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Fundamentals of Programming II

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Lecture 01

Revision of Basic Constructs

C++ **Standard ISO/IEC 14882**
Programming Language

Outline

Topics Covered

01 Variables & Constants

02 Operators & Expressions

03 Conditional Statements

04 Loop Constructs

05 Arrays Concepts

04 Pointers & References

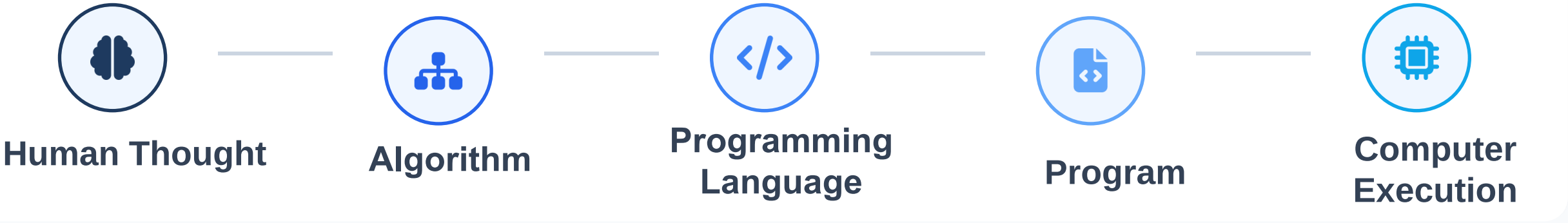
Learning Objectives

By the end of this lecture, you will be able to:

- Refresh your understanding of core programming constructs
- Identify common pitfalls in foundational programming and apply industry best practices
- Build a strong conceptual foundation for upcoming Programming II topics

1. What is a Program?

> “A **program** is a sequence of precise **instructions** written in a **programming language** that directs a computer to perform a specific task by transforming **input** data into meaningful **output** through automated processing” (*Webopedia, 2024).*



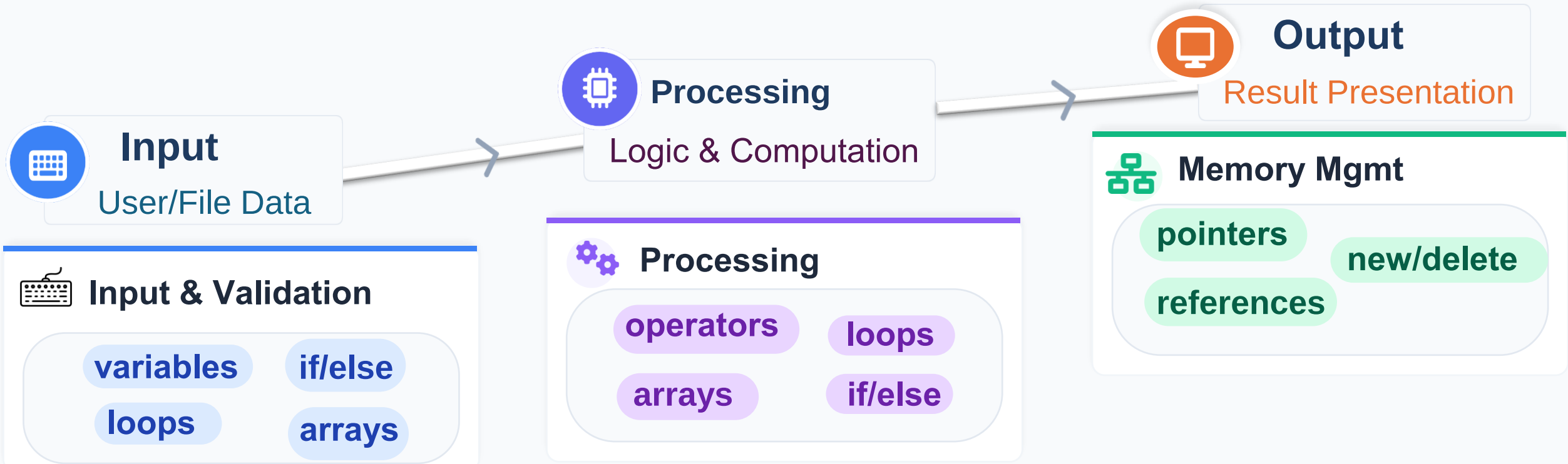
Algorithmic Thinking:

- Only **10%** is syntax in Programming, **90% logic**

2. Basic Structure of a Program

Input–Process–Output (IPO) Model

The IPO model explains how a program transforms **input** data into meaningful **output** through **processing** logic (Bjarne Stroustrup, 2013).

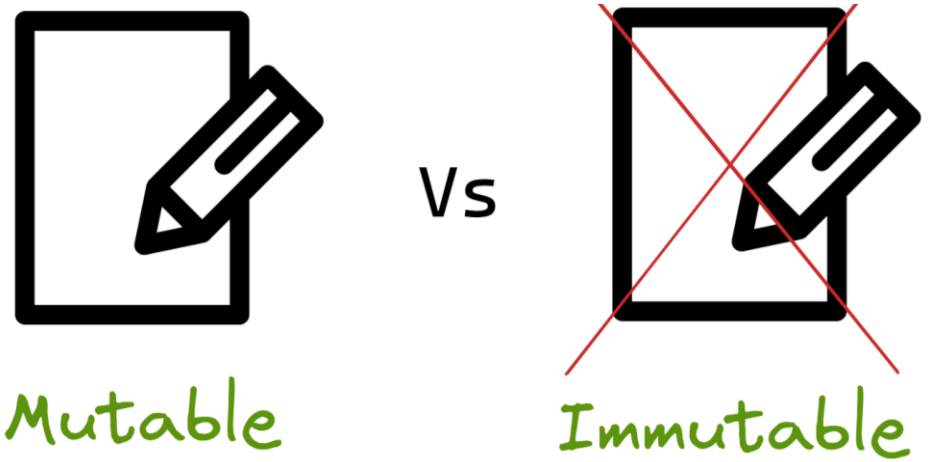


3. Variables & Constants

Core Concept

Named Storage Location

- **Variables and constants** act as human-readable **symbolic names** for specific memory addresses.
- Allow programmers to **store, retrieve, and manipulate data** without managing raw memory locations directly.



