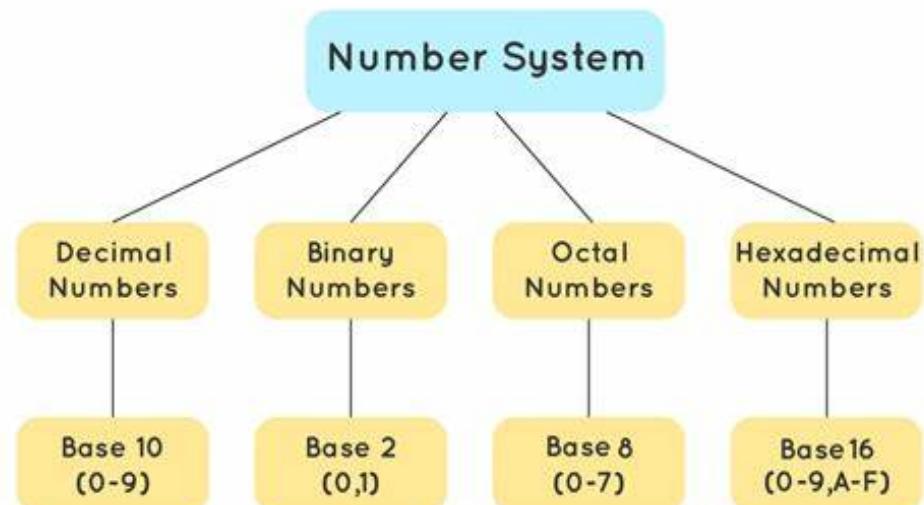


# Programming Language - C++

## Number System

### Types of Number System

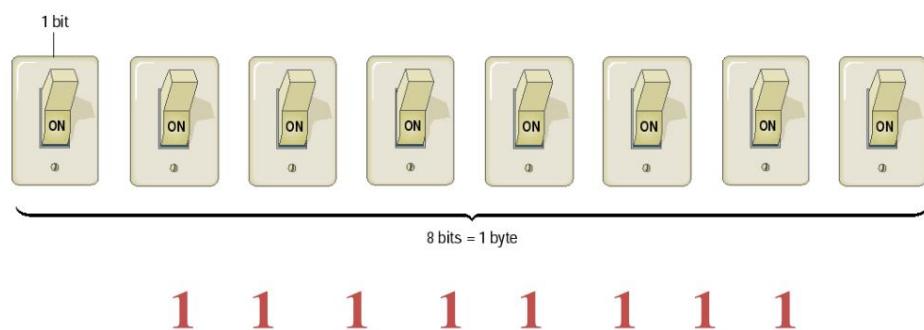


## Binary Number System

### Number System

#### Bits and Bytes

- A single unit of data is called a bit, having a value of 1 or 0.
- Computers work with collections of bits, grouping them to represent larger pieces of data, such as letters of the alphabet.
- Eight bits make up one byte. A byte is the amount of memory needed to store one alphanumeric character.
- With one byte, the computer can represent one of 256 different symbols or characters.



## Base Conversion

# Number Systems Conversion Chart

| Binary |          |          |       |       |       |       |       |       |       |       |       |       |          |          |          |          |
|--------|----------|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|----------|----------|----------|
| Place  | $2^{11}$ | $2^{10}$ | $2^9$ | $2^8$ | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ | $2^{-1}$ | $2^{-2}$ | $2^{-3}$ | $2^{-4}$ |
| Weight | 2048     | 1024     | 512   | 256   | 128   | 64    | 32    | 16    | 8     | 4     | 2     | 1     | 0.5      | 0.25     | 0.125    | 0.0625   |

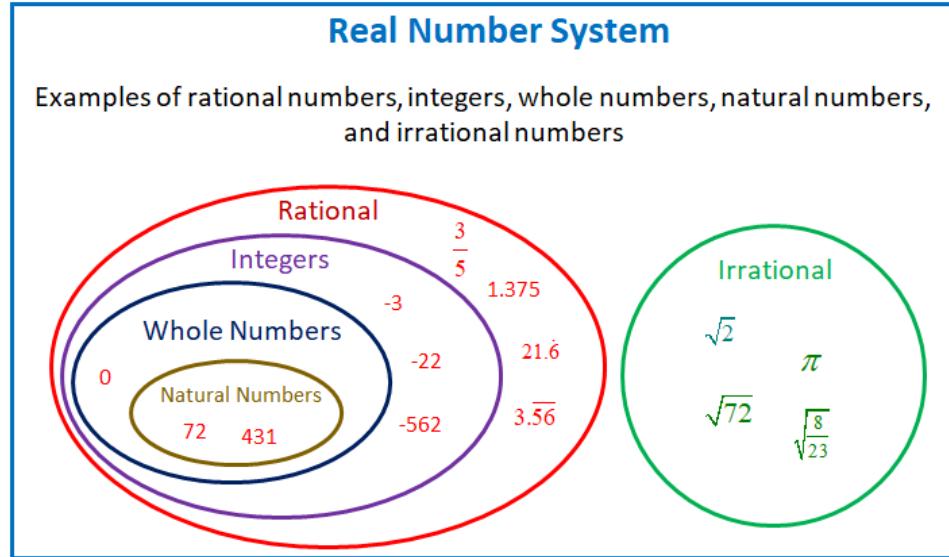
## Binary, Hex, and Octal Conversions

| Binary | Octal | Hexadecimal | Decimal |
|--------|-------|-------------|---------|
| 0000   | 0     | 0           | 0       |
| 0001   | 1     | 1           | 1       |
| 0010   | 2     | 2           | 2       |
| 0011   | 3     | 3           | 3       |
| 0100   | 4     | 4           | 4       |
| 0101   | 5     | 5           | 5       |
| 0110   | 6     | 6           | 6       |
| 0111   | 7     | 7           | 7       |
| 1000   | 10    | 8           | 8       |
| 1001   | 11    | 9           | 9       |
| 1010   | 12    | A           | 10      |
| 1011   | 13    | B           | 11      |
| 1100   | 14    | C           | 12      |
| 1101   | 15    | D           | 13      |
| 1110   | 16    | E           | 14      |
| 1111   | 17    | F           | 15      |

## Methodology

- Convert from decimal to binary  
Divide the decimal by the largest binary weight it is divisible by and place a "1" in that column. Then select the next largest weight, if it is divisible put a "1" in that column otherwise place a "0" in the column. Continue until all the columns have either a "1" or "0" resulting in a binary expression.
- Convert from decimal to hex.  
Convert to binary first, then group the binary in groups of 4 beginning on the right working to the left. For each group determine the hex value based on the table to the left.
- Convert to octal  
Convert to binary first, then group the binary in groups of 3 beginning on the right working to the left. For each group determine the octal value based on the table to the left.

# Real Number System



# Complements

# Complements of numbers

## (r-1 )'s Complement

- Given a number  $N$  in base  $r$  having  $n$  digits,
- the  $(r-1)$ 's complement of  $N$  is defined as

$$(r^n - 1) - N$$

- For decimal numbers the base or  $r = 10$  and  $r-1 = 9$ ,

- so the 9's complement of  $N$  is  $(10^n - 1) - N$

- $99999\dots\dots - N$

|         |           |            |            |             |
|---------|-----------|------------|------------|-------------|
| 9       | 9         | 9          | 9          | 9           |
| Digit n | Digit n-1 | Next digit | Next digit | First digit |

## Complements

- There are two types of complements for each base- $r$  system: the radix complement and diminished radix complement.

→ the  $r$ 's complement and the second as the  $(r-1)$ 's complement.

### Diminished Radix Complement

Given a number  $N$  in case  $r$  having  $n$  digits, the  $(r-1)$ 's complement of  $N$  is defined as  $(r^n - 1) - N$ . For decimal numbers,  $r = 10$  and  $r-1 = 9$ , so the 9's complement of  $N$  is  $(10^n - 1) - N$ .

#### Example:

The 9's complement of 546700 is  $999999 - 546700 = 453299$ .

The 9's complement of 012398 is  $999999 - 012398 = 987601$ .

- For binary numbers,  $r = 2$  and  $r-1 = 1$ , so the 1's complement of  $N$  is  $(2^n - 1) - N$ .

#### Example:

The 1's complement of 1011000 is 0100111

The 1's complement of 0101101 is 1010010

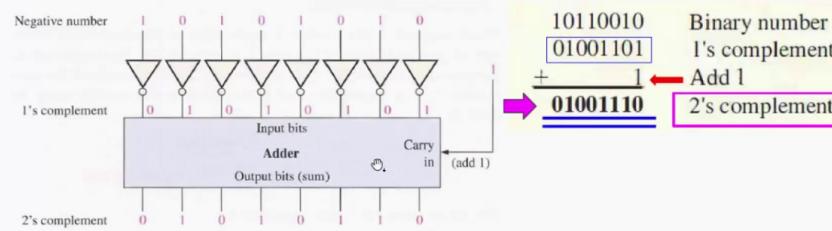
## 2.5) 1 'S and 2'S Complements of Binary Numbers

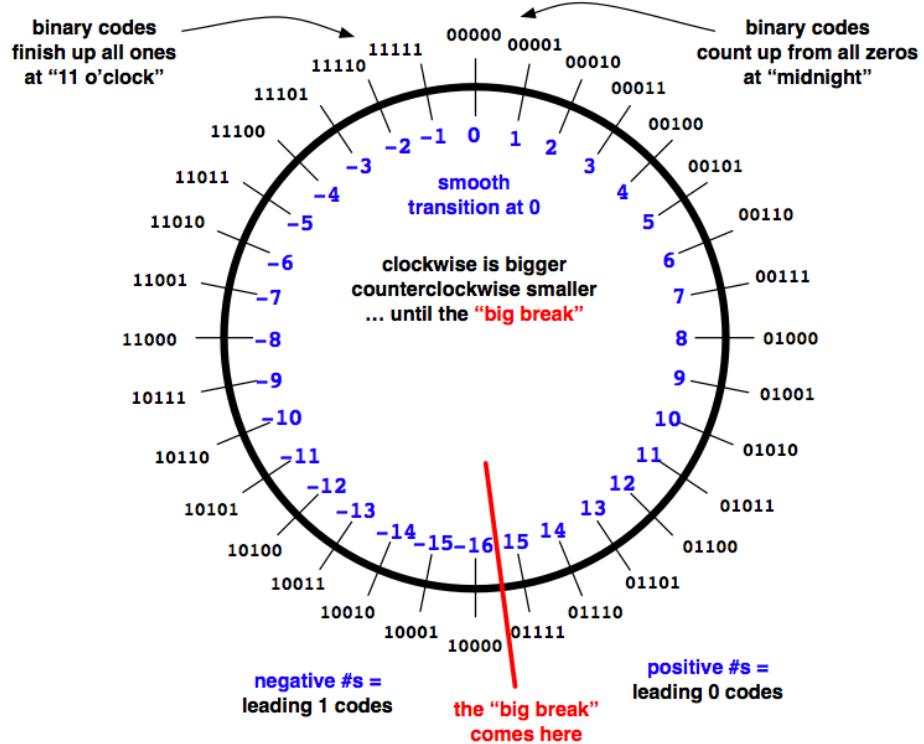
### Finding the 2 's Complement

The 2's complement of a binary number is found by adding it to the LSB of the 1's complement.

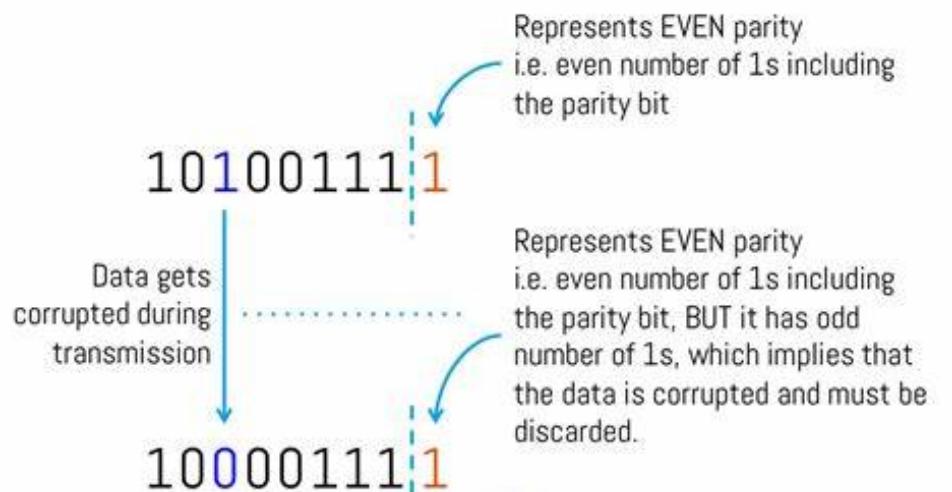
$$2\text{'s complement} = (\text{1's complement}) + 1$$

**Example 17:** Find the 2's Complement of 10110010

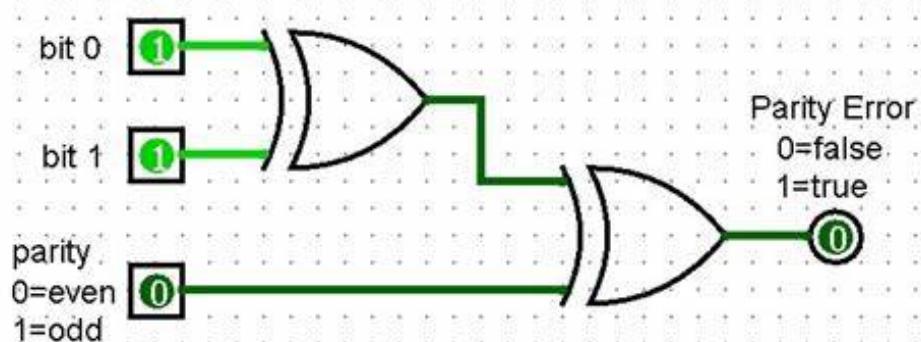




## Parity Bit

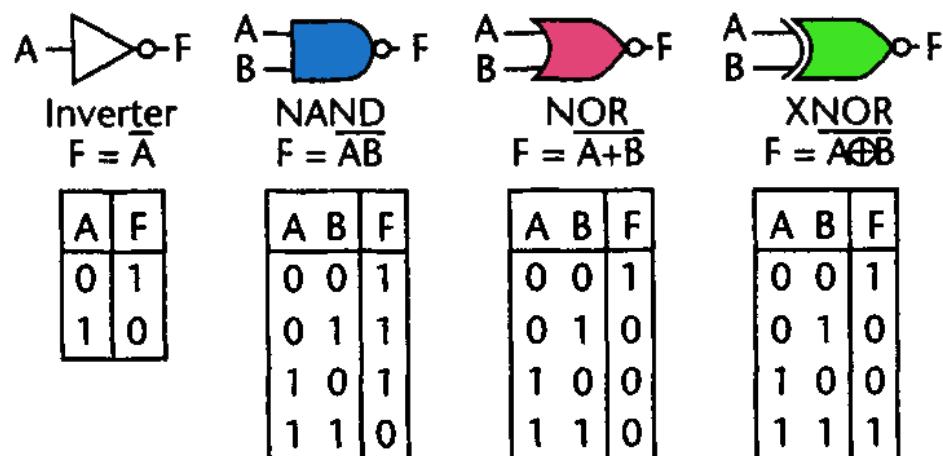
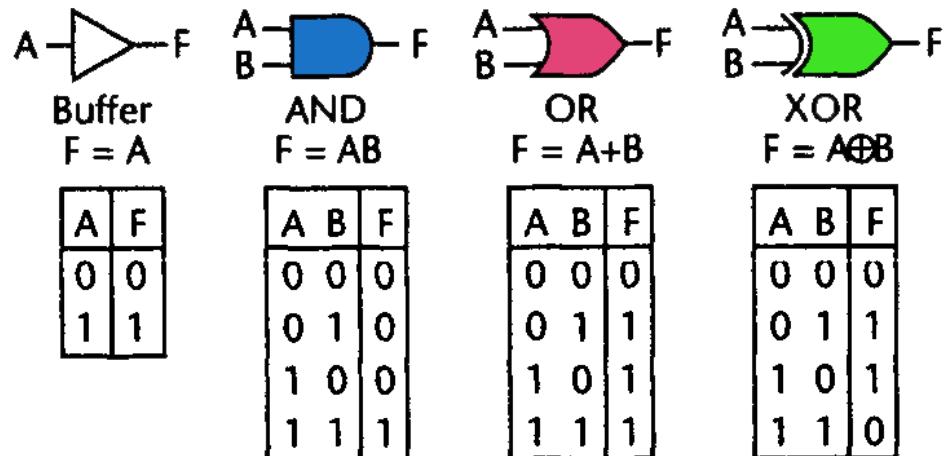


Why do we need Parity Bit?  
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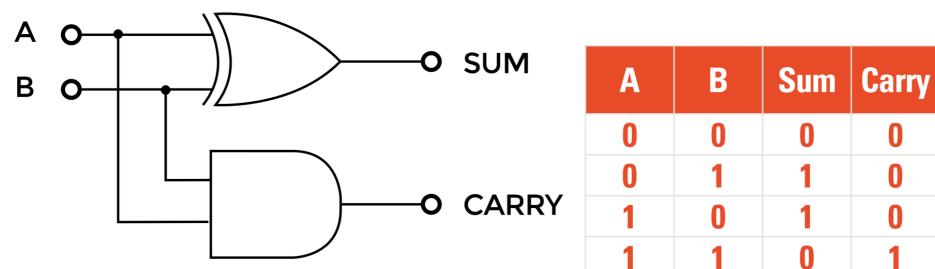


# Logic Design

## Logic Gates

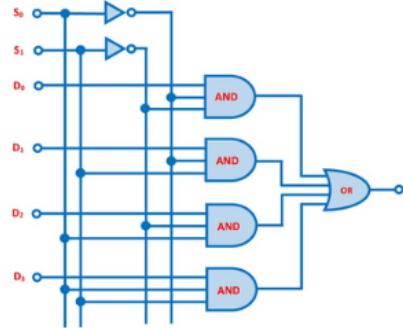
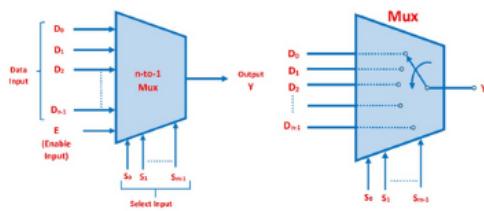


## Half-Adder



## Multiplexer

# What is a Multiplexer?



**Electrical 4 U**

## Diodes

| Symbol | Name                       | Physical Look | Applications  |
|--------|----------------------------|---------------|---|
|        | Diode                      |               | Mostly used as rectifier for converting ac to dc              |
|        | Zener Diode                |               | Used as a constant voltage source                             |
|        | Schottky Diode             |               | High current diode used for high current                      |
|        | Tunnel Diode               |               | Used in oscillator and microwave amplifier                    |
|        | Light Emitting Diode (LED) |               | Emit light when it is forward biased                          |
|        | Photodiode                 |               | Allows reverse current when light falls on it                 |
|        | Laser Diode                |               | Used in CD players  |
|        | Current Regulator Diode    |               | Maintains constant current                                    |
|        | Varactor Diode             |               | Acts as variable capacitor in reverse bias                    |
|        | Pin diode                  |               | Acts as capacitor in reverse and variable resistor in forward |

## Data Presentation and Processing

### Machine Language and Assembly Language

## Machine Language

- Instructions, like registers and words of data, are also 32 bits long
  - Example: add \$t0, \$s1, \$s2
  - registers have numbers, \$t0=8, \$s1=17, \$s2=18
- Instruction Format:

|        |       |       |       |       |        |
|--------|-------|-------|-------|-------|--------|
| 000000 | 10001 | 10010 | 01000 | 00000 | 100000 |
| op     | rs    | rt    | rd    | shamt | funct  |

- Can you guess what the field names stand for?**

op = Basic operation of the instruction: opcode

rs = The first register source operand

rt = The second register source operand

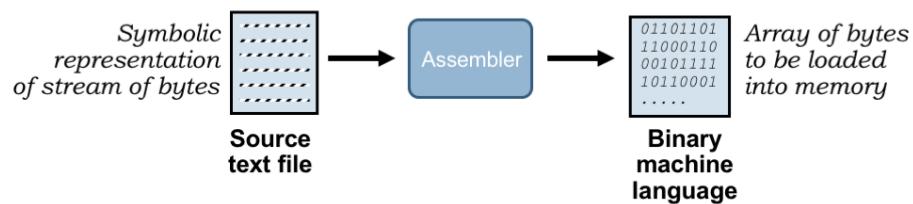
rd = The register destination operand

shamt = shift amount

funct = function code

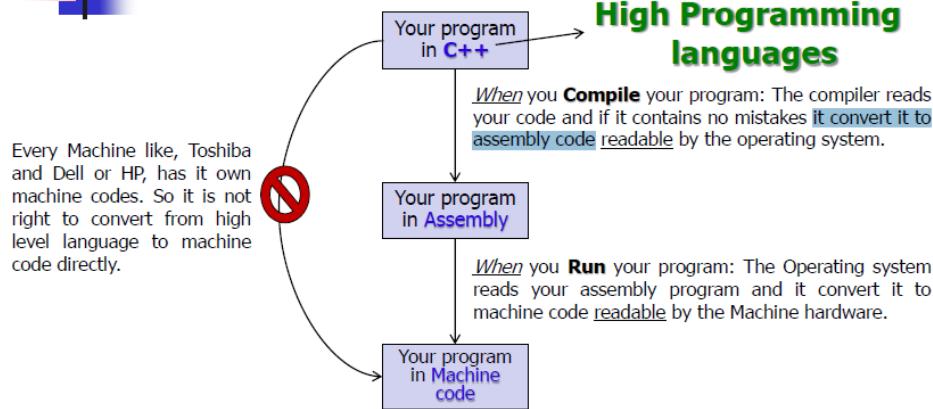
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## Assembly Language



- Abstracts bit-level representation of instructions and addresses
- We'll learn UASM ("microassembler"), built into BSim
- Main elements:
  - Values
  - Symbols
  - Labels (symbols for addresses)
  - Macros

