever	false

Precedence Chart

- ++, --, !, - (unary minus), + (unary plus)
- *, /, %
- + (addition), - (subtraction)
- <<, >>
- <, <=, >, >=
- ==, !=
- &&
- ||
- =

Boolean Expression (examples)

taxRate is over 25% and *income* is less than $20000

temperature is less than or equal to 75 or *humidity* is less than 70%

age is between 21 and 60

age is 21 or 22

Boolean Expression (examples)

(taxRate > .25) && (income < 20000)

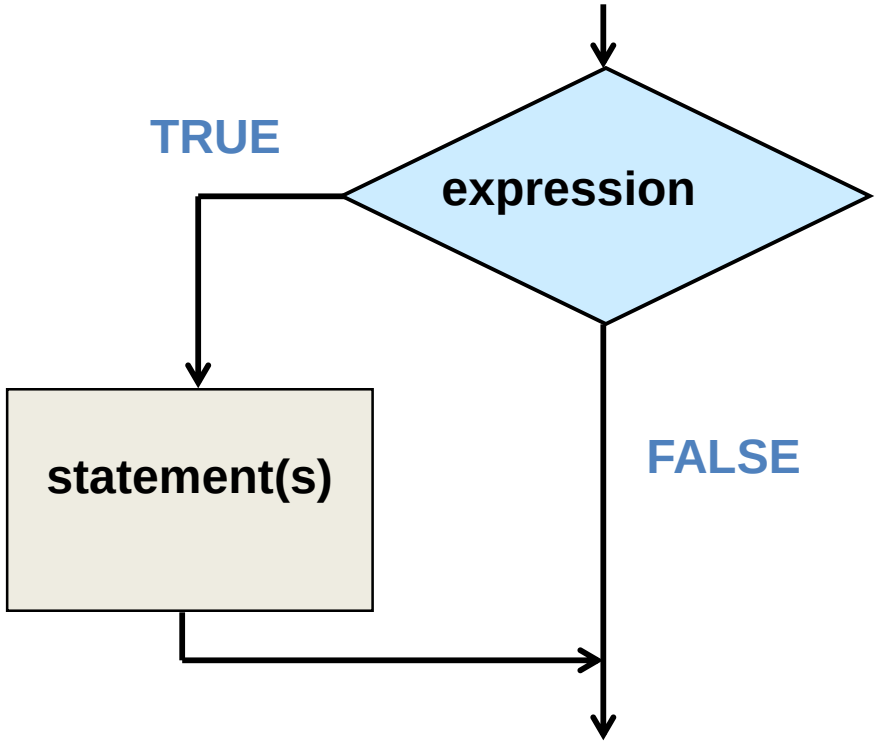
(temperature <= 75) || (humidity < .70)

(age >= 21) && (age <= 60)

(age **==** 21) || (age **==** 22)

Simple *if* Statement

- Is a **selection** of whether or not to execute a statement or a block of statement.



Simple *if* Statement Syntax

```
if (Boolean Expression)
    Statement

if (Bool-Expr)
{
    Statement_1
    …
    Statement_n
}
```

These are NOT equivalent. Why?

```
if (number == 0 )
{
      cout << "Hmmmm ";
      cout << "You entered invalid number.\n";
}
```

When number has value 0, the output will be:

Hmmmm You entered invalid number.

When number has value **NOT** 0, there is **NO** output.

```
if (number == 0 )
      cout << "Hmmmm ";
      cout << "You entered invalid number.\n";
```

When number has value 0, the output will be:

Hmmmm You entered invalid number.

When number has value **NOT** 0, the output will be:

You entered invalid number.