Variables

value can be change

Constants

value cannot be change

Cont'd

Characteristics

- **Identifiers:** Both variables and constants need names, often called identifiers
- **Naming Conventions:** Variables often use **camelCase**, while constants are frequently written fully in uppercase
- **Scope:** where variables and constants are accessible (local or global).
- **Lifetime:** How long the variable exists in memory
- **Data Types:** determines what kind of data stores, the **size and layout**

Declaration Syntax

```
type variable_name;
or
type variable_name = value;
or
type variable_name {value};
```

```
const type const_name = value;
or
#define const_name value;
```

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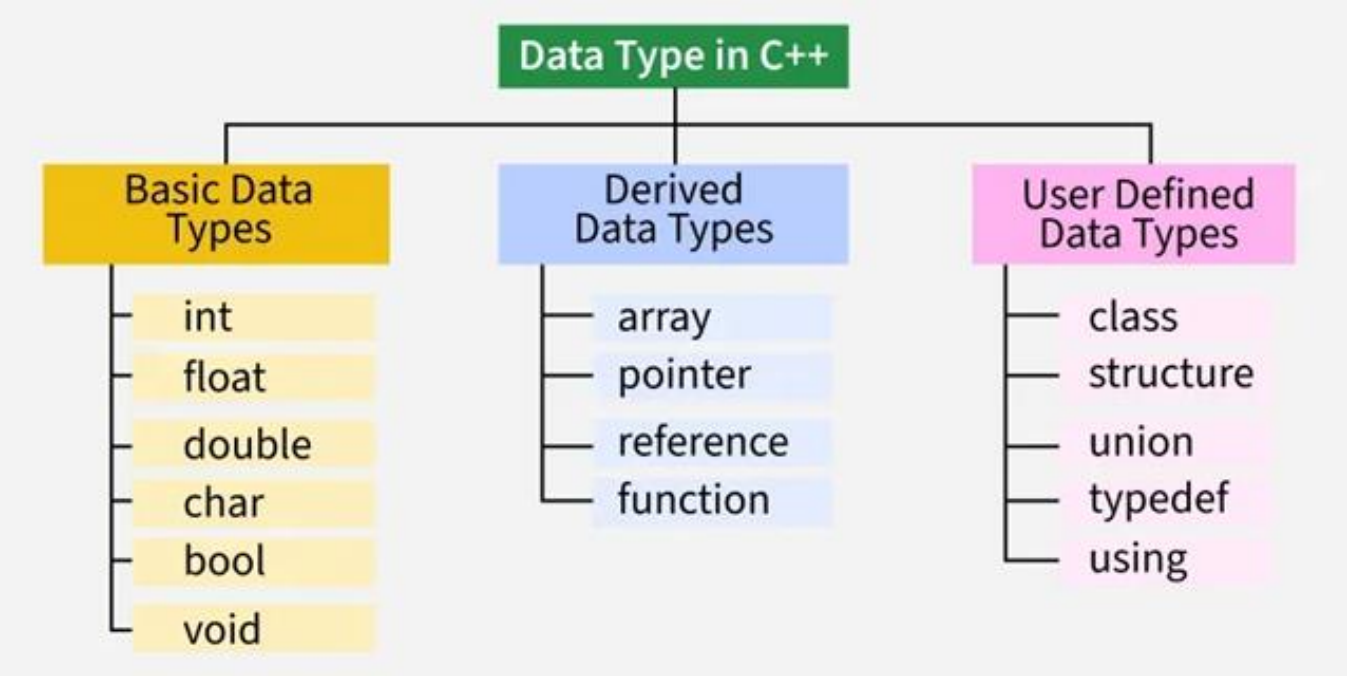
Data Types

- Describes the **property** of the data and the **size** of the reserved memory.
- Established when the variable is defined



Signed vs Unsigned

- **Unsigned**
  - a **positive integer** only
- **Signed**
  - it is either negative or positive

Source: *https://www.geeksforgeeks.org/cpp/cpp-data-types/*

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Primitive Data Types

- Every variable has a **fixed data type** determined at compile time.
- The **sizes** may vary on the compiler and **architecture of the computer system**, but relative sizes are guaranteed.

Table 1: Primitive data types built into the C++ language.

TYPE	TYPICAL SIZE	EXAMPLE DECLARATION
int	4 bytes (32-bit)	**int**count = 0;
double	8 bytes (64-bit)	**double**pi = 3.14159;
char	1 byte	**char**grade = 'A';
bool	1 byte	**bool**isValid = true;
float	4 bytes	**float**ratio = 2.5f;
void	0 bytes	Used for functions in no return