# Compiling and running your program



## ASCII

| ASCII control characters |                           | ASCII printable characters |       |    |   |     |   |     |   | Extended ASCII characters |   |     |   |     |          |  |  |
|--------------------------|---------------------------|----------------------------|-------|----|---|-----|---|-----|---|---------------------------|---|-----|---|-----|----------|--|--|
| 00                       | NULL (Null character)     | 32                         | space | 64 | @ | 96  | ` | 128 | ç | 160                       | á | 192 | l | 224 | ó        |  |  |
| 01                       | SOH (Start of Header)     | 33                         | !     | 65 | A | 97  | a | 129 | ü | 161                       | í | 193 | ł | 225 | ó        |  |  |
| 02                       | STX (Start of Text)       | 34                         | "     | 66 | B | 98  | b | 130 | é | 162                       | ó | 194 | ł | 226 | ó        |  |  |
| 03                       | ETX (End of Text)         | 35                         | #     | 67 | C | 99  | c | 131 | à | 163                       | ú | 195 | ł | 227 | ó        |  |  |
| 04                       | EOT (End of Trans.)       | 36                         | \$    | 68 | D | 100 | d | 132 | à | 164                       | ñ | 196 | — | 228 | ó        |  |  |
| 05                       | ENQ (Enquiry)             | 37                         | %     | 69 | E | 101 | e | 133 | à | 165                       | N | 197 | + | 229 | ó        |  |  |
| 06                       | ACK (Acknowledgement)     | 38                         | &     | 70 | F | 102 | f | 134 | à | 166                       | ” | 198 | á | 230 | µ        |  |  |
| 07                       | BEL (Bell)                | 39                         | '     | 71 | G | 103 | g | 135 | ç | 167                       | º | 199 | A | 231 | þ        |  |  |
| 08                       | BS (Backspace)            | 40                         | (     | 72 | H | 104 | h | 136 | ê | 168                       | ż | 200 | ł | 232 | þ        |  |  |
| 09                       | HT (Horizontal Tab)       | 41                         | )     | 73 | I | 105 | i | 137 | ë | 169                       | ® | 201 | ł | 233 | ú        |  |  |
| 10                       | LF (Line feed)            | 42                         | *     | 74 | J | 106 | j | 138 | è | 170                       | ¬ | 202 | ł | 234 | ó        |  |  |
| 11                       | VT (Vertical Tab)         | 43                         | +     | 75 | K | 107 | k | 139 | í | 171                       | ½ | 203 | ł | 235 | ú        |  |  |
| 12                       | FF (Form feed)            | 44                         | ,     | 76 | L | 108 | l | 140 | í | 172                       | ¼ | 204 | ł | 236 | ý        |  |  |
| 13                       | CR (Carriage return)      | 45                         | -     | 77 | M | 109 | m | 141 | í | 173                       | í | 205 | = | 237 | ý        |  |  |
| 14                       | SO (Shift Out)            | 46                         | .     | 78 | N | 110 | n | 142 | ä | 174                       | « | 206 | ł | 238 | —        |  |  |
| 15                       | SI (Shift In)             | 47                         | /     | 79 | O | 111 | o | 143 | å | 175                       | » | 207 | ł | 239 | —        |  |  |
| 16                       | DLE (Data link escape)    | 48                         | 0     | 80 | P | 112 | p | 144 | É | 176                       | ł | 208 | ð | 240 | ≡        |  |  |
| 17                       | DC1 (Device control 1)    | 49                         | 1     | 81 | Q | 113 | q | 145 | æ | 177                       | ł | 209 | đ | 241 | ±        |  |  |
| 18                       | DC2 (Device control 2)    | 50                         | 2     | 82 | R | 114 | r | 146 | œ | 178                       | ł | 210 | ł | 242 | ≡        |  |  |
| 19                       | DC3 (Device control 3)    | 51                         | 3     | 83 | S | 115 | s | 147 | ö | 179                       | ł | 211 | ł | 243 | ¾        |  |  |
| 20                       | DC4 (Device control 4)    | 52                         | 4     | 84 | T | 116 | t | 148 | ö | 180                       | ł | 212 | ł | 244 | ł        |  |  |
| 21                       | NAK (Negative acknowl.)   | 53                         | 5     | 85 | U | 117 | u | 149 | ö | 181                       | ł | 213 | ł | 245 | §        |  |  |
| 22                       | SYN (Synchronous idle)    | 54                         | 6     | 86 | V | 118 | v | 150 | ø | 182                       | ł | 214 | ł | 246 | +        |  |  |
| 23                       | ETB (End of trans. block) | 55                         | 7     | 87 | W | 119 | w | 151 | ù | 183                       | ł | 215 | ł | 247 | ·        |  |  |
| 24                       | CAN (Cancel)              | 56                         | 8     | 88 | X | 120 | x | 152 | ÿ | 184                       | ø | 216 | ł | 248 | ·        |  |  |
| 25                       | EM (End of medium)        | 57                         | 9     | 89 | Y | 121 | y | 153 | ö | 185                       | ł | 217 | ł | 249 | ·        |  |  |
| 26                       | SUB (Substitute)          | 58                         | :     | 90 | Z | 122 | z | 154 | ú | 186                       | ł | 218 | ł | 250 | ·        |  |  |
| 27                       | ESC (Escape)              | 59                         | ;     | 91 | [ | 123 | { | 155 | ø | 187                       | ł | 219 | ł | 251 | ·        |  |  |
| 28                       | FS (File separator)       | 60                         | <     | 92 | \ | 124 |   | 156 | £ | 188                       | ł | 220 | ł | 252 | ·        |  |  |
| 29                       | GS (Group separator)      | 61                         | =     | 93 | ] | 125 | } | 157 | ø | 189                       | ç | 221 | ł | 253 | ·        |  |  |
| 30                       | RS (Record separator)     | 62                         | >     | 94 | ^ | 126 | ~ | 158 | × | 190                       | ¥ | 222 | ł | 254 | ■        |  |  |
| 31                       | US (Unit separator)       | 63                         | ?     | 95 | — |     |   | 159 | f | 191                       | ł | 223 | ł | 255 | nbsnbsp; |  |  |
| 127                      | DEL (Delete)              |                            |       |    |   |     |   | 160 |   |                           |   |     |   |     |          |  |  |

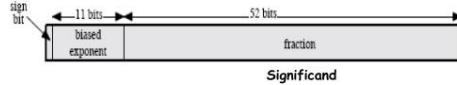
## Precision floating-point

## Double Precision Floating Point Numbers IEEE Standard

64 bit Double Precision Floating Point Numbers are stored as:

S EEEEEEEEEE FFFFFFFF...FFFF...FFFF...FFFF...FFFF...FFFF...FFFF...FFFF

S: Sign - 1 bit  
E: Exponent - 11 bits  
F: Fraction - 52 bits



The value V:

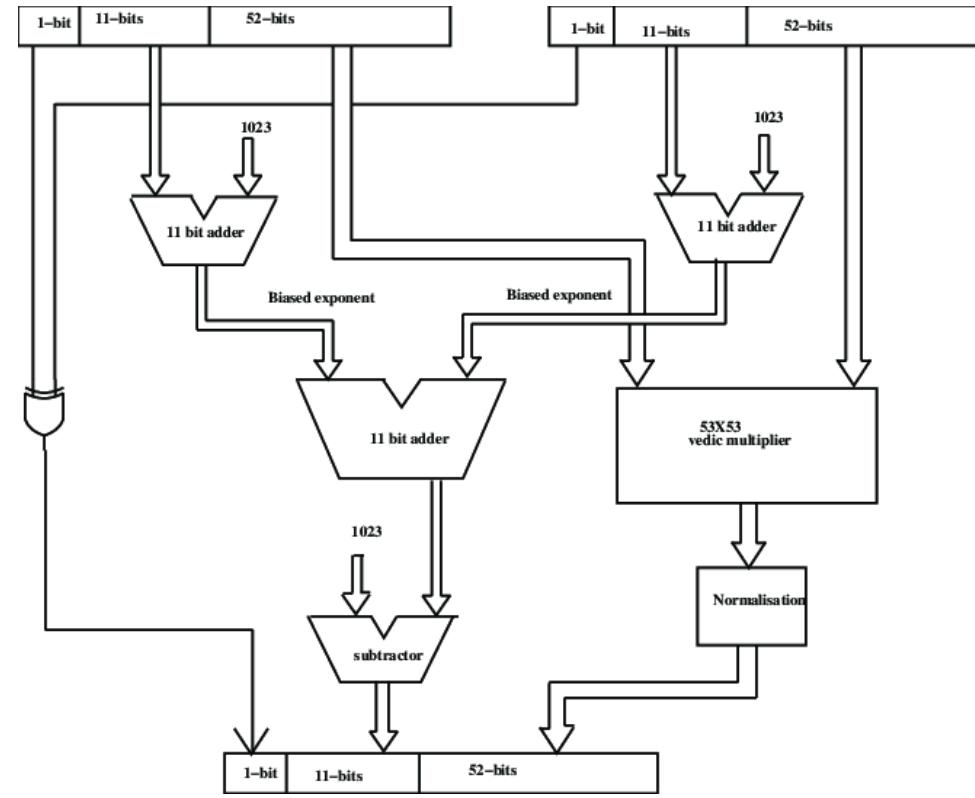
- If E=2047 and F is nonzero, then V= NaN ("Not a Number")
- If E=2047 and F is zero and S is 1, then V= - Infinity
- If E=2047 and F is zero and S is 0, then V= Infinity
- If 0<E<2047 then V= (-1)\*\*S \* 2 \*\* (E-1023) \* (1.F) (exponent range = -1023 to +1024)
- If E=0 and F is nonzero, then V= (-1)\*\*S \* 2 \*\* (-1022) \* (0.F) ("unnormalized" values)
- If E=0 and F is zero and S is 1, then V= - 0
- If E=0 and F is zero and S is 0, then V= 0

Note: 2047 decimal = 1111111111 in binary (11 bits)

## Biased Exponent - Cont'd

- ❖ For double precision, exponent field is 11 bits
  - ◊ E can be in the range 0 to 2047
  - ◊ E = 0 and E = 2047 are reserved for special use
  - ◊ E = 1 to 2046 are used for normalized floating point numbers
  - ◊ Bias = 1023 (half of 2046), val(E) = E - 1023
  - ◊ val(E=1) = -1022, val(E=1023) = 0, val(E=2046) = 1023
- ❖ Value of a Normalized Floating Point Number is

$$\begin{aligned}
 & (-1)^S \times (1.F)_2 \times 2^{E - \text{Bias}} \\
 & (-1)^S \times (1.f_1 f_2 f_3 f_4 \dots)_2 \times 2^{E - \text{Bias}} \\
 & (-1)^S \times (1 + f_1 \times 2^{-1} + f_2 \times 2^{-2} + f_3 \times 2^{-3} + f_4 \times 2^{-4} \dots)_2 \times 2^{E - \text{Bias}}
 \end{aligned}$$



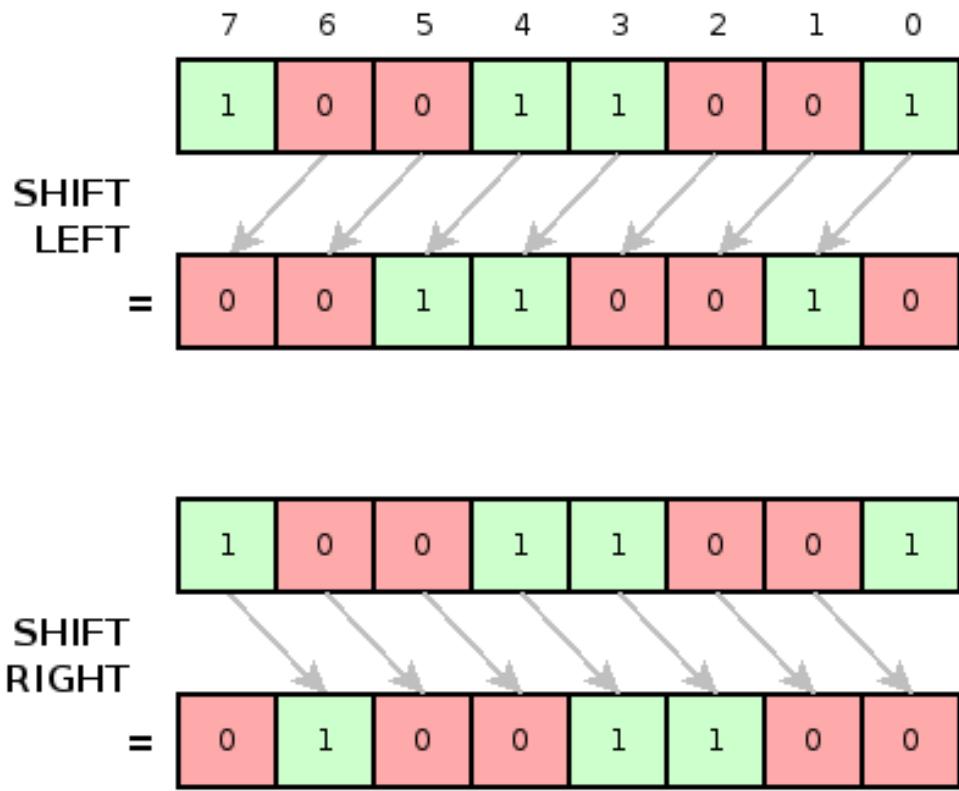
## Bitwise Operation

### Bitwise Operators

int a = 10, b = 2 for all examples below

| Operator                   | Meaning                          | Example                        | Result |
|----------------------------|----------------------------------|--------------------------------|--------|
| <code>~</code>             | Bitwise unary NOT                | <code>~a</code>                | -11    |
| <code>&amp;</code>         | Bitwise AND                      | <code>a&amp;b</code>           | 2      |
| <code> </code>             | Bitwise OR                       | <code>a b</code>               | 10     |
| <code>^</code>             | Bitwise Ex-OR                    | <code>a^b</code>               | 8      |
| <code>&gt;&gt;</code>      | Shift right                      | <code>a&gt;&gt;1</code>        | 5      |
| <code>&gt;&gt;&gt;</code>  | Shift right zero fill            | <code>a&gt;&gt;&gt;1</code>    | 5      |
| <code>&lt;&lt;</code>      | Shift left                       | <code>a&lt;&lt;1</code>        | 20     |
| <code>&amp;=</code>        | Bitwise AND assignment           | <code>a &amp;= b</code>        | 2      |
| <code> =</code>            | Bitwise OR assignment            | <code>a  = b</code>            | 10     |
| <code>^=</code>            | Bitwise Ex-OR assignment         | <code>a ^= b</code>            | 8      |
| <code>&gt;&gt;=</code>     | Shift right assignment           | <code>a &gt;&gt;= 1</code>     | 5      |
| <code>&gt;&gt;&gt;=</code> | Shift right zero fill assignment | <code>a &gt;&gt;&gt;= 1</code> | 5      |
| <code>&lt;&lt;=</code>     | Shift left assignment            | <code>a &lt;&lt;= 1</code>     | 20     |

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## Programming Language - C & C++

### Escape Sequence

**Table 3.2. C++ Escape Sequence Codes**

| Character Name  | ASCII Symbol | C++ Code | ASCII Decimal Code | ASCII Hex Code |
|-----------------|--------------|----------|--------------------|----------------|
| Newline         | NL (LF)      | \n       | 10                 | 0xA            |
| Horizontal tab  | HT           | \t       | 9                  | 0x9            |
| Vertical tab    | VT           | \v       | 11                 | 0xB            |
| Backspace       | BS           | \b       | 8                  | 0x8            |
| Carriage return | CR           | \r       | 13                 | 0xD            |
| Alert           | BEL          | \a       | 7                  | 0x7            |
| Backslash       | \            | \\       | 92                 | 0x5C           |
| Question mark   | ?            | \?       | 63                 | 0x3F           |
| Single quote    | '            | \'       | 39                 | 0x27           |
| Double quote    | "            | \"       | 34                 | 0x22           |

| ASCII control characters |                           | ASCII printable characters |       |    |   |     |   |     |   | Extended ASCII characters |   |     |   |     |      |  |  |
|--------------------------|---------------------------|----------------------------|-------|----|---|-----|---|-----|---|---------------------------|---|-----|---|-----|------|--|--|
| 00                       | NULL (Null character)     | 32                         | space | 64 | @ | 96  | ` | 128 | Ç | 160                       | á | 192 | l | 224 | ó    |  |  |
| 01                       | SOH (Start of Header)     | 33                         | !     | 65 | A | 97  | a | 129 | ü | 161                       | i | 193 | ł | 225 | ß    |  |  |
| 02                       | STX (Start of Text)       | 34                         | "     | 66 | B | 98  | b | 130 | é | 162                       | ó | 194 | ł | 226 | ö    |  |  |
| 03                       | ETX (End of Text)         | 35                         | #     | 67 | C | 99  | c | 131 | à | 163                       | ú | 195 | ł | 227 | ö    |  |  |
| 04                       | EOT (End of Trans.)       | 36                         | \$    | 68 | D | 100 | d | 132 | â | 164                       | ñ | 196 | — | 228 | ô    |  |  |
| 05                       | ENQ (Enquiry)             | 37                         | %     | 69 | E | 101 | e | 133 | ä | 165                       | N | 197 | ł | 229 | ö    |  |  |
| 06                       | ACK (Acknowledgement)     | 38                         | &     | 70 | F | 102 | f | 134 | å | 166                       | º | 198 | á | 230 | µ    |  |  |
| 07                       | BEL (Bell)                | 39                         | ,     | 71 | G | 103 | g | 135 | ç | 167                       | º | 199 | À | 231 | þ    |  |  |
| 08                       | BS (Backspace)            | 40                         | (     | 72 | H | 104 | h | 136 | é | 168                       | ç | 200 | Ł | 232 | þ    |  |  |
| 09                       | HT (Horizontal Tab)       | 41                         | )     | 73 | I | 105 | i | 137 | ë | 169                       | ® | 201 | Ł | 233 | Ú    |  |  |
| 10                       | LF (Line feed)            | 42                         | *     | 74 | J | 106 | j | 138 | è | 170                       | ¬ | 202 | Ł | 234 | Ó    |  |  |
| 11                       | VT (Vertical Tab)         | 43                         | +     | 75 | K | 107 | k | 139 | í | 171                       | ½ | 203 | Ł | 235 | Ü    |  |  |
| 12                       | FF (Form feed)            | 44                         | ,     | 76 | L | 108 | l | 140 | í | 172                       | ¼ | 204 | Ł | 236 | ý    |  |  |
| 13                       | CR (Carriage return)      | 45                         | -     | 77 | M | 109 | m | 141 | í | 173                       | í | 205 | = | 237 | Ý    |  |  |
| 14                       | SO (Shift Out)            | 46                         | .     | 78 | N | 110 | n | 142 | À | 174                       | « | 206 | Ł | 238 | .    |  |  |
| 15                       | SI (Shift In)             | 47                         | /     | 79 | O | 111 | o | 143 | Á | 175                       | » | 207 | Ł | 239 | .    |  |  |
| 16                       | DLE (Data link escape)    | 48                         | 0     | 80 | P | 112 | p | 144 | É | 176                       | ² | 208 | Ł | 240 | ≡    |  |  |
| 17                       | DC1 (Device control 1)    | 49                         | 1     | 81 | Q | 113 | q | 145 | æ | 177                       | ¤ | 209 | Ł | 241 | ±    |  |  |
| 18                       | DC2 (Device control 2)    | 50                         | 2     | 82 | R | 114 | r | 146 | Æ | 178                       | ¤ | 210 | Ł | 242 | ¤    |  |  |
| 19                       | DC3 (Device control 3)    | 51                         | 3     | 83 | S | 115 | s | 147 | ó | 179                       | — | 211 | Ł | 243 | ¤    |  |  |
| 20                       | DC4 (Device control 4)    | 52                         | 4     | 84 | T | 116 | t | 148 | ó | 180                       | — | 212 | Ł | 244 | ¶    |  |  |
| 21                       | NAK (Negative acknowl.)   | 53                         | 5     | 85 | U | 117 | u | 149 | ò | 181                       | À | 213 | í | 245 | §    |  |  |
| 22                       | SYN (Synchronous idle)    | 54                         | 6     | 86 | V | 118 | v | 150 | ó | 182                       | Á | 214 | í | 246 | +    |  |  |
| 23                       | ETB (End of trans. block) | 55                         | 7     | 87 | W | 119 | w | 151 | ú | 183                       | À | 215 | í | 247 | .    |  |  |
| 24                       | CAN (Cancel)              | 56                         | 8     | 88 | X | 120 | x | 152 | ÿ | 184                       | ® | 216 | ł | 248 | °    |  |  |
| 25                       | EM (End of medium)        | 57                         | 9     | 89 | Y | 121 | y | 153 | ó | 185                       | — | 217 | ł | 249 | .    |  |  |
| 26                       | SUB (Substitute)          | 58                         | :     | 90 | Z | 122 | z | 154 | ó | 186                       | — | 218 | ł | 250 | .    |  |  |
| 27                       | ESC (Escape)              | 59                         | ;     | 91 | [ | 123 | { | 155 | ø | 187                       | — | 219 | ł | 251 | ı    |  |  |
| 28                       | FS (File separator)       | 60                         | <     | 92 | \ | 124 |   | 156 | £ | 188                       | — | 220 | ł | 252 | ³    |  |  |
| 29                       | GS (Group separator)      | 61                         | =     | 93 | ] | 125 | } | 157 | ø | 189                       | ¢ | 221 | ł | 253 | ²    |  |  |
| 30                       | RS (Record separator)     | 62                         | >     | 94 | ^ | 126 | ~ | 158 | × | 190                       | ¥ | 222 | ł | 254 | ■    |  |  |
| 31                       | US (Unit separator)       | 63                         | ?     | 95 | _ |     |   | 159 | f | 191                       | ł | 223 | ł | 255 | nbsp |  |  |
| 127                      | DEL (Delete)              |                            |       |    |   |     |   |     |   |                           |   |     |   |     |      |  |  |

## Variables

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

int Integer;
char aCharacter;
char string [20];
unsigned int NumberOfSons;

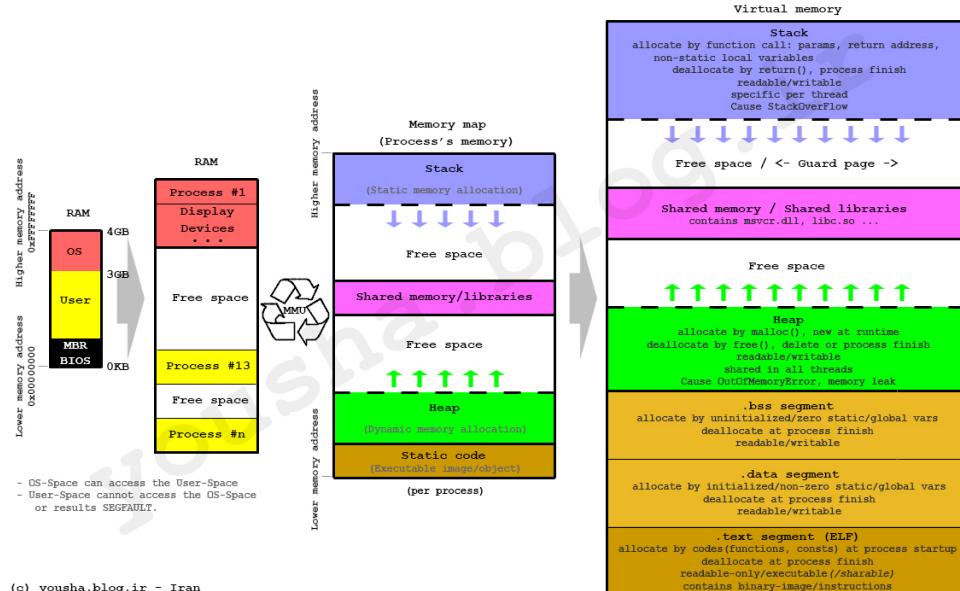
int main ()
{
    unsigned short Age;
    float ANumber, AnotherOne;

    cout << "Enter your age:" ;
    cin >> Age;
    ...
}
```

Global variables

Local variables

Instructions



(c) yousha.blog.ir - Iran

Computer programming Basic structure and cout Variable declaration and cin  
the if and while statements Formatting a C++ program

## Variable declaration

- Before we use a variable, we must first **declare** it.
  - We need to specify its **name** and **data type**.
- The syntax of a variable declaration statement is
 

```
✓ type variable name;
```

  - For example,
 

```
✓ int myInt;
```

 declares an integer variable called **myInt**.
- A variable name is an **identifier**.
  - We do not need to memorize the memory address (which is a sequence of numbers).
  - We access the space through the variable name.

| Address  | Identifier | Value |
|----------|------------|-------|
| 0x22fd4c | myInt      | ???   |
|          |            |       |

Memory

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## Declaration and assignment

- Beside declaring a variable, we may also **assign** values to a variable.
  - `int myInt;` declares an integer variable.
  - `myInt = 10;` **assigns 10 to myInt**.
- We may do these together:
 

```
✓ type variable name = initial value;
```

  - `int yourInt = 5;` declares an integer variable **yourInt** and assigns 5 to it.
  - The assignment is called **initialization** if it is done with declaration.
- Without initialization**, the variable may be of **any value** (depending on what was left since the last time this space is used)!

| Address  | Identifier | Value |
|----------|------------|-------|
| 0x20c648 | yourInt    | 5     |
|          |            |       |
| 0x22fd4c | myInt      | 10    |
|          |            |       |

Memory

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Computer programming      Basic structure and cout      Variable declaration and cin  
the if and while statements      Formatting a C++ program

## When we execute this program

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

int main()
{
    int num1 = 13, num2 = 4;
    cout << num1 + num2;

    return 0;
}
```

|     | Address  | Identifier | Value |
|-----|----------|------------|-------|
| (3) | 0x20c630 | (no name)  | 17    |
| (1) | 0x20c648 | num1       | 13    |
| (2) | 0x22fd4c | num2       | 4     |
|     |          |            |       |

Console
Memory

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Computer programming      Basic structure and cout      Variable declaration and cin  
the if and while statements      Formatting a C++ program