These are equivalent. Why?

```
if (number == 0 )
{
        .
        .
}
```

Read as:

If *number* is 0

```
if (!number )
{
        .
        .
}
```

Read as:

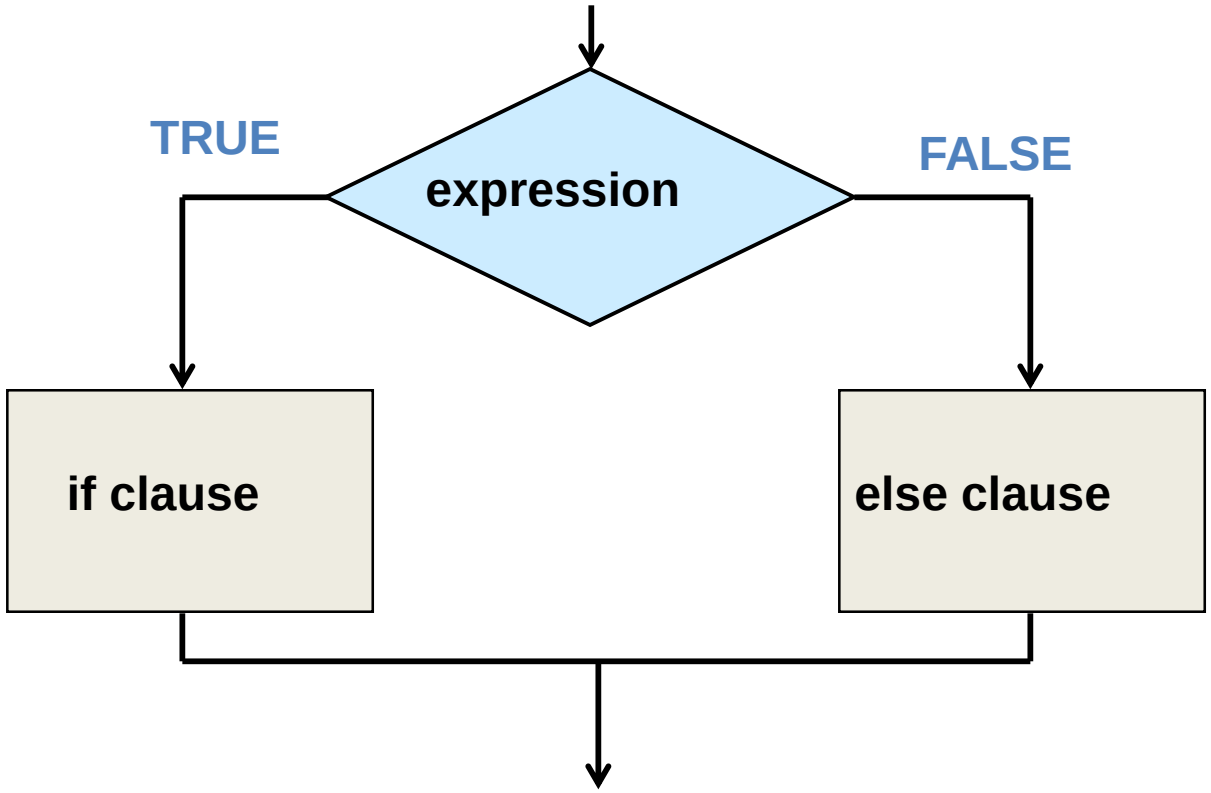
If *number* is NOT true

If *number* is false

Each expression is only true when number has value 0.

If-else Statement

- provides **selection** between executing **one of 2 clauses** (the if clause or the else clause)



Use of blocks

- Denoted by **{ .. }**
- Recommended in controlled structures (if and loop)
- Also called compound statement.

if (*Bool-Expression*)
{

}
else
{

}

Loop

- is a repetition control structure.
- causes a single statement or block of statements to be executed repeatedly until a condition is met.
- There are 3 kinds of loop in C++:
  - While loop
  - Do-While loop
  - For loop