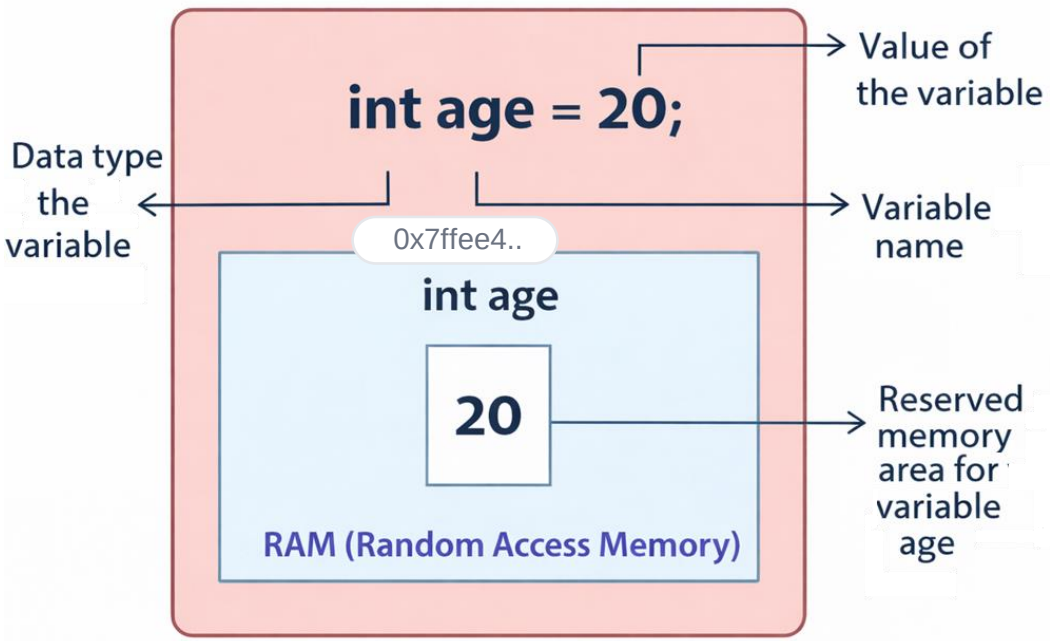
Note: Use sizeof() to determine the exact size on your system

Cont'd

Example of Declaration and Initialization

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

int main() {

  // 1. Basic Initialization (C-style)
  int count = 10;
  char grade = 'A';

  // 2. Constructor Style (C++)
  int score(85);

  // 3. Multiple Declaration
  int width = 5, height = 10;

  // 4. Constants & Inference (Modern C++)
  const double PI = 3.14159;
  auto isReady = true; // Deducts bool

  return 0;
}
```

Memory Abstraction

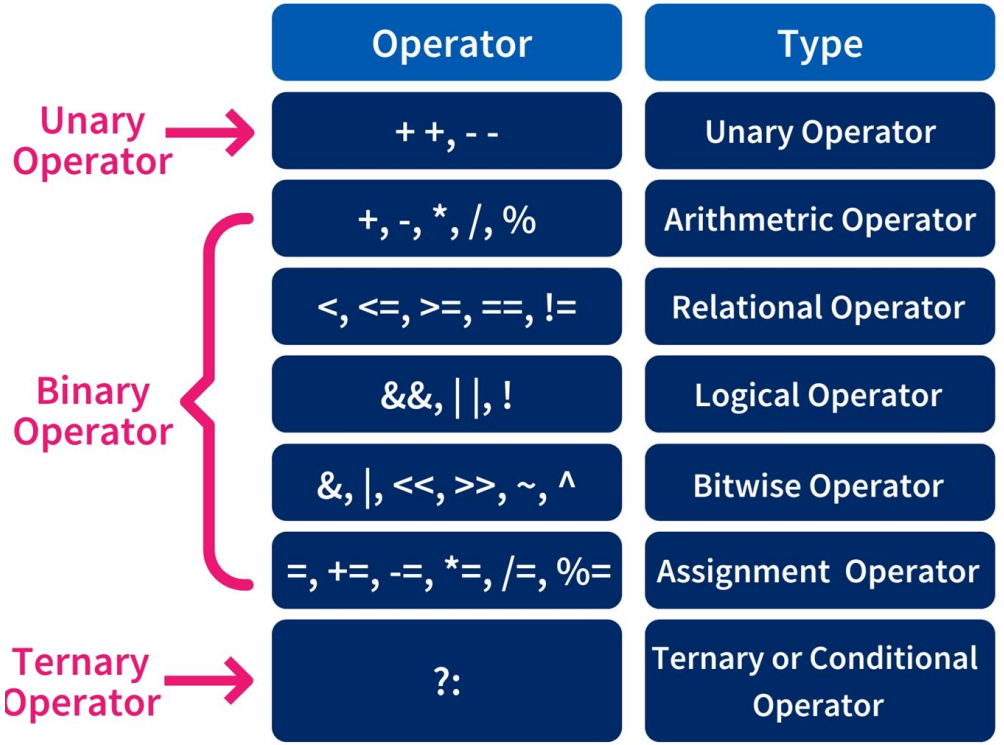


***Source**: Generate by ChatGPT 4.0*

4. Operators and Expressions

Core Concept

- **Operators** are **special symbols** or **keywords** that instruct a computer what operations to perform (**mathematical / logical / data manipulation**).
- Fundamental building blocks for expressions and logic in programming.
- An **expression** is a combination of *operands (variables, constants, or values) and operators* that is evaluated to produce a single value.



Source: https://www.scaler.com/topics/cpp/operators-in-cpp/

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Operator Precedence & Associativity

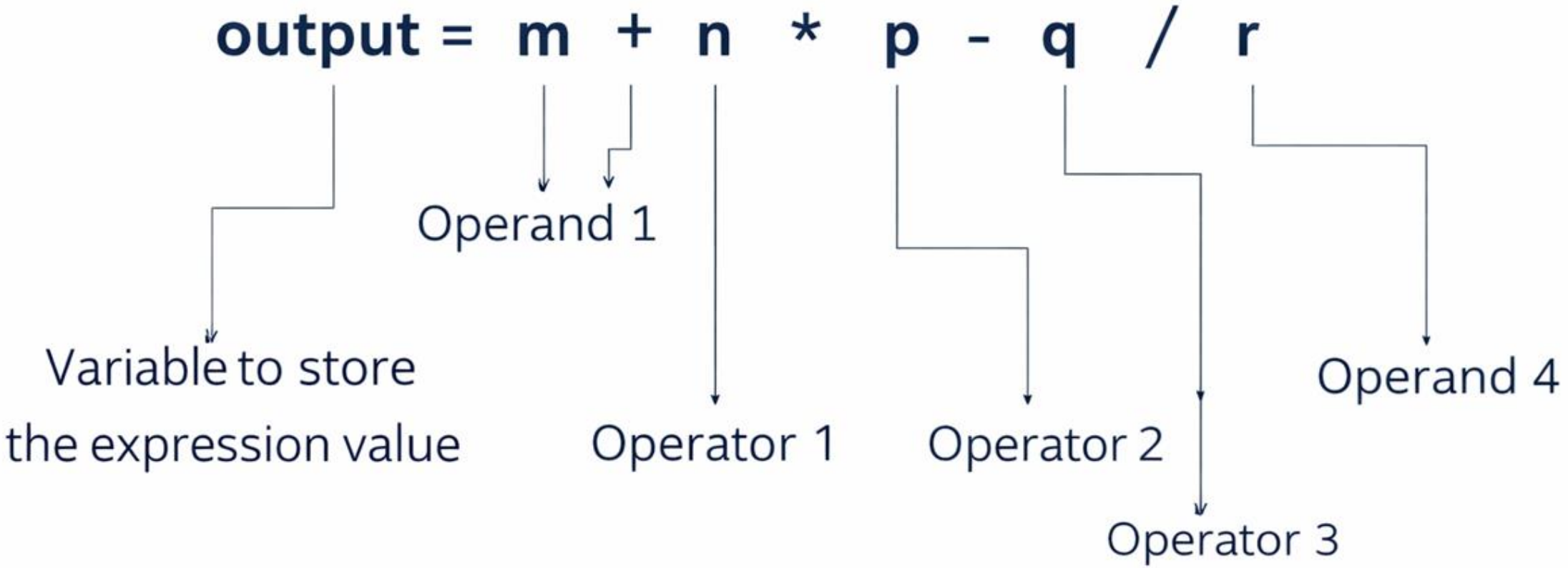
- ✓ Precedence refers to the order in which **operators** are evaluated.
- ✓ When operators have the same precedence, **associativity** rules apply

Sample Precedence Table (High to Low)

LEVEL	OPERATORS	ASSOCIATIVITY
1 (Highest)	::	Left to Right
2	++ -- () [] . ->	Left to Right
3	++ -- + - ! ~ * & (unary)	Right to Left
5	* / %	Left to Right
6	+ -	Left to Right
7	&&	Left to Right
8	||	Left to Right
9 (Lowest)	= += -= *= /=	Right to Left

Cont'd

Example of an Expression



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Challenge Exercise:

Expression Evaluation

Instructions

- ✓ Calculate the result of each expression using operator precedence rules.
- ✓ Don't just guess—break it down step-by-step!

Tip: For equal precedence, check associativity!
Most are Left-to-Right.

1: Mixed Arithmetic — Easy