## When we execute this program

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

int main()
{
    int num1 = 13, num2 = 4;
    cout << num1 + num2;

    return 0;
}
```

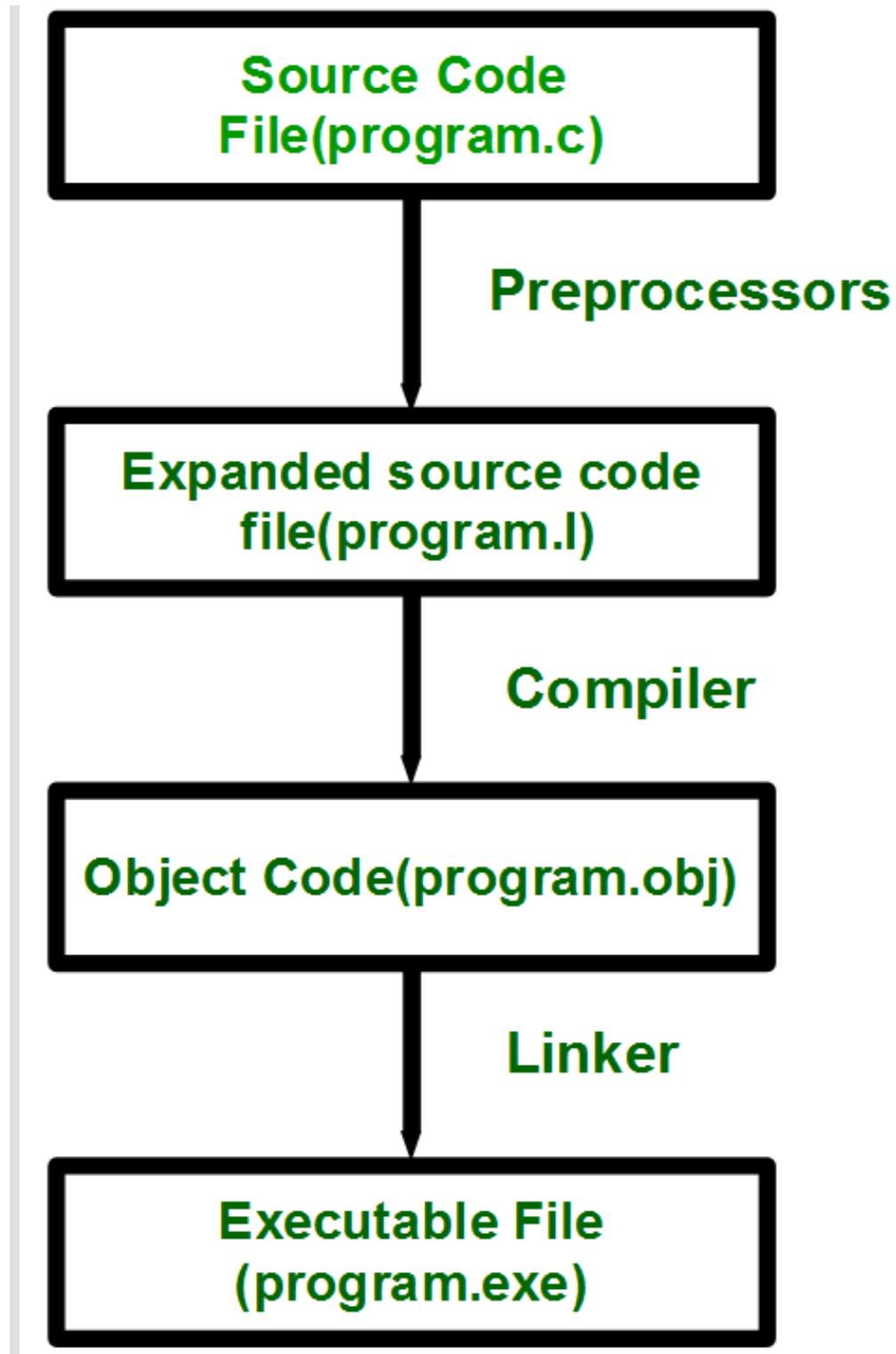
|     | Address  | Identifier | Value |
|-----|----------|------------|-------|
| (3) |          |            |       |
| (1) | 0x20c648 | num1       | 13    |
| (2) | 0x22fd4c | num2       | 4     |
| (4) | 17       |            |       |

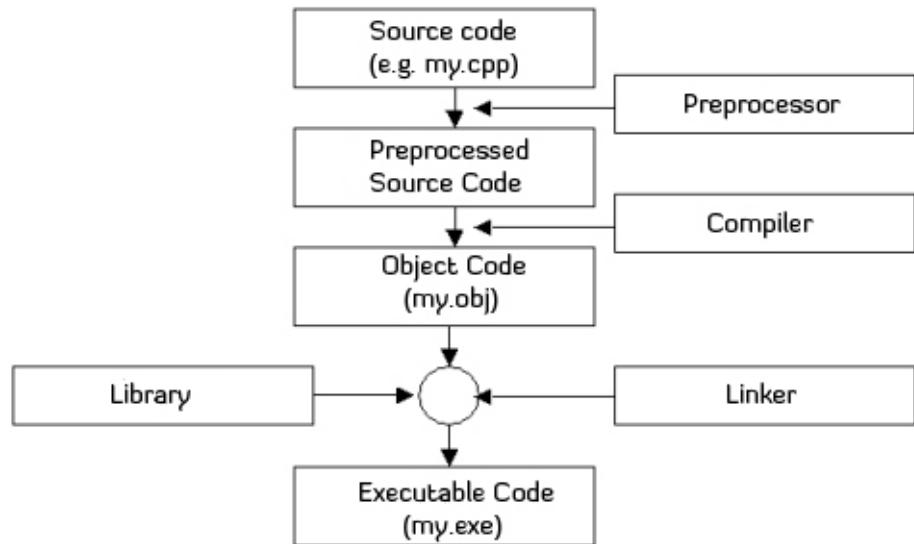
Console
Memory

Programming Design – Introduction      31 / 62      Ling-Chieh Kung (NTU IM)

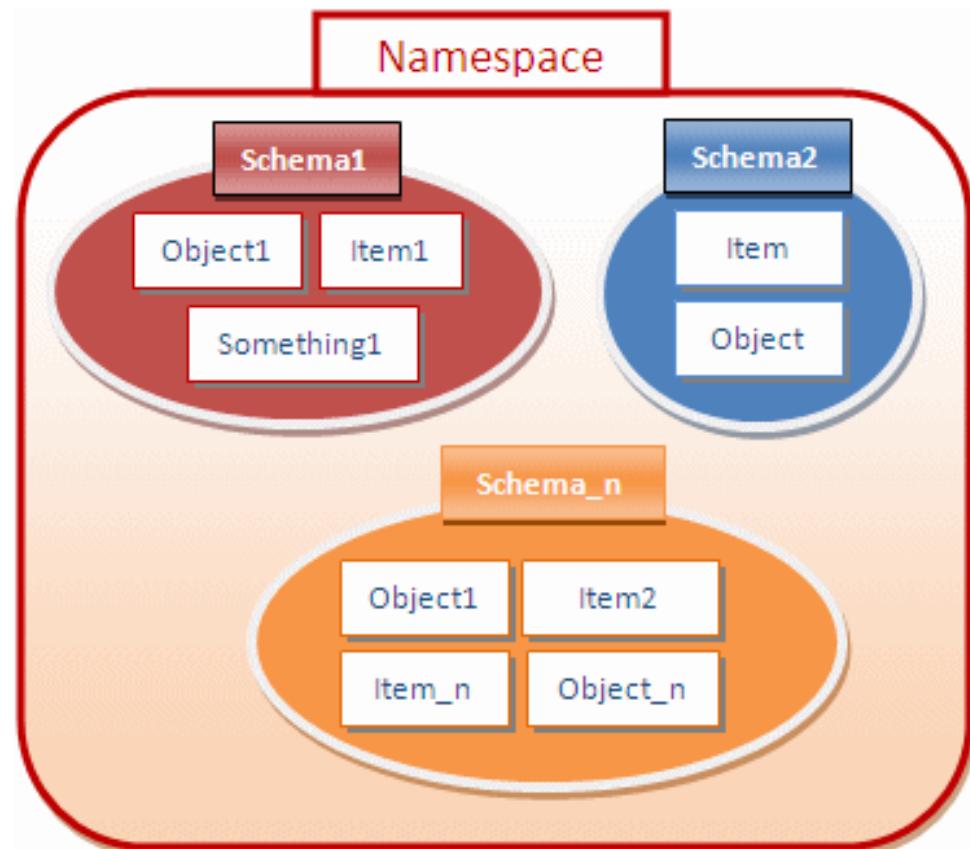
| Storage Class          | Specifier (Keyword) | Visibility (Scope)                      | Lifetime |
|------------------------|---------------------|---|----------|
| Automatic              | None (or auto)      | Function                                | Function |
| Register               | register            | Function                                | Function |
| Local static           | static              | Function                                | Program  |
| External (definition)  | None                | File (can be declared in other files)   | Program  |
| External (declaration) | extern              | File                                    | Program  |
| External               | static              | File (can't be declared in other files) | Program  |

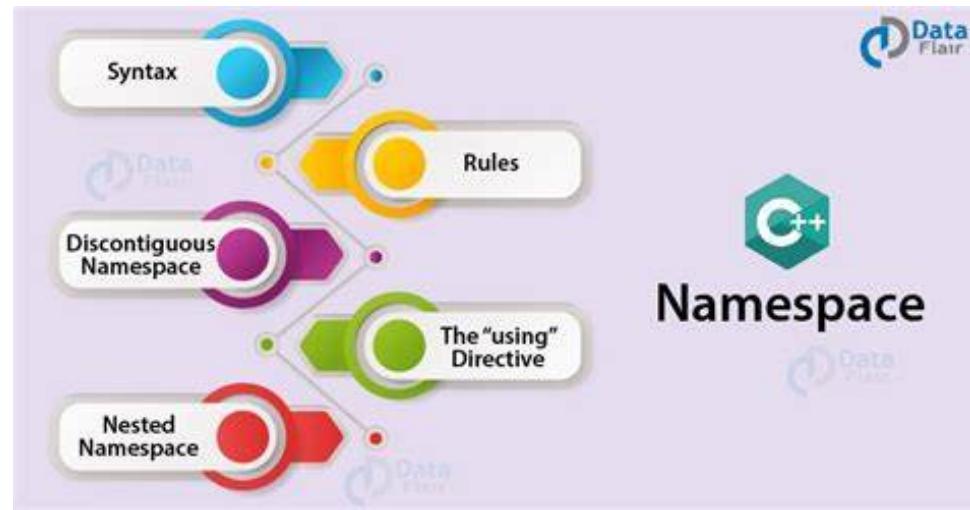
## Preprocessors





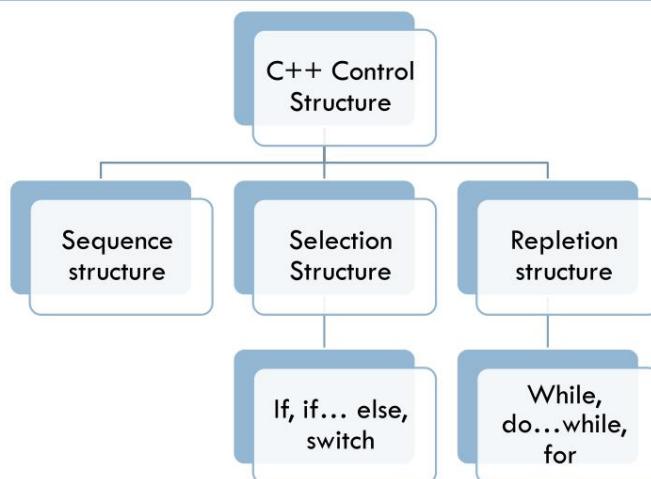
## Namespace





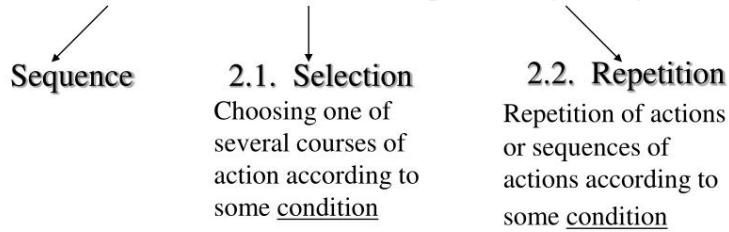
## Selection and Repetition

### Control structures in C++



### 3. Control Structures

Bohm, Jacopini (1966) showed that only the three following control structures are needed for representing an algorithm:



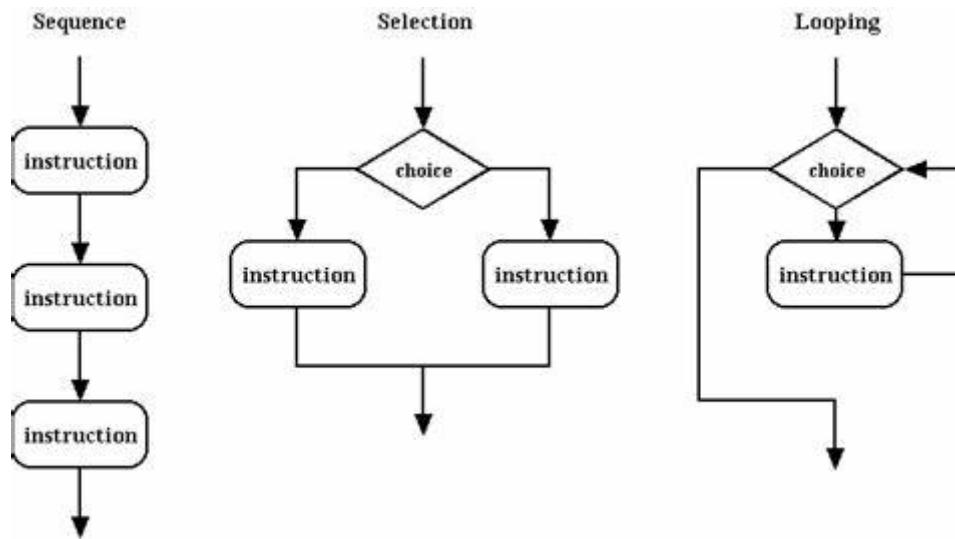
Syntax Constructs:

|          |  |   |
|----------|--|---|
| built in | <b>if</b><br><b>if/else</b><br><b>? :</b><br><b>switch</b> | <b>while</b><br><b>for</b><br><b>do/while</b> |
|----------|--|---|

09/15/08

MET CS 563 -Fall 2008  
3. Control Structures

1



## Selection

- A Selection control structure is used to choose among alternative courses of action.
- There must be some *condition* that determines whether or not an action occurs.
- C++ has a number of selection control structures:
  - If
  - if/else
  - switch

09/2013

C++ Programming

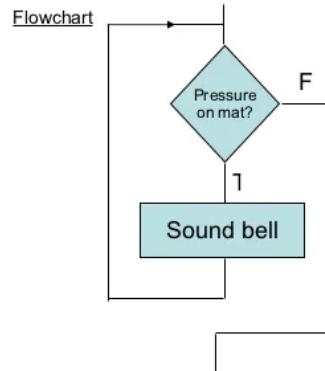
L2.42

# Repetition

- Carries out a particular action over and over again until the condition is met.
- A loop is created to return the program to where the repetition has started for as long as it takes until the condition is met.
- There are two ways of testing to see if the end condition is met: 1) pre-test loops 2) post-test loops.
- In pre-test loops the condition is tested at the start. If the condition is false the first time, the processes will never carry out. Pre-test loops end when the condition is false. Uses WHILE ... ENDWHILE.
- Counted loops are special types of pre-test loops. They are used when a known number of repetitions will occur.
- Pre-test loops are also known as guarded loops because the loop is only operated when the condition is met.

Pseudocode

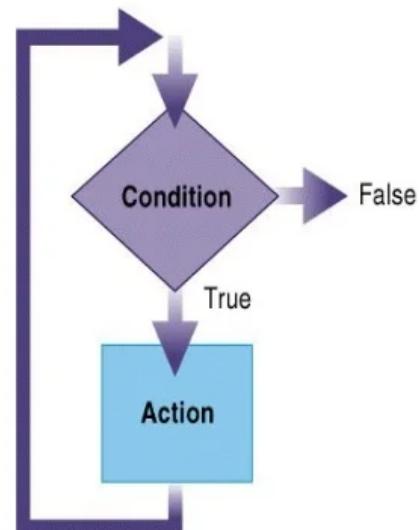
```
WHILE there is pressure on the mat
    Sound the bell
ENDWHILE
```



## Repetition (Loop)

- **Repetition structure:** directs computer to repeat one or more instructions until some condition is met
  - Also called a **loop** or **iteration**

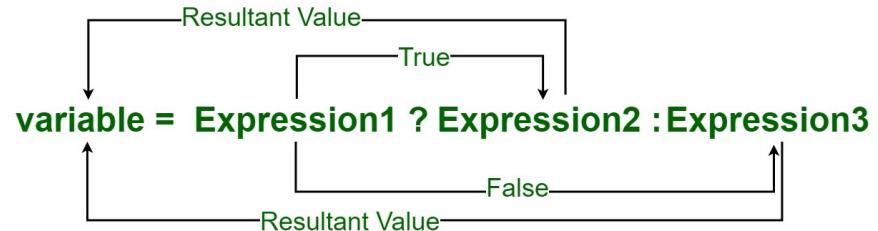
Do-While Control Structure



<https://www.facebook.com/AriiLK0221>

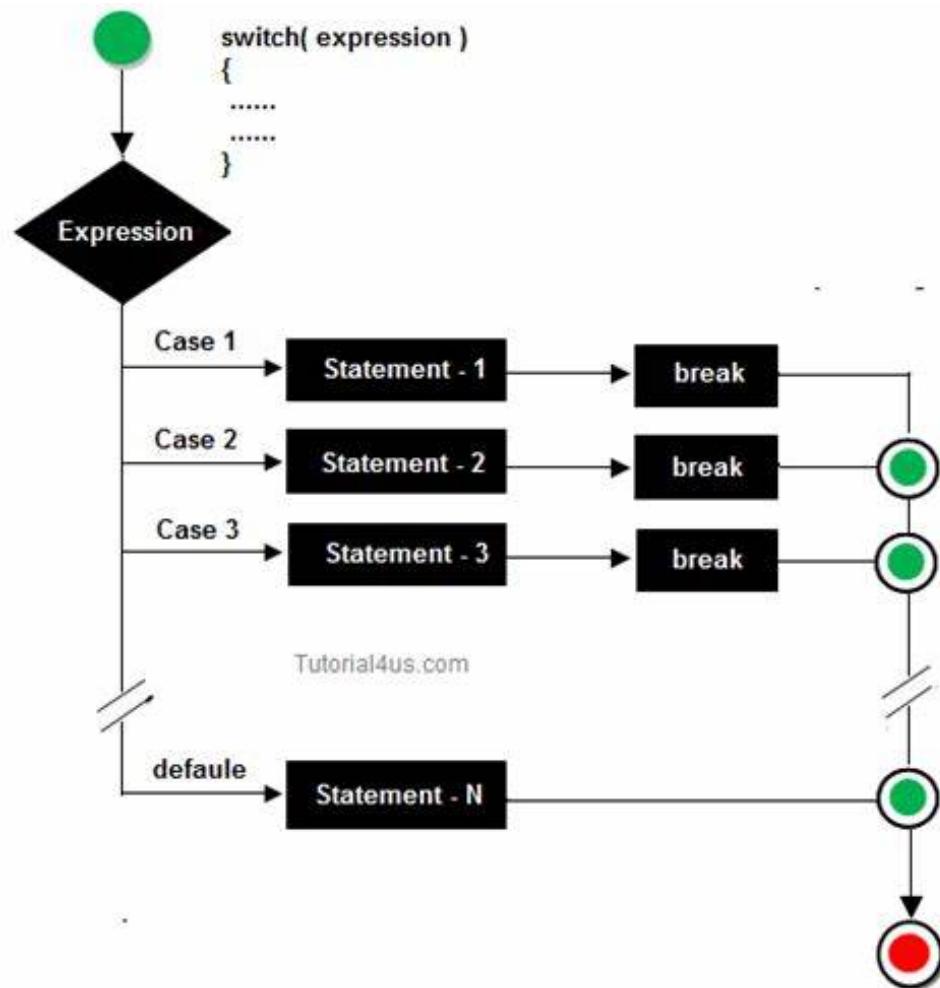
## Ternary If

## Conditional or Ternary Operator (?:) in C/C++



DG

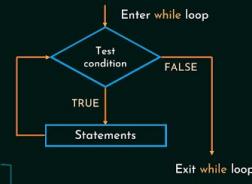
## Switch Case



## While

# while Statement in C++

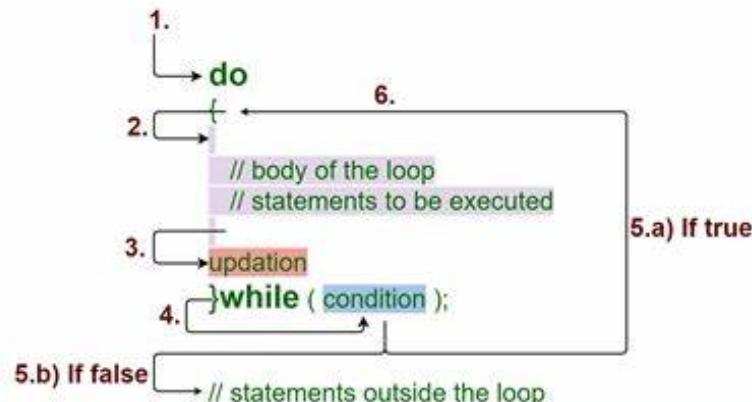
```
#include <iostream>
int main()
{
    int count = 1;
    while (count <= 10)
        { std::cout << "Hello there" << std::endl;
          count = count + 1;
        }
    return 0;
}
```



IO / C++

## Do-While

### Do - While Loop



DG

## Increment and Decrement Operators

| OPERATOR         | MEANING   |
|------------------|---|
| <code>++a</code> | Increment <code>a</code> by 1, then use new value of <code>a</code> |
| <code>a++</code> | Use value of <code>a</code> , then increment <code>a</code> by 1    |
| <code>--b</code> | Decrement <code>b</code> by 1, then use new value of <code>b</code> |
| <code>b--</code> | Use value of <code>b</code> , then decrement <code>b</code> by 1    |

## Scope of Variables

# Scope of variables