While Loop

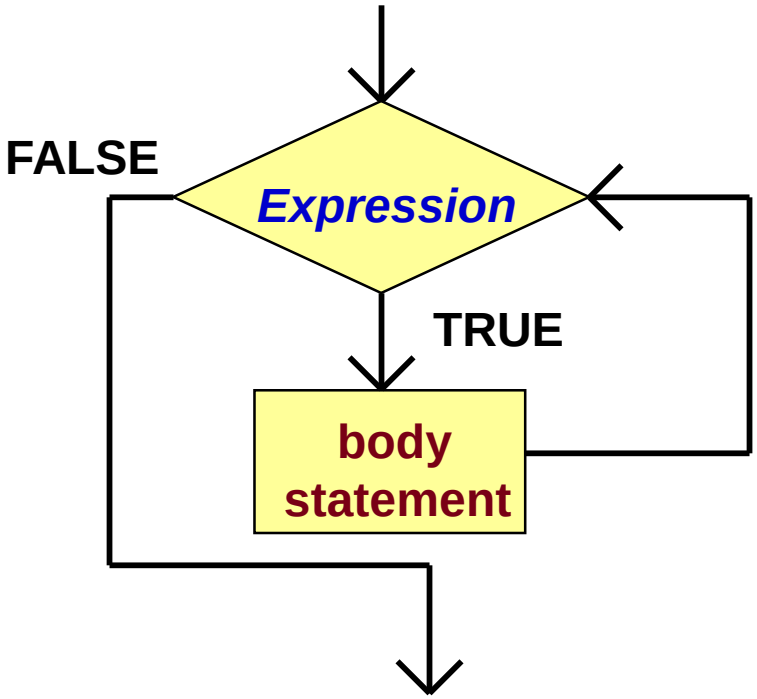
SYNTAX

```
while ( Expression )
{
    … // loop body
}
```

- No semicolon after the boolean expression
- Loop body can be a single statement, a null statement, or a block.

While Loop Mechanism

- When the expression is tested and found to be false, the loop is exited and control passes to the statement which follows the loop body.



- When the expression is tested and found to be true, the loop body is executed. Then, the expression is tested again.

While Loop Example

```
int   count ;
count  =  0;                          // initialize LCV
while (count < 5)                     // test expression
{
        cout  << count  << " ";       // repeated action
        count =   count + 1;          // update LCV
}
cout  << "Done" << endl ;
```

Loop Tracing

```
int   count ;
count  =  0;
while (count < 5)
{
    cout  << count  << " ";
    count =   count + 1;
}
cout  << "Done" << endl ;
```

count	Expression	Output
0	true	0
1	true	0 1
2	true	0 1 2
3	true	0 1 2 3
4	true	0 1 2 3 4
5	false	0 1 2 3 4 Done

Increment and Decrement Operators

- Denoted as **++** or **--**
- Mean increase or decrease by 1
- Pre increment/decrement: ++a, --a
  - Increase/decrease by 1 before use.
- Post increment/decrement: a++, a--
  - Increase/decrease by 1 after use.
- Pre and Post increment/decrement yield different results when combining with another operation.

Pre and Post Increment and Decrement

```
int   count ;
count  =  0;
while (count < 5)
{
     cout  << count++  << " " ;
}
cout  << "Done" << endl ;
```

count	Expression	Output
0	true	0
1	true	0 1
2	true	0 1 2
3	true	0 1 2 3
4	true	0 1 2 3 4
5	false	0 1 2 3 4 Done

```
int   count ;
count  =  0;
while (count < 5)
{
     cout  << ++count  << " " ;
}
cout  << "Done" << endl ;
```

count	Expression	Output
0	true	1
1	true	1 2
2	true	1 2 3
3	true	1 2 3 4
4	true	1 2 3 4 5
5	false	1 2 3 4 5 Done

Do-While Loop

SYNTAX

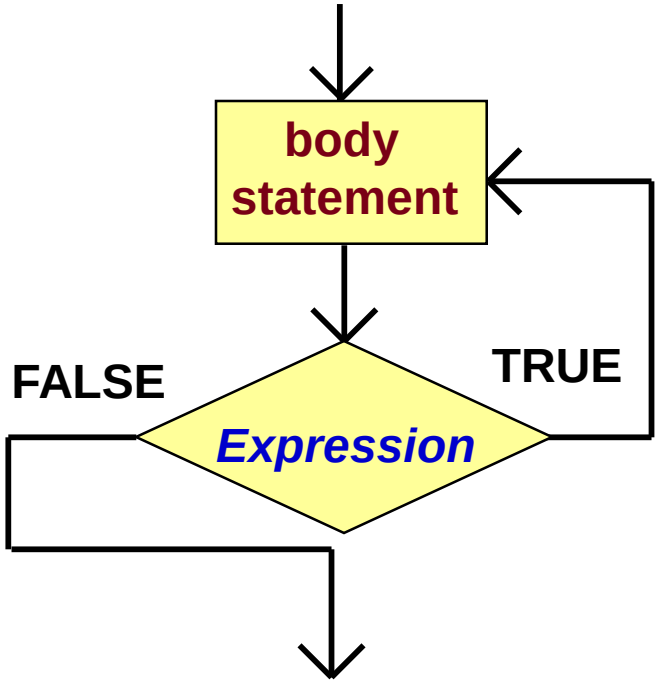
```
do
{
    … // loop body
} while ( Expression );
```

- Insured that the loop is executed at least once
- The LCV is initialized/updated before the end of the loop.
- Boolean expression is tested at the end of the loop.
- There is a semicolon after the boolean expression.