```
10 + 20 * 3 - 5
```

→ ?

2: Integer Division & Modulo — Medium

```
100 + 10 % 3
```

→ ?

3: Precedence Trap — Tricky

```
2 + 3 << 1
```

→ ?

4; Assignment Side Effects — Hard

```
// a,b=0 initially
(a=5) +(b=2) * 4
```

Result:?
Final a, b:?

Cont'd

Solutions

1: Mixed Arithmetic — Easy

`10 + 20 * 3 - 5` → `10 + (20 * 3) - 5` → `10 + 60 - 5` → `70- 5` → **65**

2: Integer Division & Modulo — Medium

`100 + 10 % 3` → `100 + (10 % 3)` → `100 + 1` → **101**

3: Precedence Trap — Tricky

`2 + 3 << 1` → `(2 + 3) << 1` → `5 << 1` → **10**

4; Assignment Side Effects — Hard

`(a=5) + (b=2) * 4` → `5 + 2 * 4` → `5 + (2 * 4)` → `5 + 8` → **Result: 13**
Final a=5, b=2

5. Flow Controls

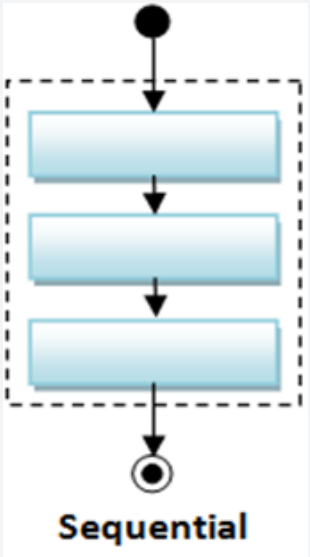
What is Flow Control?

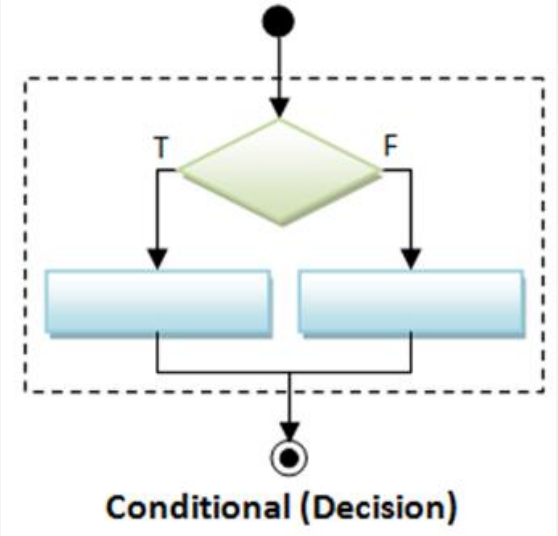
It refers to the **order** in which **statements or instructions** in a program are executed.

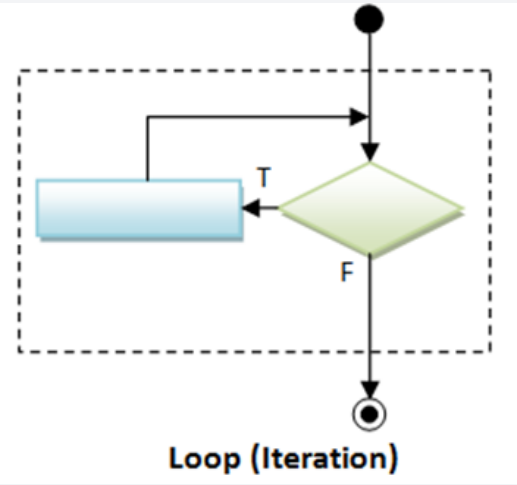
It determines **how** the program **moves from one instruction to another** during execution.

By default, a program executes **sequentially**, but flow control structures allow the program to:

- **Make decisions** (selection)
- **Repeat actions** (iteration)
- **Change the execution path**



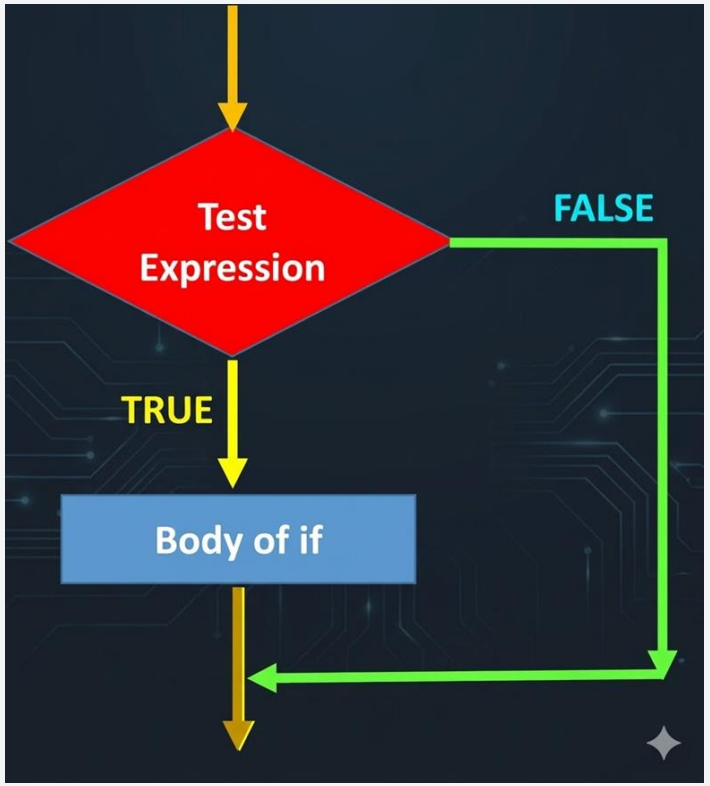




5.1. Selection Statements

Overview

- Allow programs to **make decisions** and handle different scenarios dynamically
- Allow programs to **execute different code blocks** based on boolean expressions.
- This **breaks** the linear execution of code.



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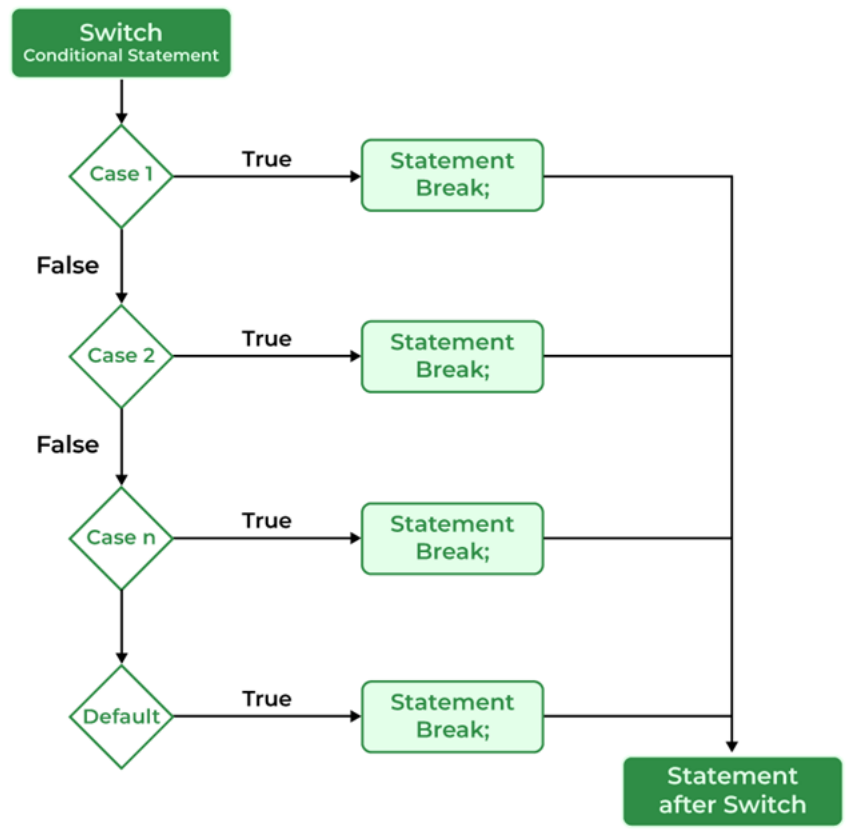
Common Patterns

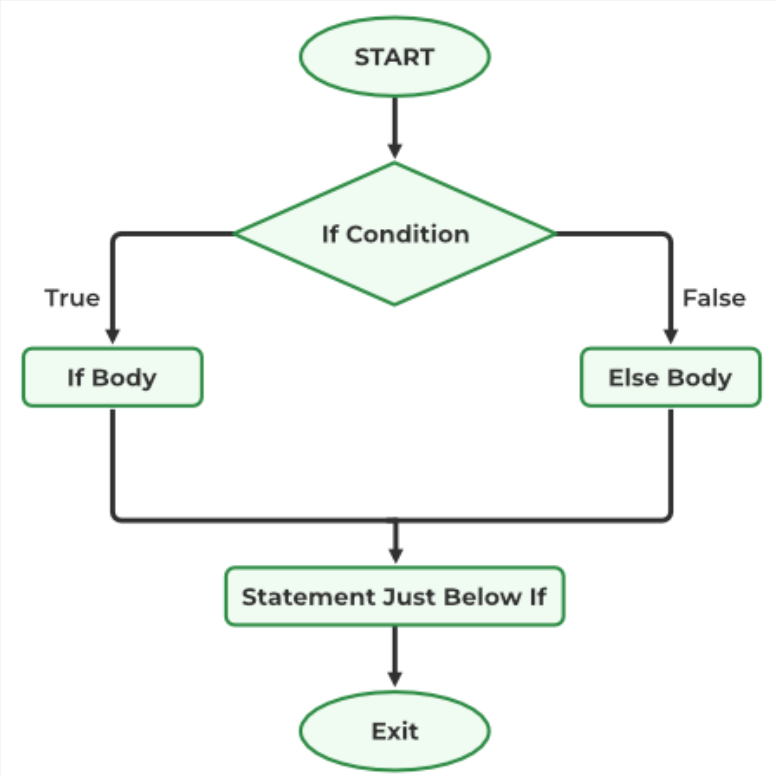
1. switch:-

- selecting one path from multiple constant



2. if / else:

- basic **binary** decisions and chaining conditions



***Source**:*
https://www.geeksforgeeks.org/ cpp

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Example 1: if – else if ladder

Execution Flow Analysis

Check 1. score >= 90 (78 >= 90) → **false**

Check 2:score >= 80 (78 >= 80) → **false**

Check 3:score >= 70 (78 >= 70) → **true**

↳ Executes body: prints "Grade: C“

Remaining else block is skipped.

grading.cpp