```
#include <iosteam.h>

int x;
char ch; → Global variables

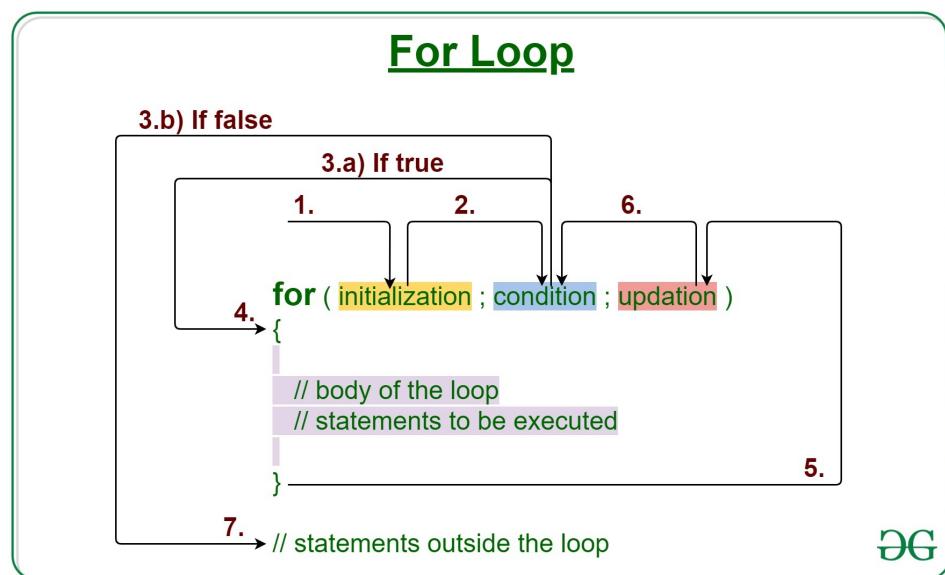
main()
{
    int age;
    float number; → Local variables

    cout << "Enter your age: ";
    cin >> age;
    ...
}
```

Lecturer: Hong Mom

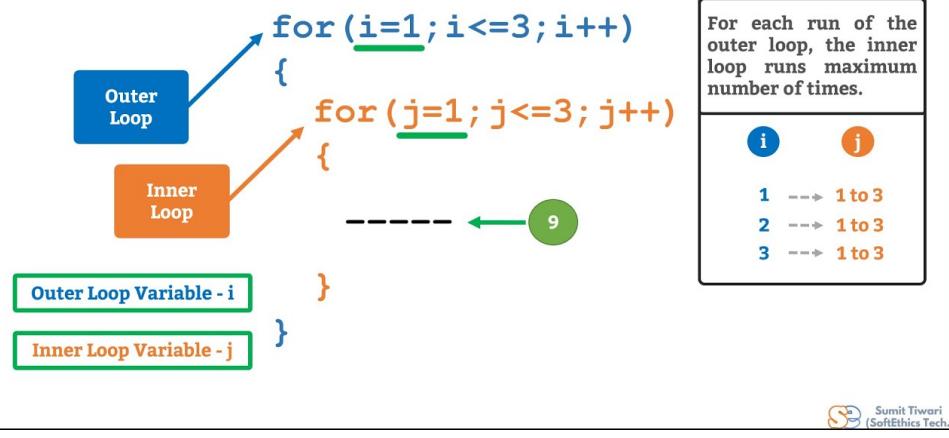
11

## For Loop



## Nested Loop

# Nested Loops



Sumit Tiwari (SoftEthics Tech.)

## Break and Continue

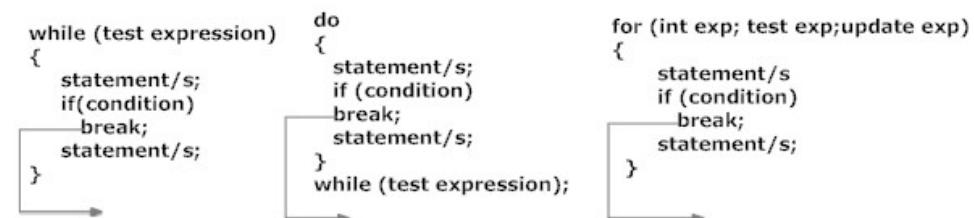
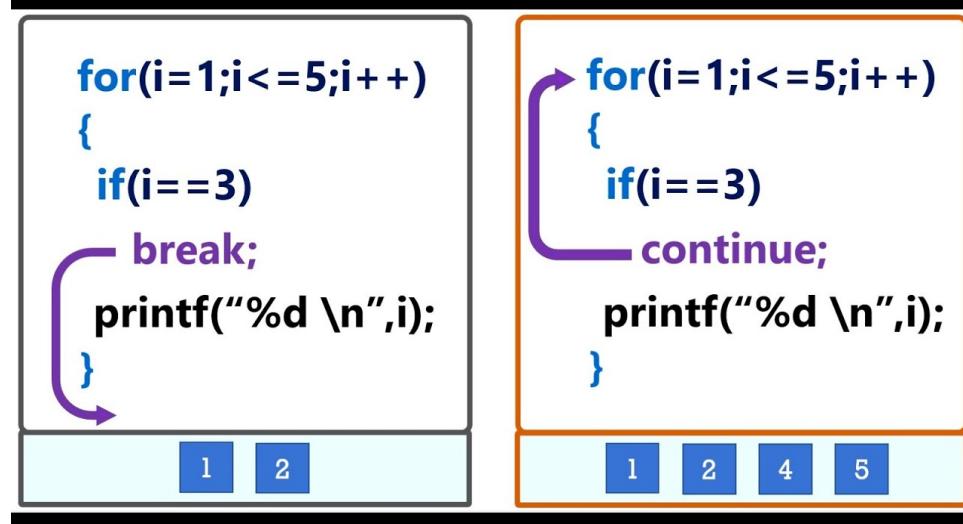


Fig: Working of break statement in different loops

```

→ while (test expression) {
    statement/s
    if (test expression) {
        continue;
    }
    statement/s
}

do {
    statement/s
    if (test expression) {
        continue;
    }
    statement/s
}
→ while (test expression);

→ for (initial expression; test expression; update expression) {
    statement/s
    if (test expression) {
        continue;
    }
    statements/
}

```

NOTE: The continue statement may also be used inside body of else statement.

## Operations in C

| Operators in C   |  |
|------------------|--|
| Unary operator   | Operator      Type                             |
|                  | + +, - -      Unary operator                   |
|                  | +, -, *, /, %      Arithmetic operator         |
|                  | <, <=, >, >=, ==, !=      Relational operator  |
| Binary operator  | &&,   , !      Logical operator                |
|                  | &,  , <<, >>, ~, ^      Bitwise operator       |
|                  | =, +=, -=, *=, /=, %=      Assignment operator |
| Ternary operator | ?:   |
|                  | Ternary or conditional operator                |

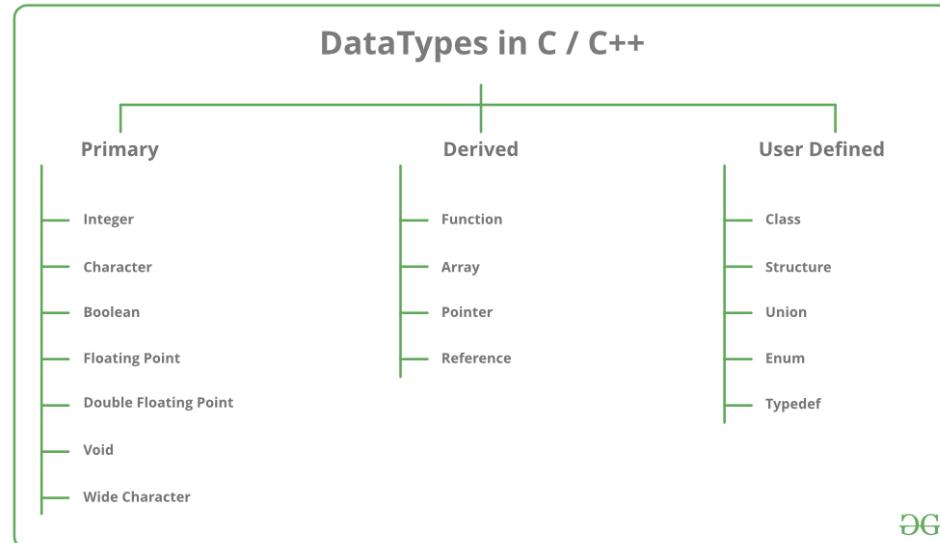
DG

## Priority of Operations

| Operator Precedence |                                 |  |
|---------------------|---------------------------------|--|
| <b>1</b>            | <b>! Logical not (Highest)</b>  |  |
| <b>2</b>            | <b>( ) Parenthesis</b>          |  |
| <b>3</b>            | <b>*, /, %</b>                  |  |
| <b>4</b>            | <b>+, -</b>                     |  |
| <b>5</b>            | <b>&gt;, &gt;=, &lt;, &lt;=</b> |  |
| <b>6</b>            | <b>==, !=</b>                   |  |
| <b>7</b>            | <b>&amp;&amp; (AND)</b>         |  |
| <b>8</b>            | <b>   (OR)</b>                  |  |
| <b>9</b>            | <b>= (Lowest)</b>               |  |

| Signs of operations                              | Name of operation, explanation        | Associativity      |
|--|---------------------------------------|--------------------|
| () [] . ->                                       | Primary                               | From left to right |
| + - ~ ! * & ++ --<br>sizeof(type)<br>(type cast) | Unary                                 | From right to left |
| * / %  | Multiplicative, arithmetical, binary  | From left to right |
| + -  | Additive, arithmetical, binary        | From left to right |
| >> <<  | Shift                                 | From left to right |
| < > <= >=  | Relation                              | From left to right |
| == !=  | Relation                              | From left to right |
| &  | Bitwise "AND", logical, binary        | From left to right |
| ^  | Bitwise XOR, logical, binary          | From left to right |
|  | Bitwise logical "OR", logical, binary | From left to right |
| &&   | Logical "AND", binary                 | From left to right |
|  | Logical "OR", binary                  | From left to right |
| ? :  | Conditional, ternary                  | From right to left |
| = *= /= %= += -=<br><<= >>= &=  = ^=             | Simple and complex assignment         | From right to left |
| ,  | Sequential computation                | From left to right |

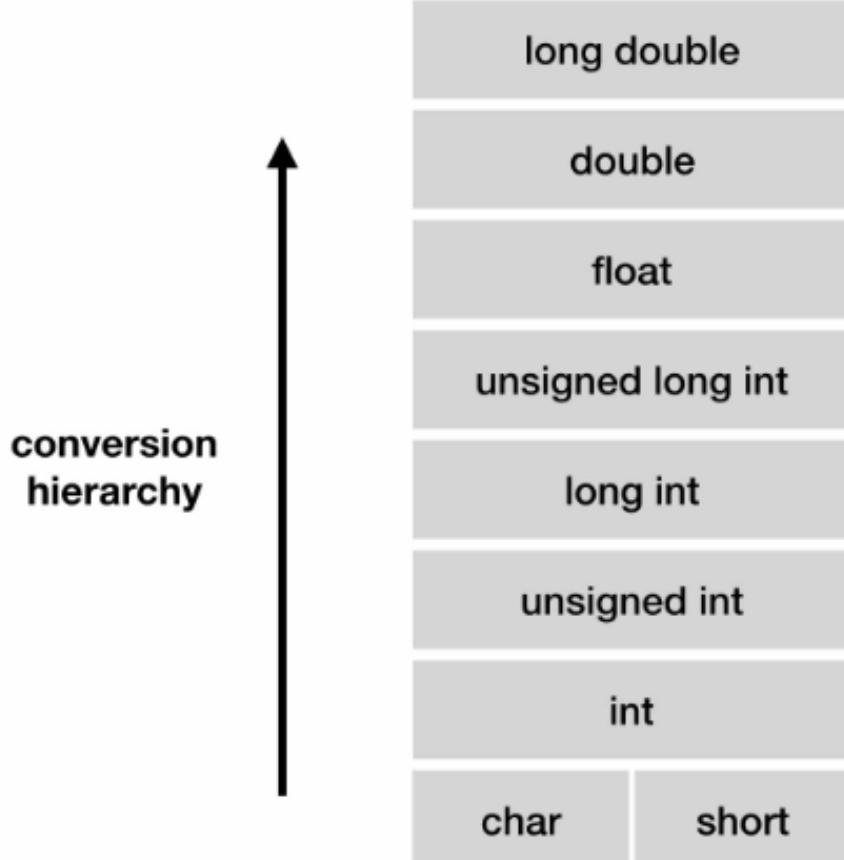
## Data Type



DG

| <b>Key word</b>                   | <b>Size in bytes</b> | <b>Interpretation</b>   | <b>Possible values</b>   |
|-----------------------------------|----------------------|---|--|
| bool                              | 1                    | boolean   | true and false   |
| unsigned char                     | 1                    | Unsigned character  | 0 to 255   |
| char (or signed char)             | 1                    | Signed character  | -128 to 127  |
| wchar_t                           | 2                    | Wide character (in windows, same as unsigned short)   | 0 to $2^{16}-1$  |
| short (or signed short)           | 2                    | Signed integer  | $-2^{15}$ to $2^{15}-1$  |
| unsigned short                    | 2                    | Unsigned short integer  | 0 to $2^{16}-1$  |
| int (or signed int)               | 4                    | Signed integer  | $-2^{31}$ to $2^{31}-1$  |
| unsigned int                      | 4                    | Unsigned integer  | 0 to $2^{32}-1$  |
| Long (or long int or signed long) | 4                    | signed long integer   | $-2^{31}$ to $2^{31}-1$  |
| unsigned long                     | 4                    | unsigned long integer   | 0 to $2^{32}-1$  |
| float                             | 4                    | Signed single precision floating point (23 bits of significand, 8 bits of exponent, and 1 sign bit. ) | $3.4 \times 10^{-38}$ to $3.4 \times 10^{38}$ (both positive and negative)   |
| long long                         | 8                    | Signed long long integer  | $-2^{63}$ to $2^{63}-1$  |
| unsigned long long                | 8                    | Unsigned long long integer  | 0 to $2^{64}-1$  |
| double                            | 8                    | Signed double precision floating point(52 bits of significand, 11 bits of exponent, and 1 sign bit. ) | $1.7 \times 10^{-308}$ to $1.7 \times 10^{308}$ (both positive and negative) |
| long double                       | 8                    | Signed double precision floating point(52 bits of significand, 11 bits of exponent, and 1 sign bit. ) | $1.7 \times 10^{-308}$ to $1.7 \times 10^{308}$ (both positive and negative) |

## Casting



## Introduction to C++

### C++ Casting Operators

- **static\_cast<type> (expr):**
- **static\_cast operator** is used to convert a given expression to the specified type. For example, it can be used to cast a base class pointer into a derived class pointer.

```
int main() {
    int a = 31;
    int b = 3;
    float x = a/b;
    float y = static_cast<float>(a)/b;
    cout << "Output without static_cast = " << x << endl;
    cout << "Output with static_cast = " << y << endl;
}
```

In this type casting example, using the static\_cast to an integer as "float" returns a float value.

Lecture Slides By Adil Aslam

# Explicit type conversion

- **C++ casts**
  - `static_cast` between 2 related types  
(int/float, int/enum, 2 pointers in class hierarchy)
  - `reinterpret_cast` between 2 unrelated types  
(int/ptr, pointers to 2 unrelated classes)
  - `const_cast` cast away constness
  - `dynamic_cast` used for polymorphic types  
Run-time type info (RTTI)
- **Avoid casts, but use these instead of C casts**
  - e.g., compiler can perform minimal checking for `static_cast`, none for `reinterpret_cast`

## Array

| Column subscript |            |            |            |
|------------------|------------|------------|------------|
| Row subscript    | arr[0] [0] | arr[0] [1] | arr[0] [3] |
|                  | arr[1] [0] | arr[1] [1] | arr[1] [2] |
|                  | arr[2] [0] | arr[2] [1] | arr[2] [2] |

The array arr can be conceptually viewed in matrix form with 3 rows and columns. point to be noted here is since the subscript starts with 0 arr [0][0] represents the first element.

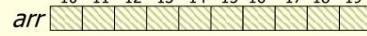
Figure 12.4

# Array Declaration

- An **array** is a collection of objects with same type stored **consecutively** in memory

- Declaring an array

```
IntCell arr[10]; //an array consisting of 10 IntCell
objects
```



- The size of the array must be known at compile time.
- arr* actually is a constant pointer. The value of *arr* **cannot** be changed.

```
IntCell * p = new IntCell[10];
arr = p; // invalid
```

- The  $(i+1)$ -st object in the array *arr* can be accessed either by using *arr[i]*, or by *\*(arr+i)*.

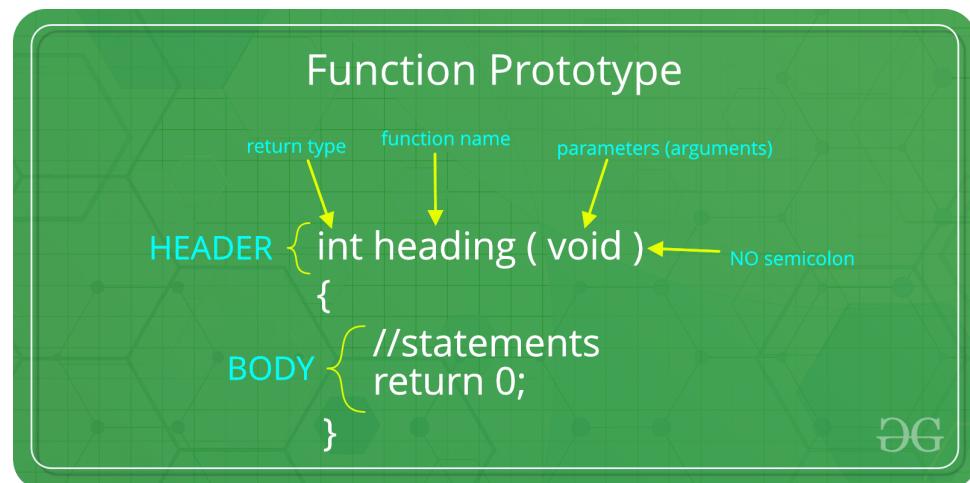
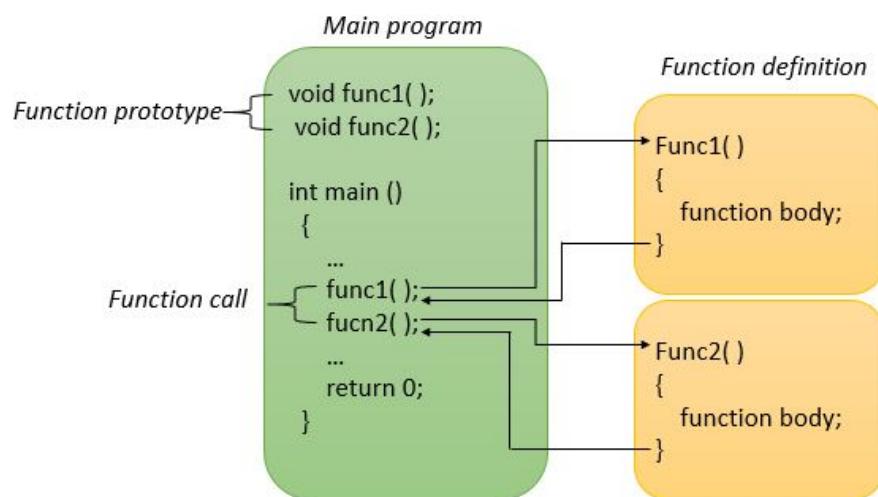
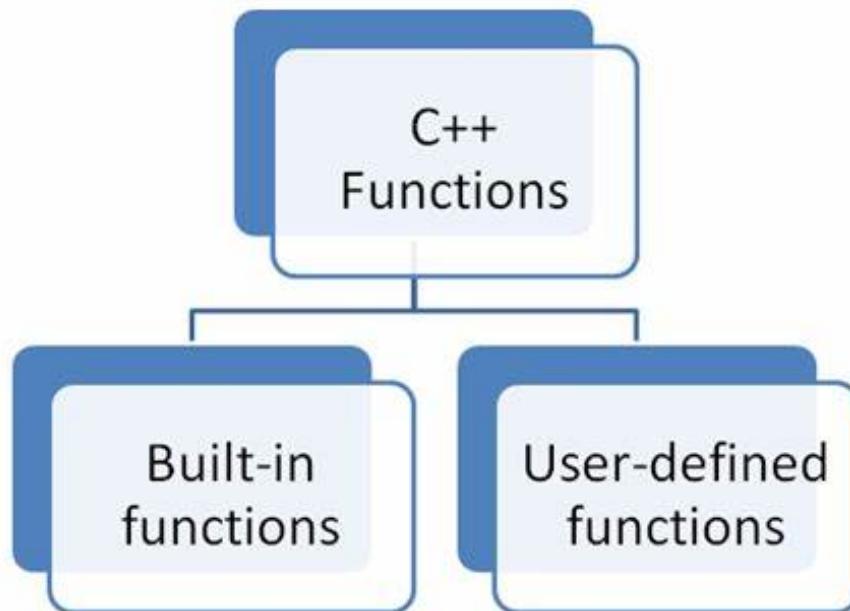
- There is no index range checking for arrays in C++
- Cannot be copied with =
- Arrays are *not* passed by copy. Instead, the address of the first element is passed to the function

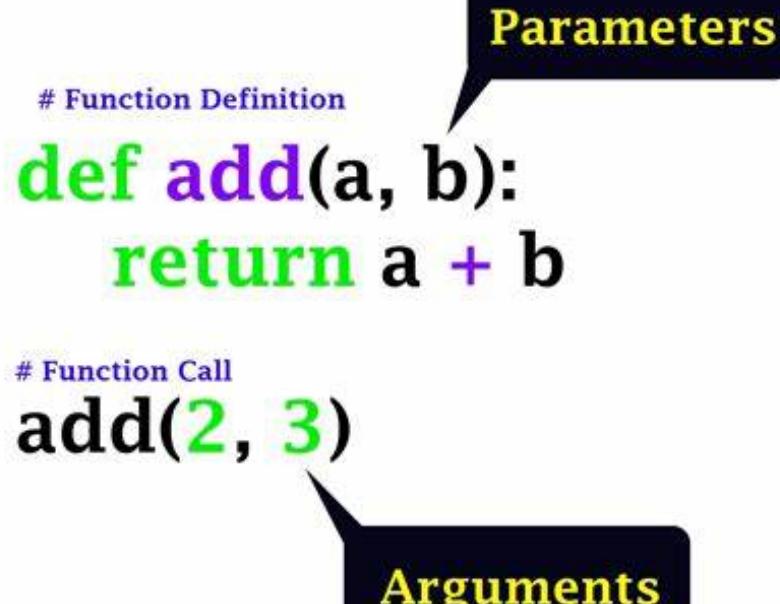
```
int sumOfArray( int values[], int numValues )
```

21

| language built-in array  | container library array  |
|--|--|
| <pre>#include &lt;iostream&gt; using namespace std;  int main() {     int myarray[3] = {10,20,30};      for (int i=0; i&lt;3; ++i)         ++myarray[i];      for (int elem : myarray)         cout &lt;&lt; elem &lt;&lt; '\n'; }</pre> | <pre>#include &lt;iostream&gt; #include &lt;array&gt; using namespace std;  int main() {     array&lt;int,3&gt; myarray {10,20,30};      for (int i=0; i&lt;myarray.size(); ++i)         ++myarray[i];      for (int elem : myarray)         cout &lt;&lt; elem &lt;&lt; '\n'; }</pre> |

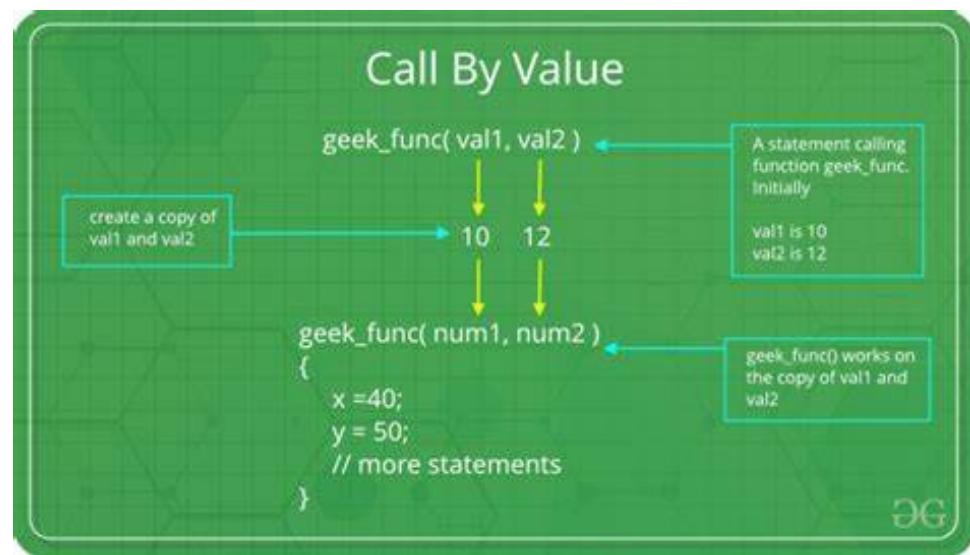
# Function

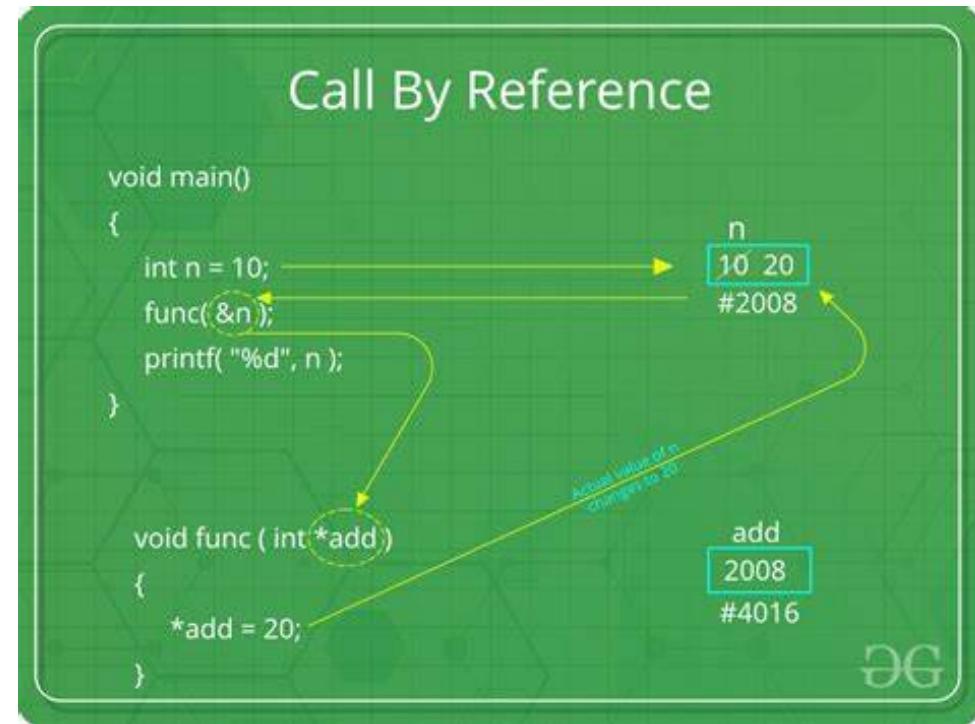




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## Call by Value and Call by Reference





## Programming in C - Call By

| CALL BY VALUE   | CALL BY REFERENCE   | CALL BY ADDRESS   |
|---|---|---|
| <p>The call to the function passes either the values or the normal variables to the called function. The actual arguments are copied to the formal arguments, hence any operation performed by function on arguments doesn't affect actual parameters.</p> <pre> void swap(int a, int b) {     int t=a; a=b; b=t; } void main() {     int a=5, b=10;     printf("Before swap: a=%d,b=%d",a,b);     swap(a,b); /*calling swap function*/     printf("After swap: a=%d,b=%d",a,b); }</pre> <p>Output:<br/>Before swap: a=5,b=10<br/>After swap: a=5,b=10<br/>Because variable declared 'a', 'b' in main() is different from variable 'a', 'b' in swap(). Only variable names are similar but their memory address are different and stored in different memory locations.</p> | <p>The call to the function passes base address to the called function. The actual arguments are not copied to the formal arguments, only referencing is made. Hence any operation performed by function on formal arguments / parameters affects actual parameters.</p> <pre> void change(int b[]) {     b[0]=10; b[1]=20; b[2]=30; } void main() {     int a[3]={ 5, 15, 25 };     printf("BeforeChange:%d,%d,%d",a[0],a[1],a[2]);     change(a); /*calling swap function*/     printf("AfterChange:%d,%d,%d",a[0],a[1],a[2]); }</pre> <p>Output:<br/>BeforeChange:5,15,25<br/>AfterChange:10,20,30<br/>Because array variable declared 'b' in change() is referencing/ pointing to array variable 'a' in main(). Only variable name is different but both are pointing / referencing to same memory address locations.</p> | <p>The call to the function passes variable's address to the called function. The actual arguments are not copied to the formal arguments, the addresses of actual arguments (or parameters) are passed to the formal parameters. Hence any operation performed by function on formal arguments / parameters affects actual parameters.</p> <pre> void swap(int *x, int *y) {     int t=*x; *x=*y; *y=t; } void main() {     int a=5, b=10;     printf("Before swap: a=%d,b=%d",a,b);     swap(&amp;a,&amp;b); /*calling swap function*/     printf("After swap: a=%d,b=%d",a,b); }</pre> <p>Output:<br/>Before swap: a=5,b=10<br/>After swap: a=10,b=5<br/>Because variable declared 'a', 'b' in main() is different from variable 'x', 'y' in swap(). Only variable names are different but both a and x, b and y point to the same memory address locations.</p> |

# CALL BY ADDRESS VERSUS CALL BY REFERENCE

## CALL BY ADDRESS

A way of calling a function in which the address of the actual arguments are copied to the formal parameters

Programmer passes the addresses of the actual arguments to formal parameters

Memory is allocated for both actual arguments and formal parameters

## CALL BY REFERENCE

A method of passing arguments to a function by copying the reference of an argument into the formal parameter

Programmer passes the references of the actual arguments to the formal parameters

Memory is allocated only for actual arguments and formal parameters share that memory

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## Passing Array to Function

### Passing array to function in C