Do-While Loop Mechanism

- The loop body is executed first

- When the expression is tested and found to be false, the loop is exited and control passes to the statement which follows the loop body.



- When the expression is tested and found to be true, the loop body is executed. Then, the expression is tested again.

Do-While Loop Example

```
int   ans;
do
{
     cout  << “Choose a number from 1 to 4: “;// repeated action
     cin >> ans;                              // LCV is initialized or updated
} while (ans >= 1 && ans <= 4);               // test expression
cout << “Done”;
```

Output	Input	ans	Expression
Choose a number from 1 to 4:	2	2	true
Choose a number from 1 to 4:	3	3	true
Choose a number from 1 to 4:	1	1	true
Choose a number from 1 to 4:	5	5	false
Done			

Loop-Controlled Types

Count-controlled: repeat a specified number of times.

Event-driven: some condition within the loop body changes and this causes the repeating to stop.

Sentinel-controlled: using a specific value to end.

Sentinel: a value that cannot occur as valid data.

Ask-before-Continuing: ask users if they want to continue.

Flag-Controlled Loops: use a variable whose value is changed when an event occurs (usually from false to true).

Count-Controlled Loop

- Has a loop control variable (LCV) as a counter.
- LCV must be
  - Initialized before start of the loop
  - Tested (boolean expression)
  - Updated

Event-driven loop

```
double salary;
cout << "Enter you salary: ";
cin >> salary;
int years = 0;
while (salary < 50000) {
    salary = salary * 1.02;
    years++;
}
cout << “You need “ << years << “years to get to 50K";
```

Sentinel-Controlled

```
do
{
    cout<< ”Enter salary, type -1 to exit”; // no one earns negative salary
    cin>>salary;
    // process income
} while (salary > 0);
```

Ask-before-Continuing

```
char ans = ‘y’;                          // LCV is initialized
while (ans == ‘Y’ || ans == ‘y’)         // test expression
{
      doSomething;                       // repeated action
      cout << “Do you want to continue? ”;
      cin >> ans;                        // LCV is updated
};
```

BREAK statement

allows to exit from any loop.

```
do
{
        cin>>x;
        if (x % 2 ==0)
              break;
} while (x > 0); // exits when an even number is entered
```

CONTINUE Statement

allows you to skip the rest of the loop body and go back to the beginning of the loop.

```
do
{
        cin>>x;
        if (x % 2 == 0)
                continue;
        cout<<x<<endl;
} while (x <100);
//prints out all odd numbers entered less than 100
```

Program Style

- **Indenting:**
  - Separate processes with blank lines
  - Blank lines are also ignored and are used to increase readability.
  - indent statements within statements (loop body)
- **Comments:**
  - **//** tells the computer to ignore this line.
  - for internal documentation. This is done for program clarity and to facilitate program maintenance.

General rules for Comments

- Place a comment at the beginning of every file with the file name, version number, a brief program description, programmer's name.
- Place a descriptive comment after each variable declared.
  - Use a blank line before and after variable declarations
- Place a descriptive comment and a blank line before each subtask.

Constants

- Syntax: const type identifier = value;
- Ex: const double TAX_RATE = 0.08;
- Convention: use upper case for constant ID.

Why use constants?

- Clarity: Tells the user the significance of the number. There may be the number 0.08 elsewhere in the program, but you know that it doesn't stand for TAXRATE.
- Maintainability. Allows the program to be modified easily.
  - Ex: Program tax compute has **const double TAXRATE=0.0725**. If taxes rise to 8%, programmer only has to change the one line to **const double TAXRATE=0.08**
- Safety: Cannot be altered during program execution