```cpp
#include <iostream>

int main() {
    int score{78};

    // If-else-if ladder example
    if (score >= 90) {
        std::cout << "Grade: A\n";
    }
    else if (score >= 80) {
        std::cout << "Grade: B\n";
    }
    else if (score >= 70) {
        std::cout << "Grade: C\n";
    }
    else {
        std::cout << "Grade: D/F\n";
    }

    return 0;
}
```

>_ PROGRAM OUTPUT

```
Grade: C_
```

Cont'd

Example 2: switch case

Assume use input:

- num1 = 212, num2 = 43
- Operator (oper): /

Output?

- 4.93

```
int main() {
    char oper;
    float num1, num2;
    cout << "Enter an operator (+, -, *, /): ";
    cin >> oper;
    cout << "Enter two numbers: " << endl;
    cin >> num1 >> num2;

    switch (oper) {
        case '+':
            cout <<"Addition Result: "<< num1 + num2;
            break;
        case '-':
            cout <<"Subtraction Result: "<< num1 - num2;
            break;
        case '*':
            cout <<"Multiplication Result: "<< num1 * num2;
            break;
        case '/':
            cout <<"Division Result: "<< num1 / num2;
            break;
        default:
            cout << "Incorrec operator!";
            break;
    }
    return 0;
}
```

5.2. Loops

Overview

Loops enable repeated execution of code blocks until a specific condition is met.

- **Repetition:**
  - *Allow execution of a block of code multiple times.*
- **Efficiency:**
  - *Avoid code duplication (DRY principle).*

Key Components

1. **Initialization:** Setup loop variable.
2. **Update:** Change loop variable.
3. **Body:** Code to execute

Cont’d

Loop Types & Usage

1) while loop:

- ✓ Repeat until condition becomes false (pre-check)

```
while (condition) { ... }
```

2) for loop:

- ✓ Counted iteration (known number of times)
- ✓ Iterating over arrays/vectors (index-based)

```
for (int i=0; i<10; ++i) { ... }
```

3) do-while loop:

- ✓ Execute at least once, then check condition (post-check)

```
do { ... } while (condition);
```

4) Range-based for (C++11):

- ✓ Cleanest syntax for iterating over containers

Cont'd

Example:

- for loop
- while loop

```cpp
#include <iostream>
int main() {
    int n;
    cout << "Enter a number (N): ";
    cin >> n;

    cout << "\nFor Loop (1 to " << n << "): ";
    for (int i = 1; i <= n; ++i) {
        cout << i << " ";
    }

    cout << "\nWhile Loop (" << n << " down to 1): ";
    int temp = n; // Initialize counter
    while (temp >= 1) {
        std::cout << temp << " ";
        temp--; // Decrement to break the condition
    }

    cout << "\n";
    return 0;
}
```

Output

```
Enter a number (N): 5

For Loop (1 to 5): 1 2 3 4 5

While Loop (5 down to 1): 5 4 3 2 1
```

6. Arrays - Concept and Declaration

What is an Array?

A fixed-size collection of elements of the **same data type**, stored in **contiguous memory locations**.

- **Homogeneous Data:** *All elements must be of the same type*
- **Fixed Size:** *Size must be known at compile-time.*
- **Zero-Based Indexing:** *Access elements using indices from 0 to N-1.*
- **Contiguous Memory:** Elements are stored side-by-side in RAM.

Cont'd

Declaration Syntax

General Form:

```
// 1D array
type arrayName[arraySize];