```

void func( int arr[], int size )
{
}

int main()
{
    int n=5;
    int arr[5] = { 1, 2, 3, 4, 5 };
    func( arr, n );
    return 0;
}

```

Pointer a takes the base address of array arr

Pointer to arr

Length of arr

The length of arr is passed. It is compulsory to pass size as it is just a pointer

DEG

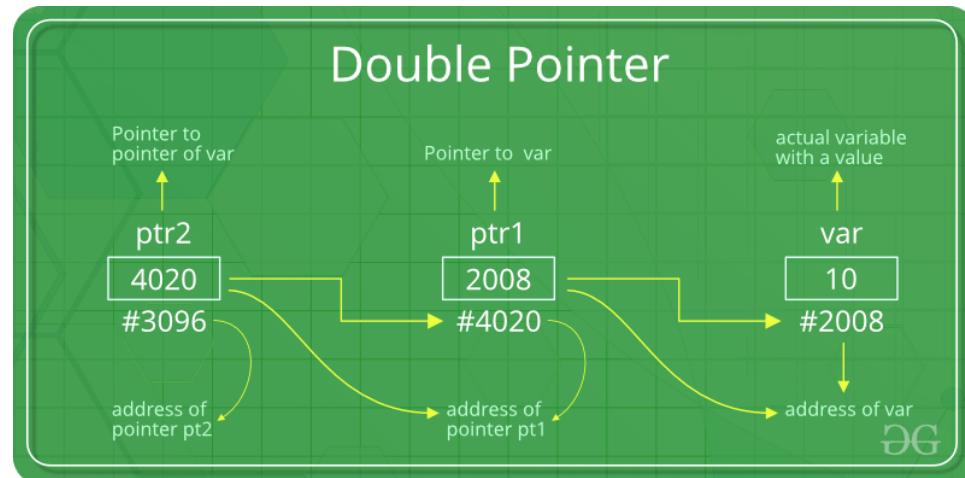
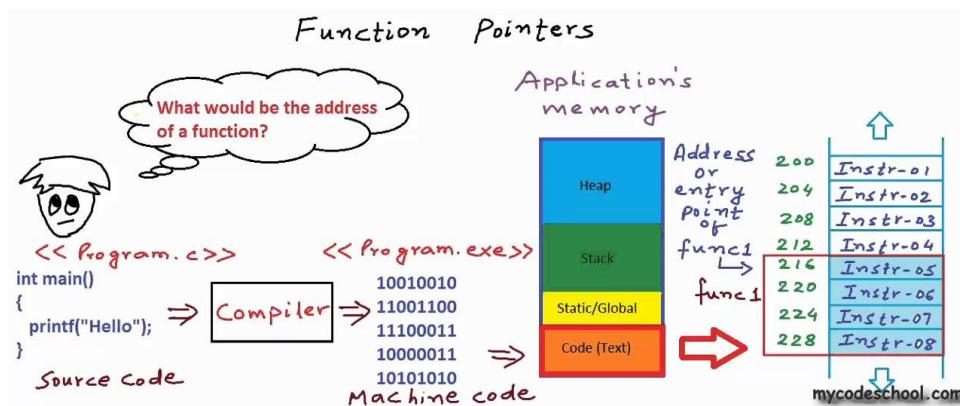
## Pointer

## What's a Pointer in C++?

- A variable holding an address
    - Of what it “points to” in memory
  - Can be untyped
- ```

int k
  7
const int j    void * v; // can point to any type
  3
int i
  7
  ↑
0x7ffffdad0
int * p
  
```
- However, usually they're typed
    - Checked by compiler
    - Can only be assigned addresses of variables of the type to which it can point
  - Addresses: garbage, something, nothing
    - When created: `int * p = i;` VS. `int * q;  
q = 0;` // now it points to nothing
    - `p = NULL;` // not portable, use 0 instead

CSE 232: C++ pointers, arrays, and references



## Address Operation

**Introduction to C++****C++ Address of Operator (&)**

- The & is a unary operator means it requires only one operand.
- The Address of Operator returns the memory address of its operand.
- Address of operator has the same precedence and right-to-left associativity as that of other unary operators.
- Symbol for the bitwise AND and the address of operator are the same but they don't have any connection between them.

**Lecture Slides By Adil Aslam****Introduction to C++****C++ Indirection/ Deference Operator \***

- Getting the address of a variable isn't very useful by itself.
- The dereference operator (\*) allows us to get the value at a particular address:
- The Indirection operator \* is a unary operator means it requires only one operand.
- Indirection Operator (\*) is the complement of Address of Operator (&).
- Indirection Operator returns the value of the variable located at the address specified by its operand.

**Lecture Slides By Adil Aslam**

## Introduction to C++

**Reference Operator (&) and Dereference Operator (\*)**

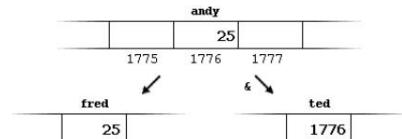
- Reference operator (&) as already discussed, gives the address of a variable.
- To get the value stored in the memory address, we use the dereference operator (\*).
- **For Example:** If a number variable is stored in the memory address 0x123, and it contains a value 5.
- The reference (&) operator gives the value 0x123, while the dereference (\*) operator gives the value 5.
- **Note:** The (\*) sign used in the declaration of C++ pointer is not the dereference pointer. It is just a similar notation that creates a pointer.

## Lecture Slides By Adil Aslam

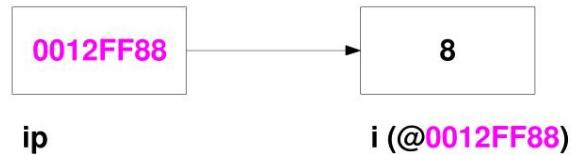
## Address Operator (&)

- The ‘&’ operator returns the ‘address of’ its operand.
- ‘&’ can be translated ‘address of’

```
andy = 25;
fred = andy;
ted = &andy;
```

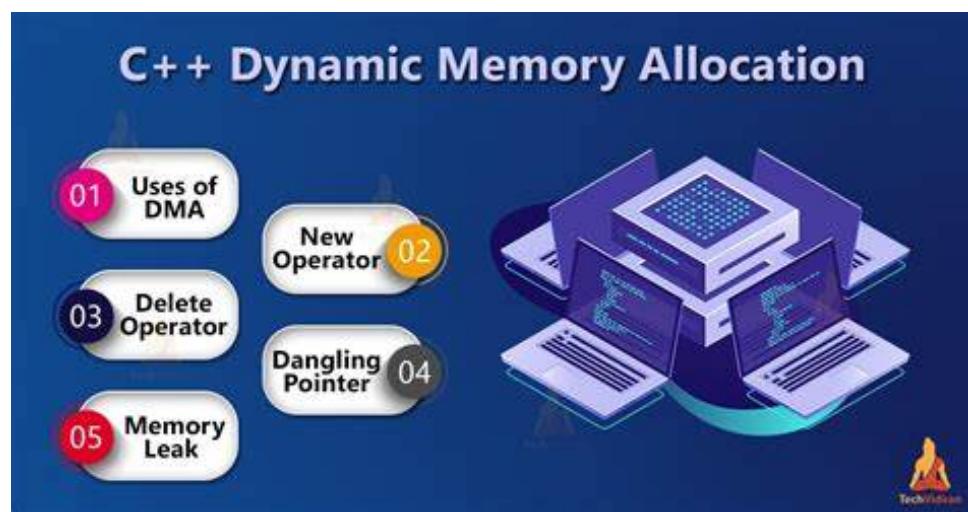
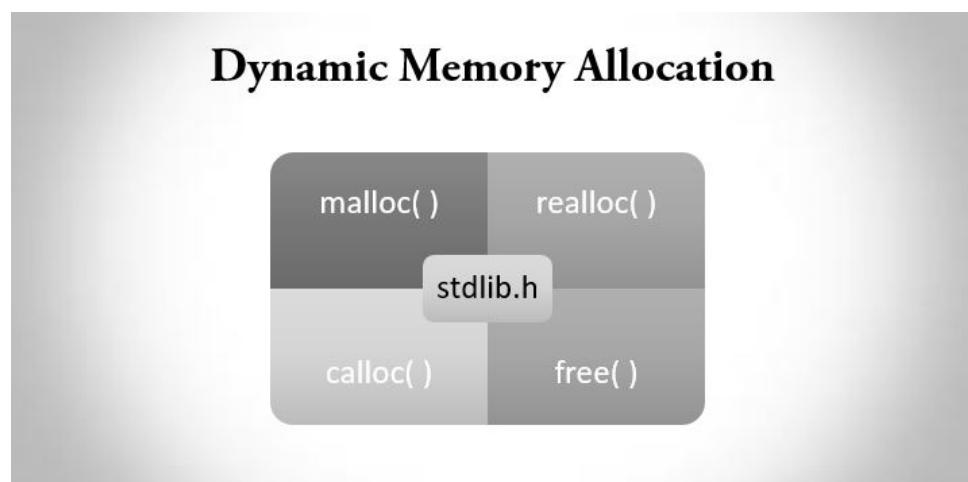


## *Address of operator*



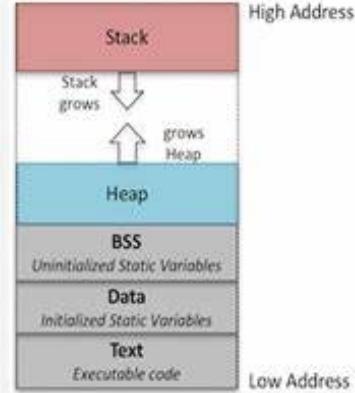
```
int i = 8;  
int *ip;  
  
ip = &i;
```

## DMA(Dynamic Memory Allocation)



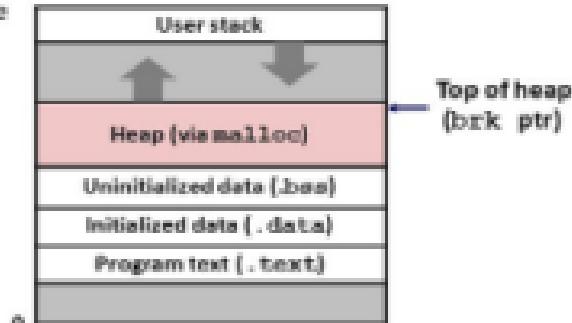
# calloc () malloc() realloc() free() new & delete

## C/C++



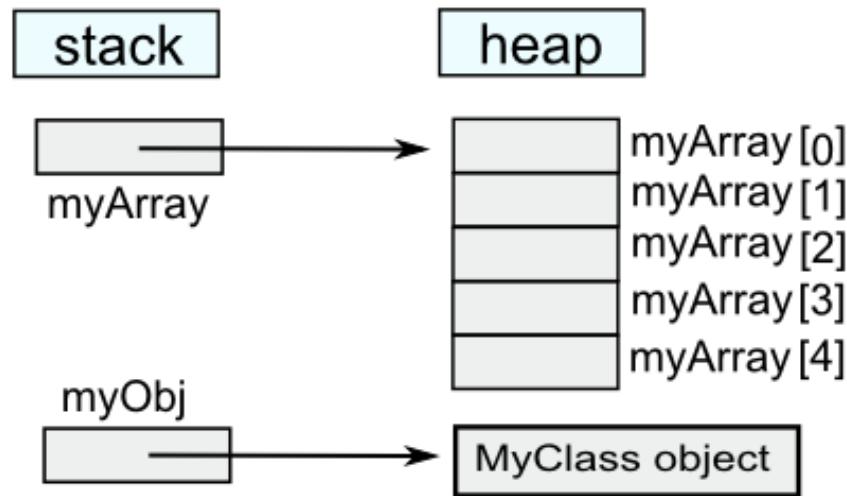
### Dynamic Memory Allocation

- Programmers use ***dynamic memory allocators*** (such as `malloc`) to acquire VM at run time.
  - For data structures whose size is only known at runtime.
- Dynamic memory allocators manage an area of process virtual memory known as the ***heap***.

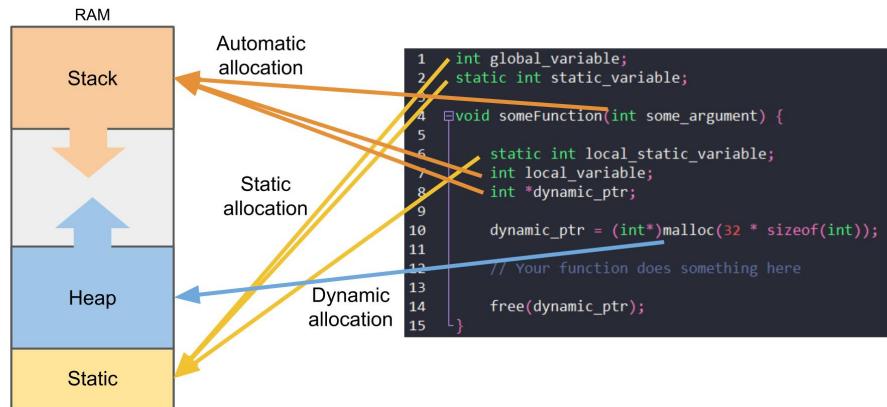


## DIFFERENCE BETWEEN MALLOC() AND CALLOC() FUNCTIONS IN C:

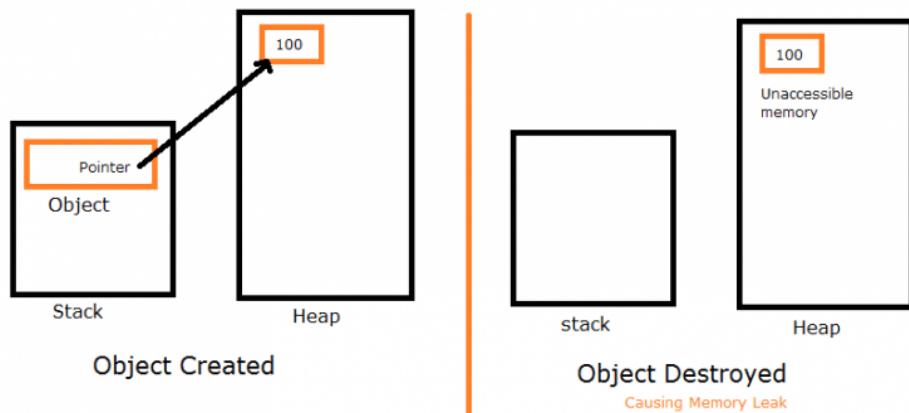
| malloc()                                                                                                                       | calloc()                                                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| It allocates only single block of requested memory                                                                             | It allocates multiple blocks of requested memory                                                                                                               |
| int *ptr;ptr = malloc( 20 * sizeof(int) );For the above, 20*4 bytes of memory only allocated in one block.<br>Total = 80 bytes | int *ptr;ptr = calloc( 20, 20 * sizeof(int) );For the above, 20 blocks of memory will be created and each contains 20*4 bytes of memory.<br>Total = 1600 bytes |
| malloc () doesn't initializes the allocated memory. It contains garbage values                                                 | calloc () initializes the allocated memory to zero                                                                                                             |
| type cast must be done since this function returns void pointer int *ptr;ptr = (int*)malloc(sizeof(int)*20);                   | Same as malloc () function int *ptr;ptr = (int*)calloc( 20, 20 * sizeof(int) );                                                                                |



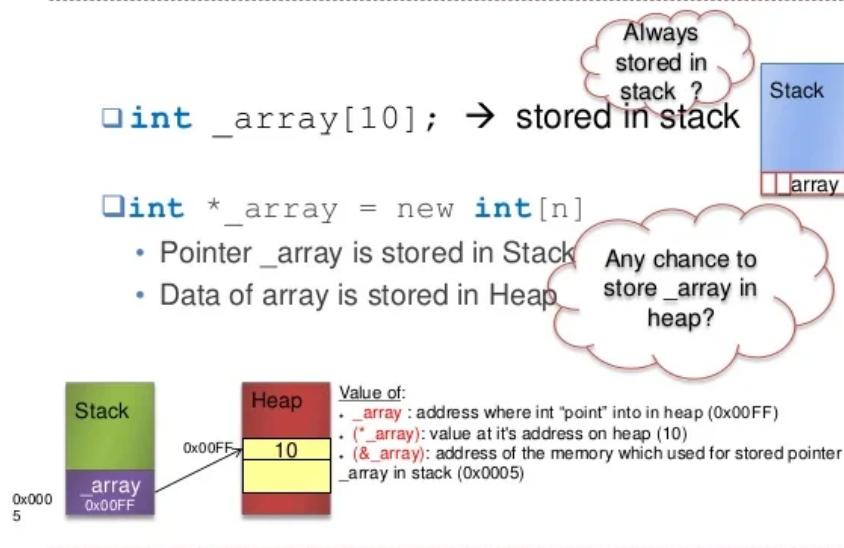
## Memory Allocation



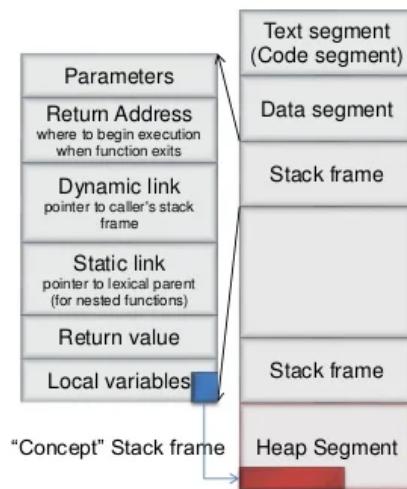
## Memory Leak



## Heap vs Stack

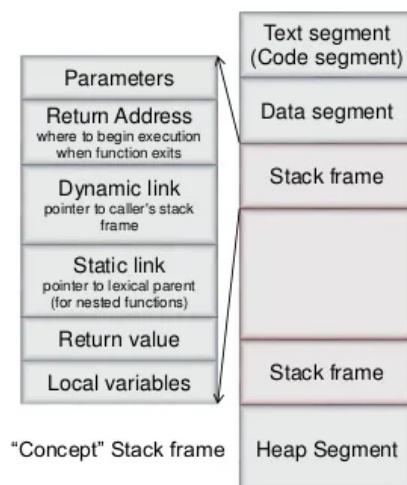


## Heap



- ▶ Large pool of memory
- ▶ Dynamic allocation
- ▶ Stays allocated until specifically deallocated → **leak!**
- ▶ Must be accessed through a pointer
- ▶ Large arrays, structures, or classes should be stored **Heap → why?**
- ▶ Large & dynamic

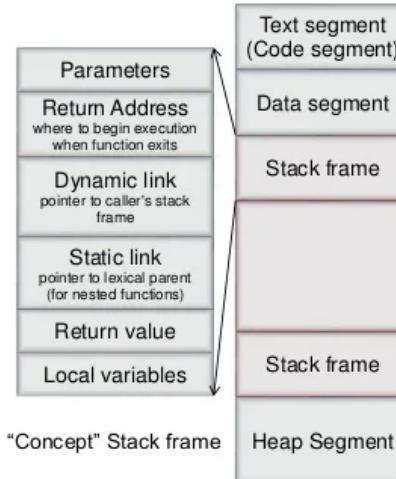
## Stack



- ❑ Where parameters and local variables are allocated
- ❑ Limited size → **Stack overflow**
- ❑ Memory use in stack is temporary and auto release
- ❑ Fast processing/low size

▶ 6

## Stack



- ❑ Where parameters and local variables are allocated
- ❑ Limited size → **Stack overflow**
- ❑ Memory use in stack is temporary and auto release
- ❑ Fast processing/low size

▶ 6

Basics of pointers      Using pointers in functions  
Dynamic memory allocation (DMA)      Arrays and pointer arithmetic

### Releasing space manually

- The `delete` operator will release a dynamically-allocated space.
- The `delete` operator will do nothing to the pointer. To avoid reusing the released space, set the pointer to `nullptr`.

