1. Introduction to Polymorphism

Polymorphism is one of the core concepts of **Object-Oriented Programming (OOP)**. The word *polymorphism* is derived from two Greek words: *poly* (many) and *morph* (forms). Hence, polymorphism means **one name, many forms**.

In C++, polymorphism allows the same function or operator to perform different actions based on the context in which it is used.

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2. Meaning of Polymorphism

Polymorphism allows objects of different classes to be treated as objects of a common base class. It enables a single function name to represent different implementations.

For example, a function named `draw()` can draw a circle, rectangle, or triangle depending on the object calling it.

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3. Need for Polymorphism

Polymorphism is required to:

- Increase code flexibility
- Reduce complexity
- Improve code readability
- Support dynamic behavior
- Make programs scalable

Without polymorphism, programs would require multiple function names for similar operations.

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4. Polymorphism in Real Life

Real-world examples of polymorphism include:

- A person playing different roles (teacher, parent, employee)
- A smartphone performing multiple tasks (calling, browsing, gaming)
- A button performing different actions in different applications

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5. Types of Polymorphism in C++

C++ supports two types of polymorphism:

1. **Compile-Time Polymorphism**
2. **Run-Time Polymorphism**

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6. Compile-Time Polymorphism

Compile-time polymorphism is also known as **static polymorphism.** It is resolved during compilation.

It is achieved using:

- Function overloading
- Operator overloading

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7. Function Overloading

Function overloading allows multiple functions to have the same name but different parameter lists.

Example

```
int add(int a, int b);
float add(float a, float b);
```

The compiler decides which function to call based on arguments.

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8. Rules of Function Overloading

- Functions must differ in number or type of parameters
- Return type alone is not sufficient
- Overloading improves readability

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9. Operator Overloading

Operator overloading allows operators to be redefined to work with user-defined data types.

Example

```
Complex operator +(Complex c);
```

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10. Advantages of Compile-Time Polymorphism

- Faster execution
- Early error detection

- Better performance
- Simple implementation

11. Run-Time Polymorphism

Run-time polymorphism is also known as **dynamic polymorphism**. It is resolved during program execution.

It is achieved using:

- Function overriding
- Virtual functions

12. Function Overriding

Function overriding occurs when a derived class provides its own implementation of a base class function.

Example

```
class Base {
  public:
    void show() {}
};

class Derived : public Base {
  public:
    void show() {}
};
```

13. Virtual Functions

A virtual function is a member function declared using the `virtual` keyword. It ensures that the correct function is called at run time based on object type.

Example

```
class Base {
  public:
    virtual void display() {}
};
```

14. Role of Virtual Functions

- Enables dynamic binding
- Supports runtime decision-making

- Ensures correct function execution
- Improves flexibility

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15. Base Class Pointer and Derived Class Object

Polymorphism is achieved using base class pointers pointing to derived class objects.

Example

```
Base* b;
Derived d;
b = &d;
```

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16. Virtual Destructor

A virtual destructor ensures that the correct destructor is called when an object is deleted using a base class pointer.

This prevents memory leaks.

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17. Polymorphism and Inheritance

Polymorphism works closely with inheritance. Without inheritance, runtime polymorphism cannot be achieved.

Inheritance provides the relationship, while polymorphism provides dynamic behavior.

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18. Advantages of Polymorphism

- Improves code reusability
- Enhances flexibility
- Simplifies maintenance
- Supports extensibility
- Enables dynamic behavior

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19. Limitations of Polymorphism

- Slight performance overhead
- Complex debugging
- Increased memory usage

- Requires careful design

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20. Common Mistakes in Polymorphism

- Forgetting to use virtual keyword
- Incorrect function signatures
- Using base objects instead of pointers
- Not using virtual destructors

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21. Polymorphism vs Function Overloading

Function Overloading	Polymorphism
Compile-time	Run-time
Static binding	Dynamic binding
Same function name	Same function interface

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22. Applications of Polymorphism

Polymorphism is used in:

- Game development
- GUI frameworks
- Operating systems
- Simulation software
- Software libraries

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23. Best Practices for Polymorphism

- Use virtual functions wisely
- Prefer base class pointers
- Keep interfaces consistent
- Avoid deep inheritance

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24. Polymorphism and Dynamic Binding

Dynamic binding means function calls are resolved at run time. It is essential for runtime polymorphism.

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25. Conclusion

Polymorphism is a powerful feature of C++ that allows one interface to represent many forms. It enhances flexibility, reusability, and maintainability of code. By understanding compile-time and run-time polymorphism, programmers can design efficient and scalable object-oriented applications.