//2D array
type arrayName[rowSize][colSize];
```

Example 1: int data[5] = {10, 20, 14}

Memory Visualization

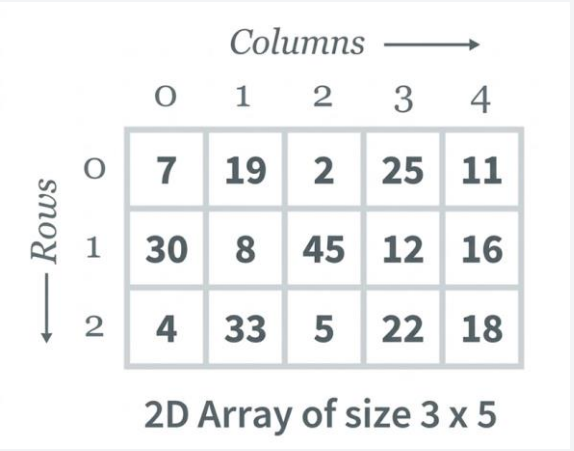
data

10	20	14	0	0
0	1	2	3	4

Since the size of int is 4 bytes, each array element takes 4 bytes

Example 2:

```
int matrix[3][5]  =
        {{7, 19, 2, 25, 11},
        {30, 8, 45, 12, 16},
        {4, 33, 5, 22, 18}}
```



2D Array of size 3 x 5

Nested braces make initialization readable and structured

Cont’d

Array Initialization:

```
// --- 1D ARRAY INITIALIZATION ---

// 1. Full Initialization
int nums[5] = {10, 20, 30, 40, 50};

// 2. Partial Initialization
// (Remaining elements become 0)
int partial[5] = {1, 2};

// 3. Universal Zero Initialization
int zeros[10] = {}; // Cleaner than {0}

// 4. Size Inference
// Compiler sets size to 3
double data[] = {1.5, 2.5, 3.5};
```

```
// --- 2D ARRAY INITIALIZATION ---

// 5. Explicit Row/Column Initialization
// Format: array[rows][columns]
int matrix[2][3] = {
    {1, 2, 3}, // Row 0
    {4, 5, 6}  // Row 1
};

// 6. 2D Size Inference
// (Only the first dimension can be omitted)
int grid[][2] = {
    {10, 20},
    {30, 40},
    {50, 60}
}; // Compiler infers 3 rows
```

Cont'd

Accessing Arrays Elements

```
// 1D Array
#include <iostream>
using namespace std;
int main() {
    int scores[5] = {85, 92, 78, 90, 88};

    // Assume the first element is the largest
    int maxVal = scores[0];

    for (int i = 1; i < 5; i++) {
        if (scores[i] > maxVal) {
          // Update maxVal if a larger one is found
            maxVal = scores[i];
        }
    }

    cout << "The highest score is: " << maxVal << endl;
    return 0;
}
```

```
The highest score is: 92
```

```
// 2D Array
#include <iostream>
using namespace std;
int main() {
int matrix[2][3] = {{1, 2, 3},  {4, 5, 6}};
int totalSum = 0;

for (int i = 0; i < 2; i++) {  // contorl row
    for (int j = 0; j < 3; j++) { // control column
        // Accessing [row][column]
        totalSum += matrix[i][j];
    }
}
cout << "Total: "<<totalSum<<endl;
}
```

```
Total: 21
```

Cont'd

Exercise: Finding the resulting array after the below code executed.

```
#include <iostream>

int main() {
    double prices[5] = {45.0, 120.0, 30.0, 65.5, 10.0};
    int size = 5;

    for (int i = 0; i < size; i++) {
        if (prices[i] > 50.0) {
            prices[i] *= 0.90;
        }
    }
    return 0;
}
```

Resulting Array:

{45.0, 108.0, 30.0, 58.95, 10.0}

7. Pointers - Fundamental Concept

What is a Pointer?

A variable that stores the **memory address** of another object, rather than holding a value directly.

```
// Declaration
int* ptr;

// Initialization
ptr = &variable;
```

Memory Visualization


```
int num=42;
int*ptr=&num;

// num is variable at memory location 0x104
// ptr stores address of num (0x104)
// *ptr access value at 0x104 (which is 42)
```

Cont'd

Key Operators

& **Address-of Operator**

"Get the address of this variable"

&x -> 0x7ffd...

***** **Dereference Operator**

- **Dereferencing** - *access the value stored at the memory address held by the pointer*
- ***Indirect modification*** - *directly modifies the variable which the pointers points to*

dereference.cpp

```cpp
#include <iostream>
int main() {
    int score = 100;
    int* pScore = &score;

    // 1. Read value via pointer
    std::cout << "Original: " << *pScore << "\n";

    // 2. Modify value via pointer
    *pScore = 200; ✓ Changes 'score'

    std::cout << "New Score: " << score << "\n";

    // 3. Double Pointer
    int** ppScore = &pScore;
    **ppScore = 500;
```

TERMINAL OUTPUT