```
int* a = new int;
delete a; // release 4 bytes
int* b = new int[5];
delete b; // release only 4 bytes!
// Unpredictable results may happen
delete [] b; // release all 20 bytes
```

```
int* a = new int;
delete a; // a is still pointing to the address
a = nullptr; // now a points to nothing
int* b = new int[5];
delete [] b; // b is still pointing to the address
b = nullptr; // now b points to nothing
```

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Dynamic memory allocation (DMA)      Arrays and pointer arithmetic

### Good programming style

- Use DMA for arrays with **no predetermined** length.
  - Even though Dev-C++ (and some other compilers) converts

|                          |                        |
|--------------------------|------------------------|
| <code>int a = 10;</code> | <code>int b[a];</code> |
|--------------------------|------------------------|

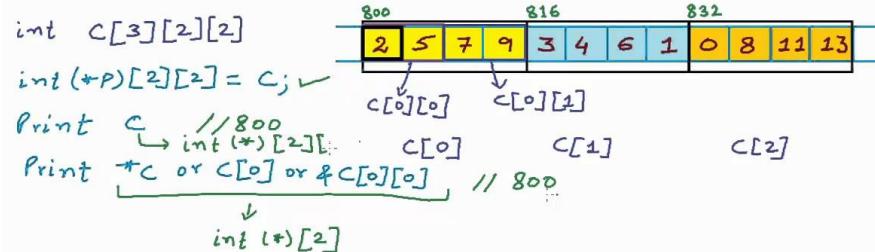
to

|                           |                                   |
|---------------------------|-----------------------------------|
| <code>int a = 10;</code>  | <code>int* b = new int[a];</code> |
| <code>// ...</code>       |                                   |
| <code>delete [] b;</code> |                                   |
- To avoid memory leak:
  - Whenever you write a `new` statement, add a `delete` statement below immediately (unless you know you really do not need it).
  - Whenever you want to change the value of a pointer, check whether memory leak occurs.
  - Whenever you write a `delete` statement, set the pointer to `nullptr`.

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## Multi-Dimesion Array

### Pointers and multi-dimensional arrays



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```
int num[3][4] = {
    {1, 2, 3, 4},
    {5, 6, 7, 8},
    {9, 10, 11, 12}
};
```

CLASSROOM

row-wise memory allocation

|                                     | ← row 0 → |      |      |      | ← row 1 → |      |      |      | ← row 2 → |      |      |      |
|-------------------------------------|-----------|------|------|------|-----------|------|------|------|-----------|------|------|------|
| value                               | 1         | 2    | 3    | 4    | 5         | 6    | 7    | 8    | 9         | 10   | 11   | 12   |
| address                             | 1000      | 1002 | 1004 | 1006 | 1008      | 1010 | 1012 | 1014 | 1016      | 1018 | 1020 | 1022 |
| ↑<br>first element of the array num |           |      |      |      |           |      |      |      |           |      |      |      |

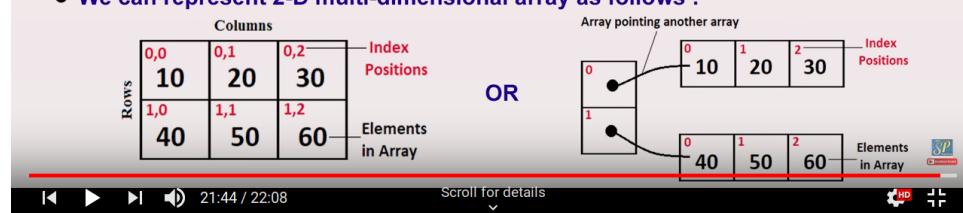
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Arrays In Java - 2D Arrays (Multidimensional Arrays) by Deepak (Part 1) || Arrays for ... ⓘ ⏱ ➔

## Multi-Dimensional (2-D)

### What is Multi-Dimensional Array :

- An array having multiple rows or columns is known as multi-dimensional array.
- These are also known as array of arrays because array is present in another array.
- There are two types of multi-dimensional array :
  1. 2-D Array
  2. 3-D Array
- We can represent 2-D multi-dimensional array as follows :



Basics of pointers      Using pointers in functions  
 Dynamic memory allocation (DMA)      Arrays and pointer arithmetic

## Example: lower triangular arrays

- Let's visualize the memory events.
- In general, the space of the three 1-dim dynamic arrays may be **separated**.
- However, the space of the array elements in each array are **contiguous**.

```
int main()
{
    int r = 3;
    int** array = new int*[r];
    for(int i = 0; i < r; i++)
    {
        array[i] = new int[i + 1];
        for(int j = 0; j <= i; j++)
            array[i][j] = j + 1;
    }
    print(array, r); // later
    // some delete statements
    return 0;
}
```

| Address  | Identifier | Value    |
|----------|------------|----------|
| 0x20c644 | r          | 3        |
| 0x20c648 | Array      | 0x20c654 |
| 0x20c650 |            |          |
| 0x20c654 | N/A        | 0x20c66c |
| 0x20c65c | N/A        | 0x20c670 |
| 0x20c664 | N/A        | 0x20c678 |
| 0x20c66c | N/A        | 1        |
| 0x20c670 | N/A        | 1        |
| 0x20c674 | N/A        | 2        |
| 0x20c678 | N/A        | 1        |
| 0x20c67c | N/A        | 2        |
| 0x20c680 | N/A        | 3        |

Memory

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 Dynamic memory allocation (DMA)      Arrays and pointer arithmetic

## Example: lower triangular arrays

- To pass a two-dimensional dynamic array, just pass that pointer.

```
int main()
{
    int r = 3;
    int** array = new int*[r];
    for(int i = 0; i < r; i++)
    {
        array[i] = new int[i + 1];
        for(int j = 0; j <= i; j++)
            array[i][j] = j + 1;
    }
    print(array, r);
    // some delete statements
    return 0;
}
```

```
void print(int** arr, int r)
{
    for(int i = 0; i < r; i++)
    {
        for(int j = 0; j <= i; j++)
            cout << arr[i][j] << " ";
        cout << "\n";
    }
}
```

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## Example: lower triangular arrays

- An alternative:

```
int main()
{
    int r = 3;
    int** array = new int*[r];
    for(int i = 0; i < r; i++)
    {
        array[i] = new int[i + 1];
        for(int j = 0; j <= i; j++)
            array[i][j] = j + 1;
    }
    print(array, r);
    // some delete statements
    return 0;
}
```

```
void print1D(int* arr, int n)
{
    for(int i = 0; i < n; i++)
        cout << arr[i] << " ";
    cout << "\n";
}
void print(int** arr, int r)
{
    for(int i = 0; i < r; i++)
        print1D(arr[i], i + 1);
}
```

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# Pointer Arithmetic

## Introduction to C++

## Pointer Arithmetic

- The C++ language allows you to perform integer addition or subtraction operations on pointers.
- If ptr points to an integer , ptr + 1 is the address of the next integer in memory after ptr.
- ptr - 1 is the address of the previous integer before ptr.
- Note** that ptr + 1 does not return the *memory address* after ptr, but the memory address of the *next object of the type* that ptr points to. If ptr points to an integer (assuming 4 bytes), ptr + 3 means 3 integers after ptr, which is 12 memory addresses after ptr. If ptr points to a char, which is always 1 byte, ptr + 3 means 3 chars after ptr, which is 3 memory addresses after ptr.
- When calculating the result of a pointer arithmetic expression, the compiler always multiplies the integer operand by the size of the object being pointed to. This is called **scaling**.

## Lecture Slides By Adil Aslam

## Pointer Arithmetic

- int \*p, \*q;**  
**q = p + 1;**
  - Construct a pointer to the next *integer* after \*p and assign it to q
- double \*p, \*r;**  
**int n;**  
**r = p + n;**
  - Construct a pointer to a *double* that is n *doubles* beyond \*p, and assign it to r
  - n may be negative

| Basics of pointers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Using pointers in functions   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| Dynamic memory allocation (DMA)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Arrays and pointer arithmetic |
| <h2>Indexing and pointer arithmetic</h2> <ul style="list-style-type: none"> <li>The array indexing operator [] is just an <b>interface</b> for doing pointer arithmetic.           <ul style="list-style-type: none"> <li>Interface: a (typically safer and easier) way of completing a task.</li> </ul> <pre>int x[3] = {1, 2, 3}; for(int i = 0; i &lt; 3; i++)   cout &lt;&lt; x[i] &lt;&lt; " "; // x[i] == *(x + i) for(int i = 0; i &lt; 3; i++)   cout &lt;&lt; *(x + i) &lt;&lt; " "; // 1 2 3</pre> <ul style="list-style-type: none"> <li>x[i] and *(x + i) are identical, but using the former is safer and easier.</li> </ul> </li> <li>The address stored in an array variable (e.g., x) <b>cannot be modified</b>.           <pre>int x[3] = {1, 2, 3}; for(int i = 0; i &lt; 3; i++)   cout &lt;&lt; *(x+i) &lt;&lt; " "; // error!</pre> </li> </ul> |                               |

Basics of pointers      Using pointers in functions  
Dynamic memory allocation (DMA)      Arrays and pointer arithmetic

## Example 3: returning a pointer

- Recall that we want to find the first negative number in an array.
  - We want its **value** and **index**.
  - We return its address.
- Three issues remain.
  - Why not return its index?
  - What if all elements in **a** are nonnegative?
  - Why not **const int a[]**?

```
#include <iostream>
using namespace std;
int* firstNeg(int a[], const int n) {
    for(int i = 0; i < n; i++) {
        if(a[i] < 0)
            return &a[i];
    }
    return 0;
}
int main()
{
    int a[5] = {0};
    for(int i = 0; i < 5; i++)
        cin >> a[i];
    int* p = firstNeg(a, 5);
    cout << *p << " " << p - a << "\n";
    return 0; // what is p - a?
}
```

Basics of pointers      Using pointers in functions  
Dynamic memory allocation (DMA)      Arrays and pointer arithmetic

## Example 3: returning a pointer

- To take the possibility of having no negative number into consideration:

```
#include <iostream>
using namespace std;
int* firstNeg(int a[], const int n) {
    for(int i = 0; i < n; i++) {
        if(a[i] < 0)
            return &a[i];
    }
    return nullptr;
}
int main()
{
    int a[5] = {0};
    for(int i = 0; i < 5; i++)
        cin >> a[i];
    int* p = firstNeg(a, 5);
    if(p != nullptr)
        cout << *p << " " << p - a << "\n";
    return 0;
}
```

Basics of pointers      Using pointers in functions  
Dynamic memory allocation (DMA)      Arrays and pointer arithmetic

## Example 3: returning a pointer

- Why not **const int a[]**?
  - We return the address of **a[i]**, which allows the caller to alter the element.
  - const int\*** and **int\*** are different!

```
#include <iostream>
using namespace std;
int* firstNeg(int a[], const int n) {
    for(int i = 0; i < n; i++) {
        if(a[i] < 0)
            return &a[i];
    }
    return nullptr;
}
int main()
{
    int a[5] = {0};
    for(int i = 0; i < 5; i++)
        cin >> a[i];
    int* p = firstNeg(a, 5);
    if(p != nullptr)
        *p = -1 * *p; // *p at the LHS of =
    return 0;
}
```

- One cannot modify the variable pointed by a **constant pointer**.

Basics of pointers  
Dynamic memory allocation (DMA)

Using pointers in functions  
Arrays and pointer arithmetic

### Example 3: returning a pointer

- To use `const int a[]`, we need to change the return type.
  - We should also `return const int*`.
  - This is an `int*` that cannot be put at the LHS of an assignment operator.

```
#include <iostream>
using namespace std;
const int* firstNeg
    (const int a[], const int n) {
    for(int i = 0; i < n; i++) {
        if(a[i] < 0)
            return &a[i];
    }
    return nullptr;
}

int main()
{
    int a[5] = {0};
    for(int i = 0; i < 5; i++)
        cin >> a[i];
    const int* p = firstNeg(a, 5);
    if(p != nullptr)
        cout << *p << "\n"; // OK
    return 0;
}
```

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## String Processing Function

|          |                                                                                           |
|----------|-------------------------------------------------------------------------------------------|
| strcpy   | Copies a string into another                                                              |
| strncpy  | Copies first n characters of one string into another                                      |
| strcmp   | Compares two strings                                                                      |
| strncmp  | Compares first n characters of two strings                                                |
| strcmpi  | Compares two strings without regard to case ("i" denotes that this function ignores case) |
| stricmp  | Compares two strings without regard to case (identical to strcmpi)                        |
| strnicmp | Compares first n characters of two strings without regard to case                         |
| strdup   | Duplicates a string                                                                       |
| strchr   | Finds first occurrence of a given character in a string                                   |
| strrchr  | Finds last occurrence of a given character in a string                                    |
| strstr   | Finds first occurrence of a given string in another string                                |
| strset   | Sets all characters of string to a given character                                        |
| strnset  | Sets first n characters of a string to a given character                                  |
| strrev   | Reverses string                                                                           |

## Substring

String = "geeks"

Substring starts with:

|   |   |   |    |     |      |       |
|---|---|---|----|-----|------|-------|
| g | → | g | ge | gee | geek | geeks |
| e | → | e | ee | eek | eeks |       |
| e | → | e | ek | eks |      |       |
| k | → | k | ks |     |      |       |
| s | → | s |    |     |      |       |

DG

# Main Function Arguments

## Command line arguments

argument count

array of string arguments

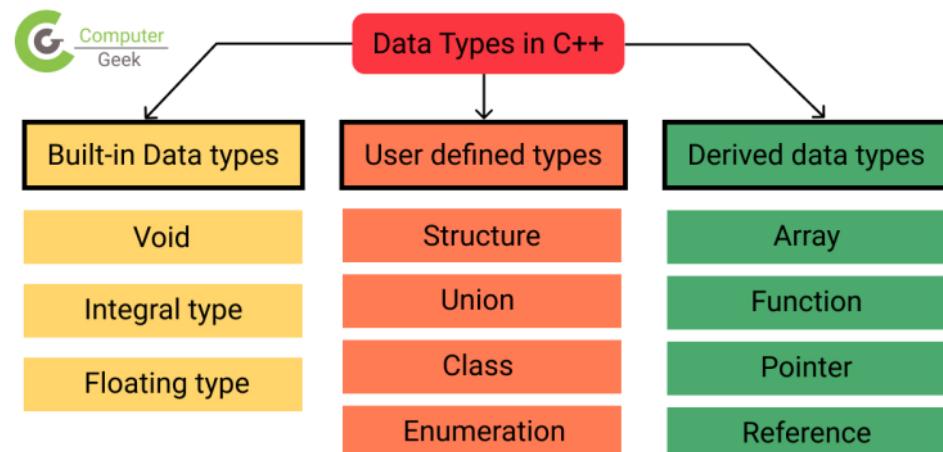
```
#include <stdio.h>
int main(int argc, char *argv[]) { }
```

argv[0] is the program name with full path

argv[1] is the first argument

argv[2] is the second argument, etc.

## Struct in C and Class in C++



# Structure Types (Using `typedef`)

```

typedef struct car { ← Old Type
    char engine[50];
    char fuel_type[10];
    int fuel_tank_cap;
    int seating_cap;
    float city_mileage;
} car; ← New Type
int main() {
    struct car c1;
}

```

car becomes a new data type.

**I53 C Programming**

## Structure

### Structures within Structures

1. C define a variable of structure type as a member of other structure type.
2. The syntax to define the structure within structure is

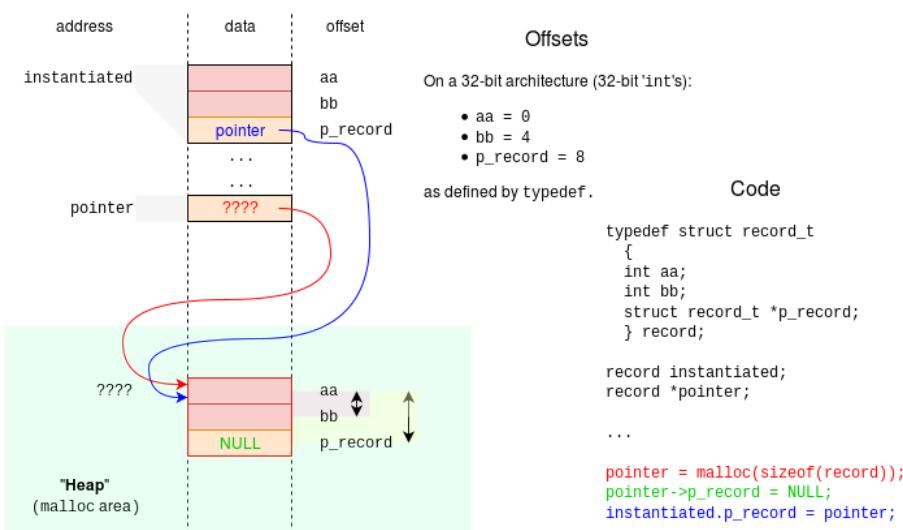
```

struct <struct_name>{
    <data_type> <variable_name>;
    struct <struct_name>
        { <data_type> <variable_name>;
            .......<struct_variable>;
        <data_type> <variable_name>;
    };

```



### Use of struct in C



```

class myClass {
public:
    int myNum;
private:
    string myStr;
protected:
    float myFloat;
}

public:
    myClass() {
    ...
}
myClass(int x, string y){
    ...
}

private:
    void myMethodOne() {
    ...
}

protected:
    void myMethodTwo() {
    ...
}
};


```

Data and Access Modifiers      Access Modifiers are used to assign the accessibility to the class members.

Constructors      A constructor is a member function which initialises objects of a class.

Methods      Methods are functions that perform operations on the class data.

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## Types of variables in C++

```

class GFG {

public:
    static int a; — Static Variable
    int b; — Instance Variable

public:
    func()
    {
        int c; — Local Variable
    };
};

```

DG

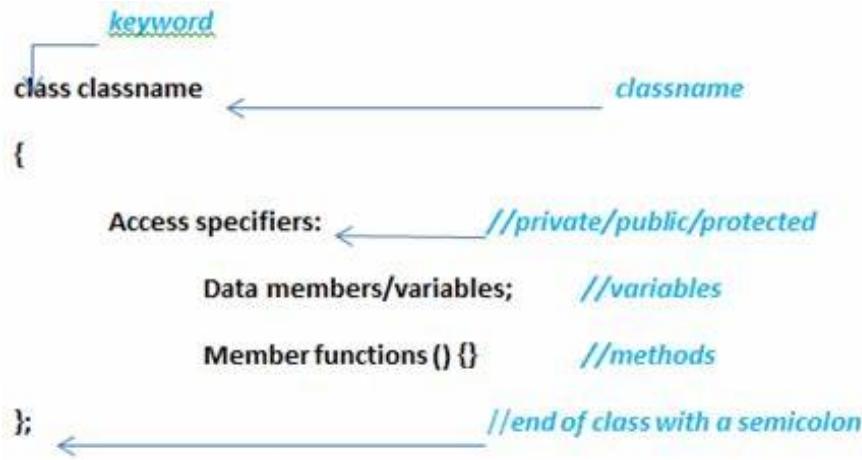
```

#include<iostream>
using namespace std;
class student
{
private :
    int id;
    char name[20];
public :
    int a;
    Void getdata(void);
    Void display (void)
    {
        cout << id << '\t' << name << endl;
    }
};

```


**Data Members**

**Member Functions**



| Structure                                                        | Class                                                     |
|------------------------------------------------------------------|-----------------------------------------------------------|
| It is a value type.                                              | It is a reference type.                                   |
| Its object is created on the stack memory.                       | Its object is created on the heap memory.                 |
| It does not support inheritance.                                 | It supports inheritance.                                  |
| The member variable of structure cannot be initialized directly. | The member variable of class can be initialized directly. |
| It can have only parameterized constructor.                      | It can have all the types of constructor and destructor.  |

## Class Constructor and Deconstructor

## Class Constructors

- A class constructor is a member function whose **purpose is to initialize the private data members** of a class object
- The name of a constructor is **always** the name of the class, and there is no return type for the constructor
- A class **may have several constructors** with different parameter lists. A constructor with no parameters is the **default constructor**
- A constructor is **implicitly and automatically invoked** when a class object is declared--if there are parameters, their values are listed in parentheses in the declaration

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3

## Destructor in C++

### Destructor



To destroy the object

Deallocates references  
and memory of object  
Members

If we do not create our  
own destructor.  
Compiler creates its  
own default destructor

Constructors are a unique class functions that do the job of destroying  
the instances of class.

Basic concepts  
Friends and static members

**Constructors and the destructor**  
Object pointers and the copy constructor

## Constructors

- A constructor's name is the same as the class.
- It does not return anything, not even **void**.
- You can (and usually will) overload them.
- The constructor with no parameter is the default constructor.
- If, and only if, a programmer does not define any constructor, the compiler makes a default one which does nothing.
- A constructor may be private.
  - Be invoked only by other constructors.

```
class MyVector
{
private:
    int n;
    int* m;
public:
    MyVector() // constructors
    MyVector(int dim);
    MyVector(int dim, int value);
    void print();
};
```

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Basic concepts  
Friends and static members

**Constructors and the destructor**  
Object pointers and the copy constructor

## Destructors

- A destructor is invoked right before an object is destroyed.
  - It must be public and have no parameter.
  - The compiler provides a default destructor that does nothing.
- To define your own destructor, use `~`.
  - Typically we release dynamically allocated space in a destructor.

```
class MyVector
{
private:
    int n;
    int* m;
public:
    // ~MyVector();
};

MyVector::~MyVector()
{
    delete [] m;
}
```

```
MyVector::MyVector
(int dim, int value)
{
    n = dim;
    m = new int[n];
    for(int i = 0; i < n; i++)
        m[i] = value;
}

int main()
{
    if (true)
        MyVector v1(1);
    // no memory leak
    return 0;
}
```

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# Getter and Setter



# Getters and Setters in C++



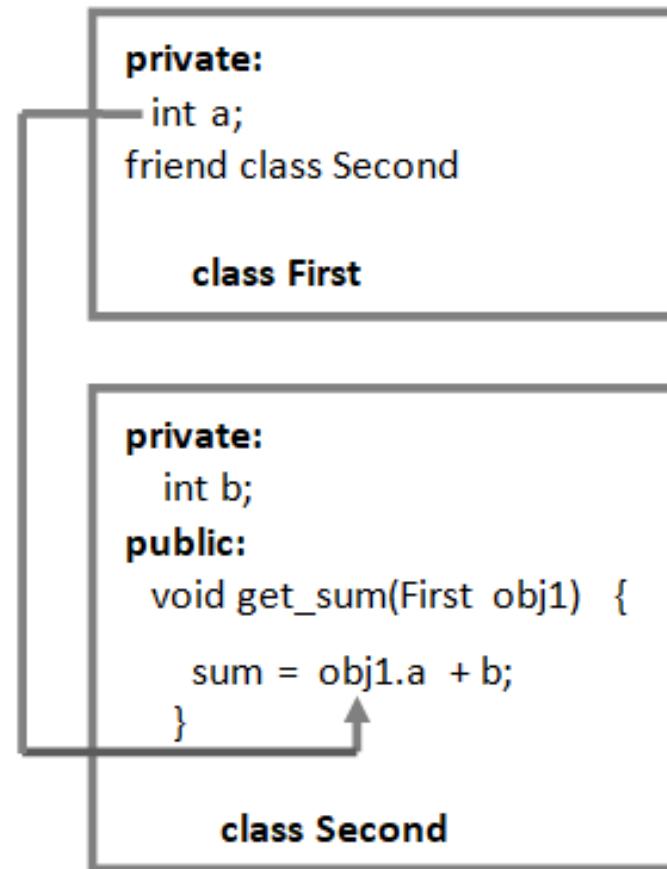
// Getters

```
int getHeight()
{
    return height;
}
```

// Setters

```
int setHeight(int h)
{
    height = h;
}
```

Friend



## Friend function characteristics

- It is not in scope of class.
- It cannot be called using object of that class.
- It can be invoked like a normal function.
- It should use a dot operator for accessing members.
- It can be public or private.
- It has objects as arguments.
- Perhaps the most common use of friend functions is **overloading << and >>** for I/O.

Basic concepts Constructors and the destructor  
**Friends and static members** Object pointers and the copy constructor

## friend for functions and classes

- Declare friends only if data hiding is preserved.
  - Do not set everything public!
  - Use structures rather than classes when nothing should be private (this is recommended but not required).
  - Be careful in offering public member functions (e.g., getters and setters).
- **friend** in fact **help you hide data**.
  - If a private member should be accessed only by another class/function, we should declare a friend instead of writing a getter/setter.

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# Static Member

Basic concepts Constructors and the destructor  
**Friends and static members** Object pointers and the copy constructor

## Static members: an example

- In MS Windows, each window is an object.
  - Windows is written in C++.
  - Mac OS is written in Objective-C.
- Each window has some object-specific attributes.
- They also share one class-specific attribute: the color of their title bars.

```
class Window
{
private:
    int width; ✓
    int height; ✓
    int locationX; ✓
    int locationY; ✓
    int status; // 0: min, 1: usual, 2: max
    static int barColor; // 0: gray, ...
    // ...
public:
    static int getBarColor();
    static void setBarColor(int color);
    // ...
};
```

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Basic concepts Constructors and the destructor  
**Friends and static members** Object pointers and the copy constructor

## Static members: an example

- We have to initialize a static variable globally.
- To access static members, use class name::member name.

```
int Window::barColor = 0; // default
int Window::getBarColor()
{
    return barColor;
}

void Window::setBarColor(int color)
{
    barColor = color;
}
```

```
int main()
{
    Window w; // not used
    cout << Window::getBarColor();
    cout << "\n";
    Window::setBarColor(1);
    return 0;
}
```

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Basic concepts Constructors and the destructor  
Friends and static members Object pointers and the copy constructor

## Good programming style

- If one attribute should be identical for all objects, it should be declared as a static variable.
  - Do not make it an instance variable and try to maintain consistency.
- Do not use an object to invoke a static member.
  - This will confuse the reader.
- Use class name::member name even inside member function definition to show that it is a static member.

```
int Window::getBarColor()
{
    return Window::barColor;
}
```

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# Object Pointer

Basic concepts Constructors and the destructor  
Friends and static members Object pointers and the copy constructor

## Object pointers

- What we have done is to use an object to invoke instance functions.
  - E.g., a.print() where a is an object and print() is an instance function.
- If we have a pointer ptrA pointing to the object a, we may write (\*ptrA).print() to invoke the instance function print().
  - \*ptrA returns the object a.
- To simplify this, C++ offers the member access operator >>
  - This is specifically for an object pointer to access its members.
  - (\*ptrA).print() is equivalent to ptrA->print().

```
int main()
{
    MyVector v(5);
    MyVector* ptrV = &v;
    v.print();
    ptrV->print();
    return 0;
}
```

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Basic concepts Constructors and the destructor  
Friends and static members Object pointers and the copy constructor

## Why object pointers? MyVector v[5]

- Object pointers can be more useful than pointers for basic data types. Why?
- When one creates an array of objects, only the default constructor may be invoked.
  - Creating an array of object pointers delays the invocation of constructors.
  - These pointers than point to dynamically allocated objects.
- Passing a pointer into a function can be more efficient than passing the object.
  - A pointer can be much smaller than an object.
  - Copying a pointer is easier than copying an object.
- Other reasons will be discussed in other lectures.

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Basic concepts Friends and static members Constructors and the destructor Object pointers and the copy constructor

## Passing object pointers into a function

- We may pass pointers rather than objects into this function:

```
MyVector sum(MyVector* v1, MyVector* v2, MyVector* v3)
{
    // assume that their dimensions are identical
    int n = v1->getN();
    int* sov = new int[n];
    for(int i = 0; i < n; i++)
        sov[i] = v1->getM(i) + v2->getM(i) + v3->getM(i);
    MyVector sumOfVec(n, sov);
    return sumOfVec;
}
```

– We need to create only one `MyVector` object in this function.  
– Nevertheless, using pointers to access members requires more time.

# Copy Constructor

Basic concepts Friends and static members Constructors and the destructor Object pointers and the copy constructor

## Copying an object

- Creating an object by “copying” an object is a special operation.
  - When we pass an object into a function using the call-by-value mechanism.
  - When we assign an object to another object.
  - When we create an object with another object as the argument of the constructor.
- When this happens, the copy constructor will be invoked.
  - If the programmer does not define one, the compiler adds a default copy constructor (which of course does not print out anything) into the class.
  - The default copy constructor simply copies all member variables one by one, regardless of the variable types.

Basic concepts Friends and static members Constructors and the destructor Object pointers and the copy constructor

## Copy constructors

- We may implement our own copy constructor.
  - In the C++ standard, the parameter must be a constant reference.
  - If calling by value, it will invoke itself infinitely many times.

```
class A
{
private:
    int i;
public:
    A() { cout << "A"; }
    A(const A& a) { cout << "a"; }
};

void f(A a1, A a2, A a3)
{
    A a4;
}
int main()
{
    A a1, a2, a3; // AAA
    cout << "\n====\n";
    f(a1, a2, a3); // aaaA
    return 0;
}
```

Basic concepts  
Friends and static members  
Constructors and the destructor  
Object pointers and the copy constructor

## Copy constructors for MyVector

- For **MyVector**, one way to implement a copy constructor is
  - This has nothing different from the default copy constructor.
  - If no member is an array/pointer, the default copy constructor is fine.
- If there is any **array or pointer member**, the default copy constructor does **"shallow copy"**.
  - And two different vectors may share the same space for values.
  - Modifying one vector affects the other!

**Code:**

```
MyVector::MyVector(const MyVector& v)
{
    n = v.n;
    m = v.m;
}
```

**int main()**

```
{ MyVector v1(5, 1);
  MyVector v2(v1); // what is bad? }
```

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Basic concepts  
Friends and static members  
Constructors and the destructor  
Object pointers and the copy constructor

## Deep copy

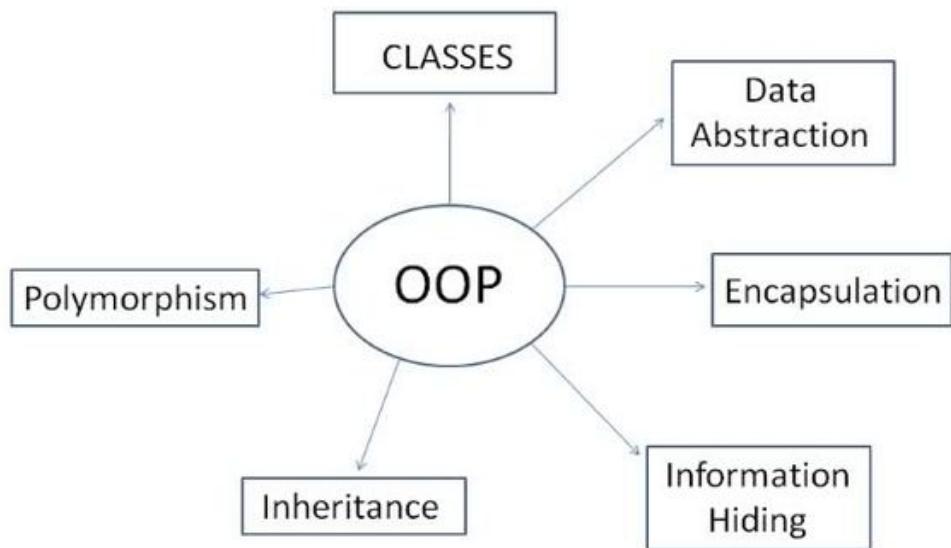
- To correctly copy a vector (by creating new values), we need to write our own copy constructor.
- We say that we implement "**deep copy**" by ourselves.
  - In the self-defined copy constructor, we manually create another dynamic array, set its elements' values according to the original array, and use **m** to record its address.

**Code:**

```
MyVector::MyVector(const MyVector& v)
{
    n = v.n;
    m = new int[n]; // deep copy
    for(int i = 0; i < n; i++)
        m[i] = v.m[i];
}
```

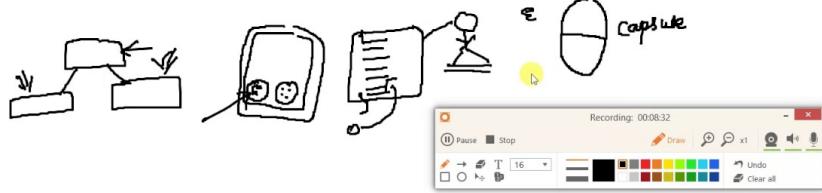
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# OOP



## Four Pillars of Object Oriented Programming.

- **Inheritance:** Process of creating new classes from existing classes.
- **Abstraction:** Refers to providing only essential information and hiding the background details from the end user.
- **Encapsulation:** Binding together of data and functions that manipulate that data and keep both safe from outside interference and misuse.
- **Polymorphism:** Refers to one interface and many forms.



## Data Abstraction

## What is Data Abstraction?

- A data abstraction is a simplified view of an object that
  - includes only features one is interested in.
  - while hides away the unnecessary details.
- In programming languages, a data abstraction becomes an abstract data type (ADT) or a user-defined type.
- In OOP, it is implemented as a class



## Data Abstraction in C++ (continued)

(11.14)

- Constructors
  - functions to initialize the data members of instances
  - may also allocate storage if part of the object is heap-dynamic
  - can include parameters to provide parameterization of the objects
  - implicitly called when an instance is created
    - » can be explicitly called
  - name is the same as the class name
- Destructors
  - functions to cleanup after an instance is destroyed; usually just to reclaim heap storage
  - implicitly called when the object's lifetime ends
    - » can be explicitly called
  - name is the class name, preceded by a tilde (~)

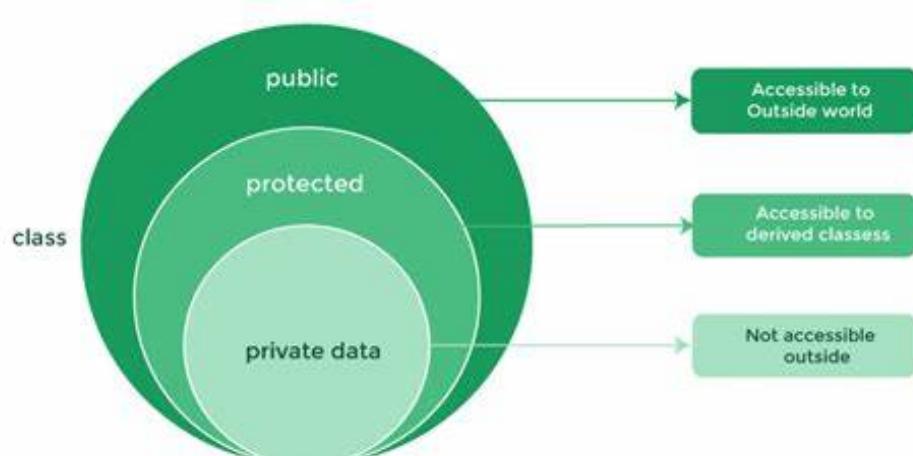
## Encapsulation

## Access Control

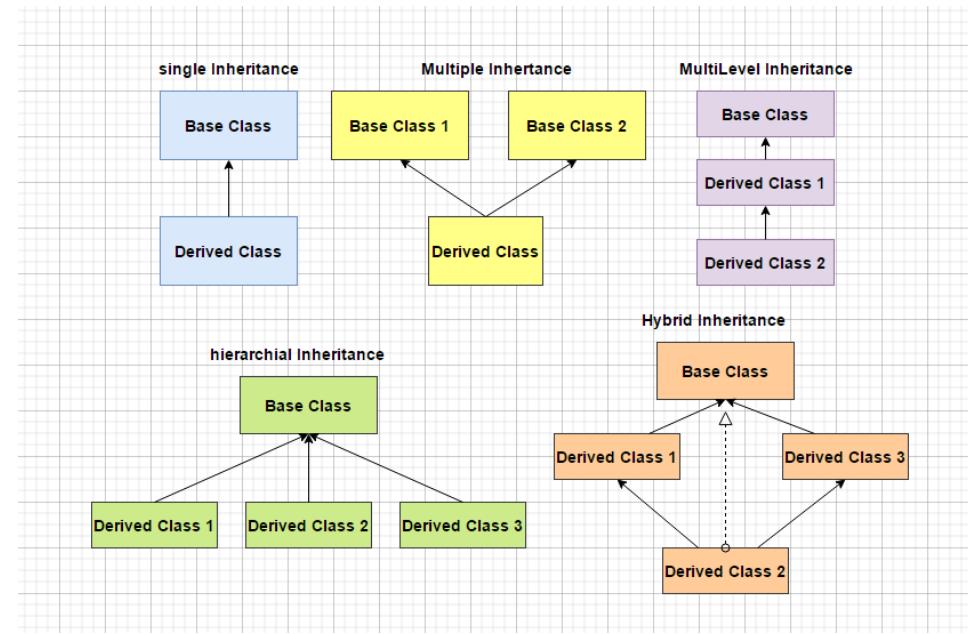
- ▶ We use the **private section** of the struct to **encapsulate** our data type as in our ADTs in C
- ▶ But if the struct is defined in the header file, doesn't this **break encapsulation?**
  - ◆ No! Encapsulation is not about *hiding information* from the user, it's about ensuring that he uses our ADT **in a safe way**, which we achieve by enabling him to use only its public interface
- ▶ However, unlike ADTs in C style, we do not get **compile-time** encapsulation
  - ◆ In other words, changing the private part of a struct will require **recompiling files** that use the ADT

## Encapsulation

- **Encapsulation** is the **packing of data** and **functions** into a single component. The features of **encapsulation** are supported using classes in most object-oriented programming languages, although other alternatives also exist.
- **Encapsulation** is:
  - A language mechanism for restricting access to some of the object's components. (public, private, protected)
  - A language construct that facilitates the bundling of data with the methods (or other functions) operating on that data.

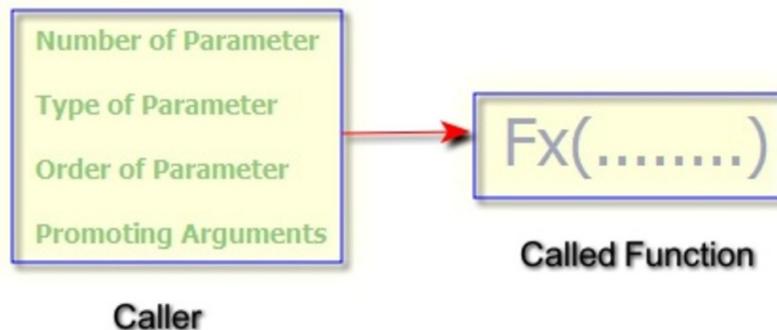
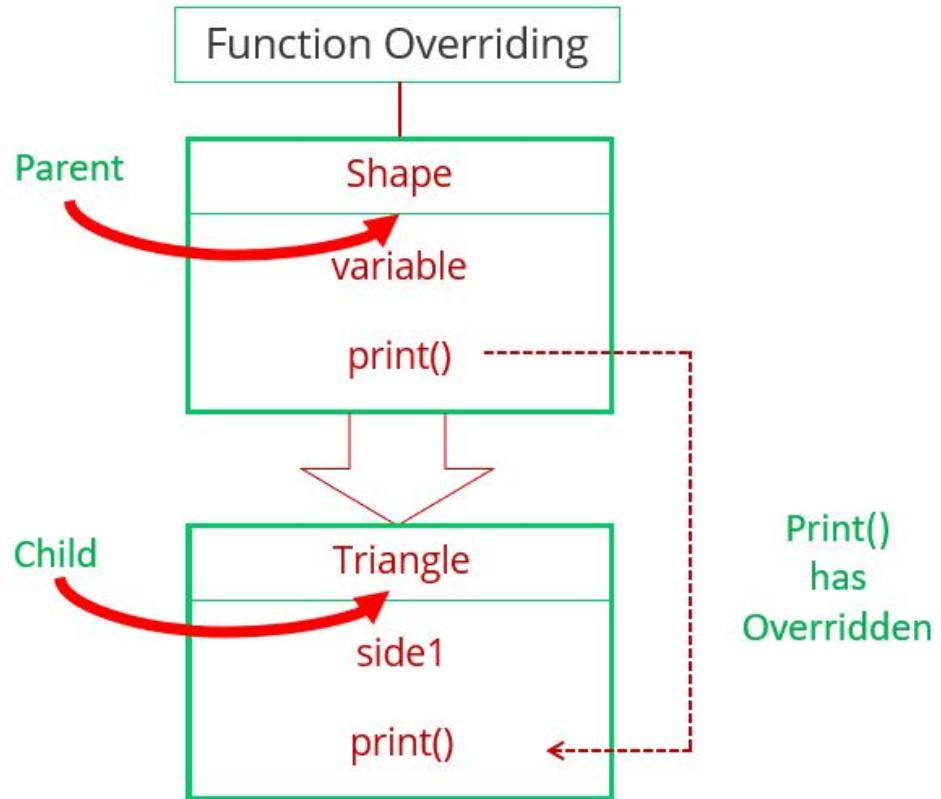


## Inheritance



| Base-class member-access specifier | Type of inheritance                                                                                                                                  |                                                                                                                                                      |                                                                                                                                                      |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                    | public inheritance                                                                                                                                   | protected inheritance                                                                                                                                | private inheritance                                                                                                                                  |
| public                             | <b>public</b> in derived class.<br>Can be accessed directly by member functions, friend functions and nonmember functions.                           | <b>protected</b> in derived class.<br>Can be accessed directly by member functions and friend functions.                                             | <b>private</b> in derived class.<br>Can be accessed directly by member functions and friend functions.                                               |
| protected                          | <b>protected</b> in derived class.<br>Can be accessed directly by member functions and friend functions.                                             | <b>protected</b> in derived class.<br>Can be accessed directly by member functions and friend functions.                                             | <b>private</b> in derived class.<br>Can be accessed directly by member functions and friend functions.                                               |
| private                            | Hidden in derived class.<br>Can be accessed by member functions and friend functions through public or protected member functions of the base class. | Hidden in derived class.<br>Can be accessed by member functions and friend functions through public or protected member functions of the base class. | Hidden in derived class.<br>Can be accessed by member functions and friend functions through public or protected member functions of the base class. |

## Overriding vs Overloading



## Overloading in C++

❑ What is overloading

- Overloading means assigning multiple meanings to a function name or operator symbol
- It allows multiple definitions of a function with the same name, but different signatures.

❑ C++ supports

- Function overloading
- Operator overloading

3

Ritika sharma



## Overloading and Overriding in C++

**Function Overloading**

```
int add(int, int);
int add(int, int, int);
double add(double, double);
```

### Base Class

### Derived Class

**class A**  
int add(int, int);  
  
**class B**  
int add(int, int);

**Function Overriding**

## Overloading vs. Overriding

- Overriding a base class member function is similar to overloading a function or operator
  - But for overriding, definitions are distinguished by their scopes rather than by their signatures
- C++ can distinguish method definitions according to either static or dynamic type
  - Depends on whether a method is virtual or not
  - Depends on whether called via a reference or pointer vs. directly on an object
  - Depends on whether the call states the scope explicitly (e.g., `Foo::baz()` ;)

# Polymorphism

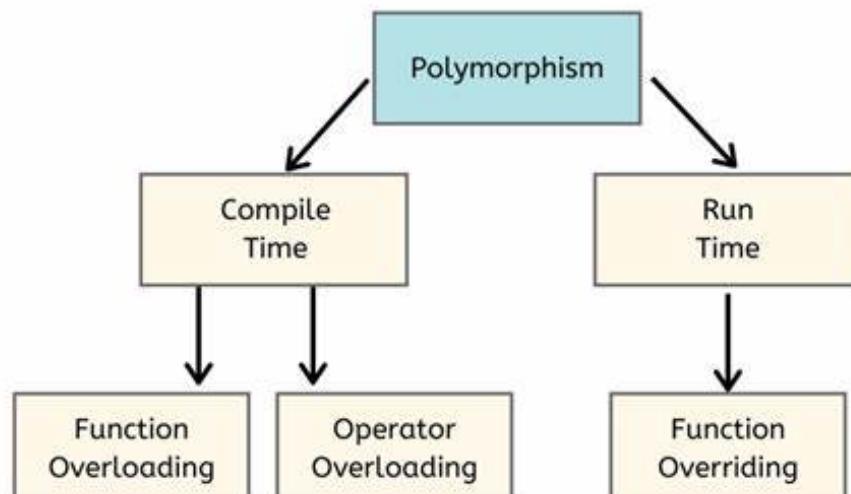
## Overview of C++ Polymorphism

- Two main kinds of types in C++: native and user-defined
  - “User” defined types: declared classes, structs, unions
    - including types provided by the C++ standard libraries
  - Native types are “built in” to the C++ language itself: int, long, float, ...
  - A `typedef` creates a new type *name* for another type (type aliasing)
- Public inheritance creates sub-types
  - Inheritance only applies to user-defined classes (and structs)
  - A publicly derived class is-a subtype of its base class
  - Known as “inheritance polymorphism”
- Template parameters also induce a subtype relation
  - Known as “interface polymorphism”
  - We’ll cover how this works in depth, in later sessions
- Liskov Substitution Principle (for both kinds of polymorphism)
  - if S is a subtype of T, then wherever you need a T you can use an S

CSE 332: C++ Polymorphism



## Polymorphism in C++



Above is achieved using virtual keyword

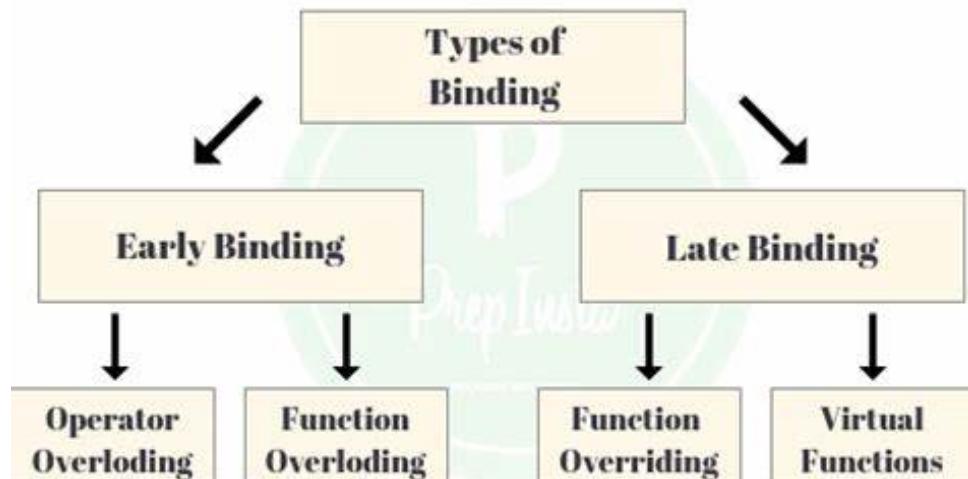
## Early Binding and Late Binding

## What is Binding ?

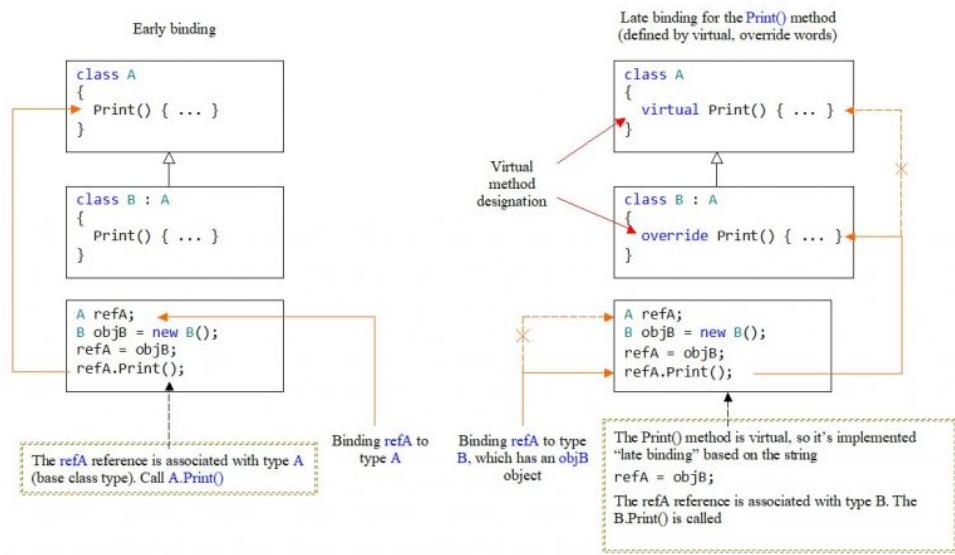
- **Binding** refers to the process that is used to convert identifiers (such as variable and function names) into machine language addresses.
- Although binding is used for both variables and functions, but we have to focus on function binding.