```
Original: 100
New Score: 200
Final Score: 500
```

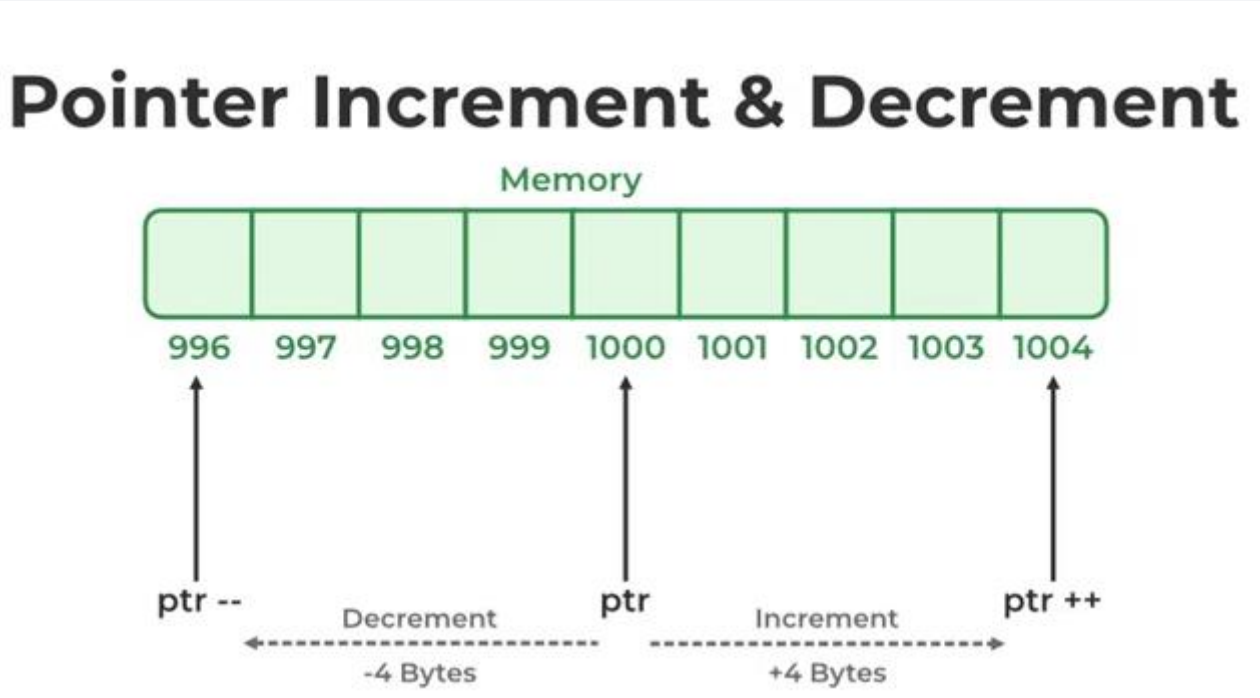
7.1 Pointer Arithmetic

Incrementing (++Ptr / ptr++)

- Incrementing a pointer moves it to the next memory address based on the data type size.
- For **int***, adds **4 bytes** to move to the next integer memory location.

Decrementing (--ptr / ptr--)

- Decreases address by data type size., moves it to the previous memory address.
- Useful for traversing arrays in reverse order.



Source: https://www.geeksforgeeks.org/cpp/cpp-pointer-arithmetic/

8. Common Programming Pitfalls

Initialization & Memory Issues

- ✕ Uninitialized arrays
- ✕ Uninitialized variables
- ✕ Missing null terminator a

Logic & Expression Errors

- ✕ Assignment (=) vs Equality (==)
- ✕ Incorrect use of modulo (%)
- ✕ Type mismatches

Control Flow Mistakes

- ✕ Infinite loops
- ✕ Missing break in switch
- ✕ Off-by-one errors
- ✕ Empty statements

Design Issues

- ✕ Accidental variable shadowing
- ✕ Overuse of global variables
- ✕ Modifying loop body incorrectly

9. Programming Best Practices

📦 Variables & Data

- ✓ Initialize variables at declaration
- ✓ Use meaningful, descriptive names
- ✓ Prefer **const** for immutable values
- ✓ Declare variables at point of first use

👓 Code Clarity

- ✓ Keep expressions simple & readable
- ✓ Use parentheses for explicit precedence
- ✓ Keep loop bodies small & focused
- ✓ Avoid deep nesting (early returns)

🔀 Control Structures

- ✓ Always use braces **{}** for blocks
- ✓ Always add **break** in switch cases
- ✓ Choose the right loop construct
- ✓ Handle all switch cases (use default)

🛡️ Memory & Safety

- ✓ Use proper initialization for arrays
- ✓ Validate indices to avoid out-of-bounds
- ✓ Check pointers for nullptr before use
- ✓ Match new/delete correctly

Summary/Takeaway

Program Logic

Storage

Variables

Data Types & Scope

Defines **what** data exists and where it lives (scope).

Computation

Operators

Arithmetic & Logic

Transforms data states through calculation and **comparison**.

Decision

Conditionals

Control Flow

*Determines **which path** execution takes based on data state.*

Iteration

Loops

Repetition

Executes tasks **repeatedly** to process collections or await conditions.

Arrays

Data Collections

Groups related data elements linearly for efficient **indexed access**.

Memory

Pointers

Direct Access

*Accesses memory **directly**, enabling dynamic structures and efficiency.*

Practice Questions

Predict Output

1. What is the output of this expression? (Apply operator precedence)

```
int a{2}, b{3}, c{4};
cout << a + b * c;
```

Answer: 14

2. Pointer Arithmetic Challenge:

   What does this print?

```
int arr[] {10, 20, 30};
int* p = arr;
cout << *(p + 2);
```

Answer: 30

3. Spot the bug! Why is this unsafe?

```
int* p = new int(5);
delete p;
*p = 10;
```

Answer: Why This is Unsafe?

- Deleting an uninitialized pointer, result in undefined behavior
- Memory management must follow strict order: **Allocate, Use, Deallocate**

References

Text Books

- **C++ How to Program** [10th edition], Deitel, P. & Deitel, H., Global Edition, Global Edition (2017).
- **Problem Solving With C++** [10th edition], Walter Savitch, University of California, San Diego, 2018.

Reference Books

- **Object-Oriented Programming in C++ (4th Edition)** by Robert Lafore, Sams Publishing, 2022.
- **Principles of Object-Oriented Programming**, by Stephen W. & Dung N., OpenStax CNX, 2022.

Online Resources

- https://www.geeksforgeeks.org/cpp/c-plus-plus/
- https://www.w3schools.com/cpp/default.asp
- https://programiz.pro/resources/cpp
- https://www.hackerrank.com/domains/cpp
- https://cplusplus.com/doc/tutorial/

Study Tip: *Don't just read the code! Retype the examples from these slides and resources into your IDE, modify and compile them to see what happens.*

Thank You!

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