## Early binding & Late binding in C++



| Sr. No. | Early Binding                                                                                     | Late Binding                                                    |
|---------|---------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| 1.      | Early binding is the process of linking a function with an object during the compilation process. | Late binding is a run-time polymorphism with method overriding. |
| 2.      | Static binding is another name for early binding.                                                 | Dynamic binding is another name for late binding.               |
| 3.      | Early binding happens at compile time.                                                            | Late binding happens at run time.                               |
| 4.      | Execution speed is faster in early binding.                                                       | Execution speed is lower in late binding.                       |
| 5.      | The class information is used by Early binding to resolve method calls.                           | The object is used by Late binding to resolve method calls.     |



## Virtual Function

| Inheritance                                                                                                                                                                                                                                                                                                                                                                                                                                       | An example                                                                                                                                                                                                                                                                                                                                                          | Polymorphism |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| <h1>Virtual functions</h1>                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                     |              |
| <ul style="list-style-type: none"><li>If we declare a parent's member function to be <b>virtual</b>, its invocation priority will be lower than a child's (if we use late binding).<ul style="list-style-type: none"><li>A child cannot declare a parent's function as <b>virtual</b> (<u>it is of no use</u>).</li></ul></li><li>In summary, we need:<ul style="list-style-type: none"><li>Late binding + virtual functions.</li></ul></li></ul> | <pre>class Parent { protected:     int x;     int y; public:     Parent(int a, int b) : x(a), y(b) {}     virtual void print() { cout &lt;&lt; x &lt;&lt; " " &lt;&lt; y; } };  class Child : public Parent { protected:     int z; public:     Child(int a, int b, int c) : Parent(a, b)     {         z = c;     }     void print() { cout &lt;&lt; z; } };</pre> |              |

| Inheritance | An example                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Polymorphism |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
|             | <h2>Abstract classes</h2> <ul style="list-style-type: none"> <li>The two virtual functions are different in their natures:           <ul style="list-style-type: none"> <li><code>print()</code> is invoked in the children's implementations.</li> <li><code>beatMonster()</code> should not be invoked by any one.</li> </ul> </li> <li>We may set <code>beatMonster()</code> to be a <u>pure virtual function</u>.</li> </ul> <pre>class Character {     // ...     virtual void beatMonster(int exp) = 0; };</pre> <ul style="list-style-type: none"> <li>Now we do not need to implement it.</li> <li>Moreover, we <u>cannot</u> create <code>Character</code> objects!</li> </ul> |              |

| Inheritance | An example                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Polymorphism |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
|             | <h2>Summary</h2> <ul style="list-style-type: none"> <li>Polymorphism is a technique to make our program <u>clearer</u>, <u>more flexible</u> and <u>more powerful</u>.           <ul style="list-style-type: none"> <li>It is based on <u>inheritance</u>.</li> <li>It is tightly related to <u>function overriding</u>, <u>late binding</u>, and <u>virtual functions</u>.</li> </ul> </li> <li>The key action is to “use a <u>parent pointer</u> to point to a <u>child object</u>”.</li> </ul> |              |

## Virtual Functions

---

```
class A {
public:
    A () {cout<< " A";}
    virtual ~A () {cout<< " ~A";}
    virtual f(int);
};

class B : public A {
public:
    B () :A() {cout<< " B";}
    virtual ~B() {cout<< " ~B";}
    virtual f(int) override; //C++11
};

int main (int, char *[]) {
    // prints "A B"
    A *ap = new B;

    // prints "~B ~A" : would only
    // print "~A" if non-virtual
    delete ap;

    return 0;
}
```

**CSE 332: C++ Polymorphism**

- Used to support polymorphism with pointers and references
- Declared virtual in a base class
- Can override in derived class
  - OVERRIDING only happens when signatures are the same
  - Otherwise it just *overloads* the function or operator name
    - More about overloading next lecture
- Ensures derived class function definition is resolved **dynamically**
  - E.g., that destructors farther down the hierarchy get called
- Use **final** (C++11) to prevent overriding of a virtual method
- Use **override** (C++11) in derived class to ensure that the signatures match (error if not)

## Virtual Functions

```

class A {
public:
    void x() {cout<<"A::x";}
    virtual void y() {cout<<"A::y";}
};

class B : public A {
public:
    void x() {cout<<"B::x";}
    virtual void y() {cout<<"B::y";}
};

int main () {
    B b;
    A *ap = &b; B *bp = &b;
    b.x (); // prints "B::x"
    b.y (); // prints "B::y"
    bp->x (); // prints "B::x"
    bp->y (); // prints "B::y"
    ap->x (); // prints "A::x"
    ap->y (); // prints "B::y"
    return 0;
}

```

- Only matter with pointer or reference
  - Calls on object itself resolved statically
  - E.g., **b.y()**;
- Look first at pointer/reference type
  - If non-virtual there, resolve statically
    - E.g., **ap->x()**;
  - If virtual there, resolve dynamically
    - E.g., **ap->y()**;
- Note that virtual keyword need not be repeated in derived classes
  - But it's good style to do so
- Caller can force static resolution of a virtual function via scope operator
  - E.g., **ap->A::y()**; prints "A::y"

## CSE 332: C++ Polymorphism

## this

|                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Motivations and prerequisites</b></p> <p>Assignment and self-assignment operators</p> <p style="text-align: center;"><b>this</b></p> <p>• When you create an object, it occupies a memory space.</p> <p>• Inside an <u>instance function</u>, <u>this</u> is a <u>pointer</u> storing the <u>address</u> of that object.       <ul style="list-style-type: none"> <li>– <b>this</b> is a C++ keyword.</li> </ul> </p> | <p>Comparison and indexing operators</p> <p>Addition operators</p> <pre> class A { private:     int a; public:     void f() { cout &lt;&lt; this &lt;&lt; "\n"; }     A* g() { return this; } }; int main() {     A obj;     cout &lt;&lt; &amp;obj &lt;&lt; "\n"; // 0x9ffe40     obj.f(); // 0x9ffe40     cout &lt;&lt; (&amp;obj == obj.g()) &lt;&lt; "\n"; // 1     return 0; } </pre> |
|                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                            |

Programming Design – Operator Overloading      10 / 49      Ling-Chieh Kung (NTU IM)

## Constant Object

|                                          |                                   |
|------------------------------------------|-----------------------------------|
| Motivations and prerequisites            | Comparison and indexing operators |
| Assignment and self-assignment operators | Addition operators                |

## Constant objects

- A constant object cannot invoke a function that modifies its instance variables.
  - In C++, functions that may be invoked by a constant object must be declared as a **constant instance function**.
- For a constant instance function:
  - It can be called by non-constant objects.
  - It cannot modify any instance variable.
- For a non-constant instance function:
  - It cannot be called by constant objects even if no instance variable is modified.

```
class MyVector
{
private:
    int n;
    int* m;
public:
    MyVector();
    MyVector(int dim, int v[]);
    MyVector(const MyVector& v);
    ~MyVector();
    void print() const;
};
```

Programming Design – Operator Overloading      15 / 49      Ling-Chieh Kung (NTU IM)

# Member Initializers

|                                          |                                   |
|------------------------------------------|-----------------------------------|
| Motivations and prerequisites            | Comparison and indexing operators |
| Assignment and self-assignment operators | Addition operators                |

## ✓ Member initializers

- We need a **member initializer**.
  - ✓ A specific operation for initializing an instance variable.
  - Can also be used for initializing non-constant instance variables.
- ✓ Member initializers are used a lot in general.

```
MyVector:: MyVector() : n(0)
{
    m = nullptr;
}
MyVector:: MyVector(int dim, int v[]) : n(dim)
{
    for(int i = 0; i < n; i++)
        m[i] = v[i];
}
MyVector:: MyVector(const MyVector& v) : n(v.n)
{
    m = new double[n];
    for(int i = 0; i < n; i++)
        m[i] = v.m[i];
}
```

Programming Design – Operator Overloading      17 / 49      Ling-Chieh Kung (NTU IM)

# Operator Overload

|                                          |                                   |
|------------------------------------------|-----------------------------------|
| Motivations and prerequisites            | Comparison and indexing operators |
| Assignment and self-assignment operators | Addition operators                |

## Overloading an operator

- An operator is overloaded by “implementing a **special instance function**”.
  - ✓ It cannot be implemented as a static function.
- Let  $\text{op}$  be the operator to be overloaded, the “special instance function” is always named
  - ✓ **operator op**
- The keyword **operator** is used for overloading operators.
- Let’s overload  $=$  for **MyVector**.

Programming Design – Operator Overloading      19 / 49      Ling-Chieh Kung (NTU IM)

Motivations and prerequisites  
Assignment and self-assignment operators  
Comparison and indexing operators  
Addition operators

## Overloading ==

- To overload ==, simply do this:

```
class MyVector
{
private:
    int n;
    double* m;
public:
    // others
    bool operator==(const MyVector& v) const;
```

```
bool MyVector::operator==(const MyVector& v) const
{
    if(this->n != v.n)
        return false;
    else {
        for(int i = 0; i < n; i++) {
            if(this->m[i] != v.m[i])
                return false;
        }
    }
    return true;
}
```

Programming Design – Operator Overloading 21 / 49 Ling-Chieh Kung (NTU IM)

Motivations and prerequisites  
Assignment and self-assignment operators  
Comparison and indexing operators  
Addition operators

## Invoking overloaded operators

- We are indeed implementing instance functions with special names.
- Regarding invoking these instance functions:

```
int main() // without overloading
{
    double d1[5] = {1, 2, 3, 4, 5};
    const MyVector a1(5, d1);

    double d2[4] = {1, 2, 3, 4};
    const MyVector a2(4, d2);
    const MyVector a3(a1);

    cout << (a1.isEqual(a2) ? "Y" : "N");
    cout << "\n";
    cout << (a1.isEqual(a3) ? "Y" : "N");
    cout << "\n";

    return 0;
}
```

```
int main() // with overloading
{
    double d1[5] = {1, 2, 3, 4, 5};
    const MyVector a1(5, d1);

    double d2[4] = {1, 2, 3, 4};
    const MyVector a2(4, d2);
    const MyVector a3(a1);

    cout << (a1 == a2 ? "Y" : "N");
    cout << "\n";
    cout << (a1 == a3 ? "Y" : "N");
    cout << "\n";

    return 0;
}
```

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# Assignment Operator

| SYMBOLS | MEANINGS                                                                                               |
|---------|--------------------------------------------------------------------------------------------------------|
| "=      | <b>EQUAL:</b> it assigns value to the variable                                                         |
| "+="    | <b>ADD EQUAL:</b> it means it updated the value of the variable after addition a+=5 (a=a+5)            |
| "-="    | <b>SUBTRACT EQUAL:</b> it means it updated the value of the variable after subtraction a-=5 (a=a-5)    |
| "*="    | <b>MULTIPLY EQUAL:</b> it means it updated the value of the variable after multiplication a*=5 (a=a*5) |
| "/="    | <b>DIVISION EQUAL:</b> it means it updated the value of the variable after division a/=5 (a=a/5)       |
| "%="    | <b>REMAINDER EQUAL:</b> it means it updated the value of the variable after remainder a%=5 (a=a%5)     |
| "&="    | <b>AND EQUAL:</b> it means both conditions are necessary                                               |
| " ="    | <b>NOTEQUAL:</b> it means condition are not equal                                                      |

# String Class



## String Class

- The **String** class contains several methods that can be used to perform operations on a string.

| <u>Method Name</u>                   | <u>Return Type</u>   | <u>Description</u>                                               | <u>Usage</u>                             |
|--------------------------------------|----------------------|------------------------------------------------------------------|------------------------------------------|
| <code>compareTo(String t)</code>     | <code>int</code>     | C.compares two strings                                           | <code>string1.compareTo(string2);</code> |
| <code>length()</code>                | <code>int</code>     | G.gets length of string                                          | <code>string1.length();</code>           |
| <code>charAt(int i)</code>           | <code>char</code>    | F.finds ith character                                            | <code>string1.charAt(3);</code>          |
| <code>equals(String t)</code>        | <code>Boolean</code> | A.are two strings equal?                                         | <code>string1.equals(string2);</code>    |
| <code>substring(int i, int j)</code> | <code>String</code>  | F.finds substring from ith character to character before jth one | <code>String1.substring(0, 2)</code>     |

## Correspondence between the C library and the C++ **string** Class

| C Library Functions         | C++ string operators/methods                             |
|-----------------------------|----------------------------------------------------------|
| <code>strcpy</code>         | <code>=</code> (the assignment operator)                 |
| <code>strcat</code>         | <code>+=</code> (assign+concat operator)                 |
| <code>strcmp</code>         | <code>==, !=, &lt;, &gt;, &lt;=, &gt;=</code>            |
| <code>strchr, strstr</code> | <code>.find( )</code> method                             |
| <code> strrchr</code>       | <code>.rfind( )</code> method                            |
| <code>strlen</code>         | <code>.size( )</code> or <code>.length( )</code> methods |

## getline()

**C++ strings**      File I/O      Self-defined header files

## string input: getline()

- For `cin >>` to input into a C++ string, **white spaces** are still delimiters.
- To fix this, now we cannot use `cin.getline()`.
  - The first argument of `cin.getline()` must be a C string.
- We use a global function `getline()` defined in `<string>` instead:

`string s; getline(cin, s);`

`istream& getline(istream& is, string& str);`

- By default, `getline()` stops when reading a **newline character**. We may specify the **delimiter character** we want:

`string s; getline(cin, s, '#');`

`istream& getline(istream& is, string& str, char delim);`

- Note that there is **no length limitation**.

Programming Design – C++ Strings, File I/O, and Header Files      9 / 62      Ling-Chieh Kung (NTU IM)

**C++ strings**      File I/O      Self-defined header files

## >> vs. getline()

- The two operations are similar but different:
  - `>>` tries to convert the piece into the specified type; `getline()` simply store that piece as a C or C++ string.
  - `>>` stops at the first character not of that type; `getline()` stops at one character after the delimiter.
- Suppose that the text file now may contain the first name and last name of a student, separated by a white space.
  - We use a colon to separate a name and a score.
- How to write a program to calculate the sum of scores?

Tony Wang: 100  
 Alex Chao: 98  
 Robin Chen: 95  
 Lin: 90  
 Mary: 100  
 Bob Tsai: 80

Programming Design – C++ Strings, File I/O, and Header Files      46 / 62      Ling-Chieh Kung (NTU IM)

**C++ strings**      File I/O      Self-defined header files

## >> vs. getline()

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

int main()
{
    ifstream inFile("score.txt");
    string name;
    int score = 0;
    int sumScore = 0;
```

```
if(inFile)
{
    while(!inFile.eof())
    {
        getline(inFile, name, ':');
        inFile >> score;
        sumScore += score;
    } // good!
    cout << sumScore << endl;
}
inFile.close();

return 0;
}
```

Tony Wang: 100  
 Alex Chao: 98  
 Robin Chen: 95  
 Lin: 90  
 Mary: 100  
 Bob Tsai: 80

Programming Design – C++ Strings, File I/O, and Header Files      47 / 62      Ling-Chieh Kung (NTU IM)

**>> vs. getline()**

- ✓ >> stops at the first character not of that type.
- After the inFile >> score operation, the input cursor stops at the newline character.
- The next getline(inFile, name) operation reads only the newline character into name.
  - The cursor gets to 'A' in the third line.
- The next inFile >> score operation then fails to convert "Alex" into an integer.
- To fix this problem, we need to manually bypass the newline character.
  - The member function ignore() ignores one character.

|            |     |
|------------|-----|
| Tony Wang  | 100 |
| Alex Chao  | 98  |
| Robin Chen | 95  |
| Lin        | 90  |
| Mary       | 100 |
| Bob Tsai   | 80  |

**>> vs. getline()**

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

int main()
{
    ifstream inFile("score.txt");
    string name;
    int score = 0;
    int sumScore = 0;
```

```
if(inFile)
{
    while(!inFile.eof())
    {
        getline(inFile, name);
        inFile >> score;
        inFile.ignore();
        sumScore += score;
    } // good!
    cout << sumScore << endl;
}
inFile.close();

return 0;
}
```

|            |     |
|------------|-----|
| Tony Wang  | 100 |
| Alex Chao  | 98  |
| Robin Chen | 95  |
| Lin        | 90  |
| Mary       | 100 |
| Bob Tsai   | 80  |

**An alternative way**

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

int main()
{
    ifstream inFile("score.txt");
    string name;
    string scoreStr;
    int score = 0;
    int sumScore = 0;
```

```
if(inFile)
{
    while(!inFile.eof())
    {
        getline(inFile, name);
        getline(inFile, scoreStr);
        score = stoi(scoreStr);
        sumScore += score;
    } // good!
    cout << sumScore << endl;
}
inFile.close();

return 0;
}
```

|            |     |
|------------|-----|
| Tony Wang  | 100 |
| Alex Chao  | 98  |
| Robin Chen | 95  |
| Lin        | 90  |
| Mary       | 100 |
| Bob Tsai   | 80  |

## substr()

**C++ strings**      File I/O      Self-defined header files

## Substrings

- We may use `substr()` to get the **substring** of a string.

```
string string::substr(size_t pos = 0, size_t len = npos) const;
```

- `string::npos` is a static member variable indicating the maximum possible value of type `size_t`.
- As an example:

```
string s = "abcdef";
cout << s.substr(2, 3) << endl; // "cde"
cout << s.substr(2) << endl; // "cdef"
```

Programming Design – C++ Strings, File I/O, and Header Files      10 / 62      Ling-Chieh Kung (NTU IM)

## find()

**C++ strings**      File I/O      Self-defined header files

## string finding

- We may use the member function `find()` to look for a string or character.
  - Just like `strstr()` and `strchr()` for C strings.

```
size_t find(const string& str, size_t pos = 0) const;
size_t find(const char* s, size_t pos = 0) const;
size_t find(char c, size_t pos = 0) const;
```

- This will return the beginning index of the argument, if it exists, or `string::npos` otherwise.

```
string s = "abcdefg";
if(s.find("bcd") != string::npos)
  cout << s.find("bcd"); // 1
```

Programming Design – C++ Strings, File I/O, and Header Files      11 / 62      Ling-Chieh Kung (NTU IM)

## Insertion, Replacement, Erasing

**C++ strings**      File I/O      Self-defined header files

## ✓ Insertion, replacement, and erasing

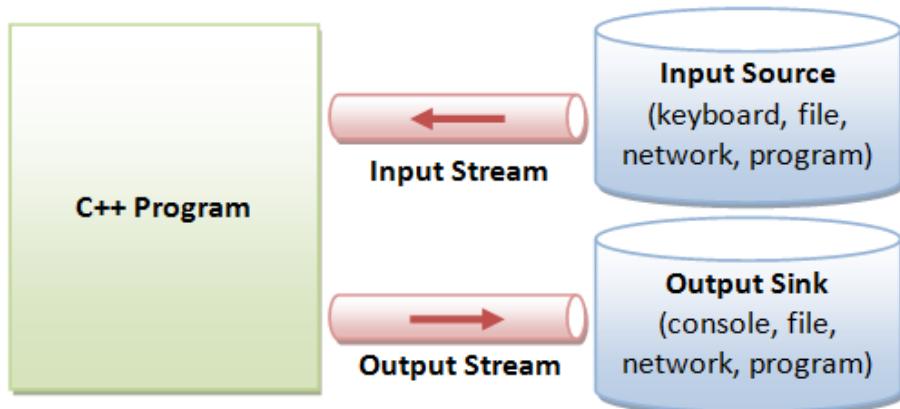
- We may use `insert()`, `replace()`, and `erase()` to modify a string.

```
string& insert(size_t pos, const string& str);
string& replace(size_t pos, size_t len, const string& str);
string& erase(size_t pos = 0, size_t len = npos);
```

```
int main()
{
  cout << "01234567890123456789\n";
  string myStr = "Today is not my day.";
  myStr.insert(9, "totally "); // Today is totally not my day.
  myStr.replace(17, 3, "NOT"); // Today is totally NOT my day.
  myStr.erase(17, 4); // Today is totally my day.
  cout << myStr << endl;
  return 0;
}
```

Programming Design – C++ Strings, File I/O, and Header Files      13 / 62      Ling-Chieh Kung (NTU IM)

## File Stream

**Internal Data Formats:**

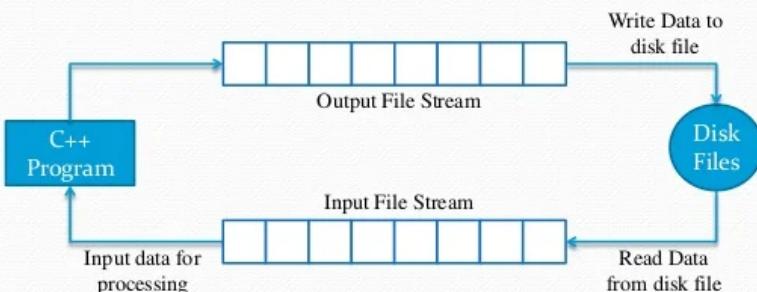
- Text: `char`, `wchar_t`
- `int`, `float`, `double`, etc.

**External Data Formats:**

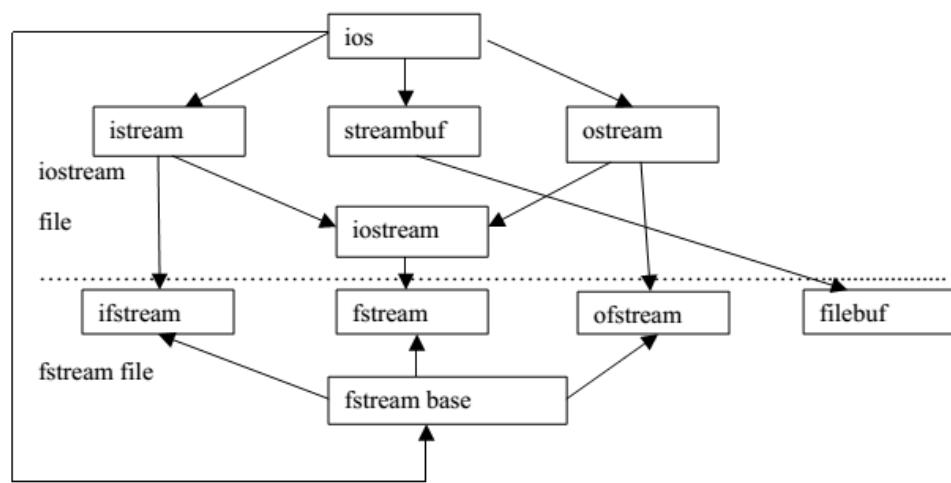
- Text in various encodings (US-ASCII, ISO-8859-1, UCS-2, UTF-8, UTF-16, UTF-16BE, UTF16-LE, etc.)
- Binary (raw bytes)

## File Streams

- File Streams are of 2 types
  - Input file stream
  - Output file stream

Rising Technologies, Jalna (MH). + 91 9423156065, <http://www.RisingTechnologies.in>

11



Stream classes for file operations

## Object Oriented Programming in C++

### File Opening Mode

| File Mode Parameter | Meaning                                                                        |
|---------------------|--------------------------------------------------------------------------------|
| ios::app            | Append mode. All output to that file to be appended to the end.                |
| ios::ate            | Open a file for output and move the read/write control to the end of the file. |
| ios::binary         | file open in binary mode                                                       |
| ios::in             | open file for reading only                                                     |
| ios::out            | open file for writing only                                                     |
| ios::nocreate       | open fails if the file does not exist                                          |
| ios::noreplace      | open fails if the file already exist                                           |
| ios::trunc          | delete the contents of the file if it exist                                    |

Lecture Slides By Adil Aslam

## Self-defined Library

The screenshot shows a presentation slide with a blue header bar containing the text 'C++ strings', 'File I/O', and 'Self-defined header files'. The main content area has a dark background and features a blue title 'Libraries'. Below the title is a bulleted list of points:

- There are many C++ standard **libraries**.
  - `<iostream>`, `<fstream>`, `<cmath>`, `<cctype>`, `<string>`, etc.
- We may also want to define **our own libraries**.
  - Especially when we collaborate with others.
  - Typically, one implements classes or global functions for the others to use.
  - That function can be defined in a self-defined library.
- A library includes a **header file (.h)** and a **source file (.cpp)**.
  - The header file contains **declarations**.
  - The source file contains **definitions**.

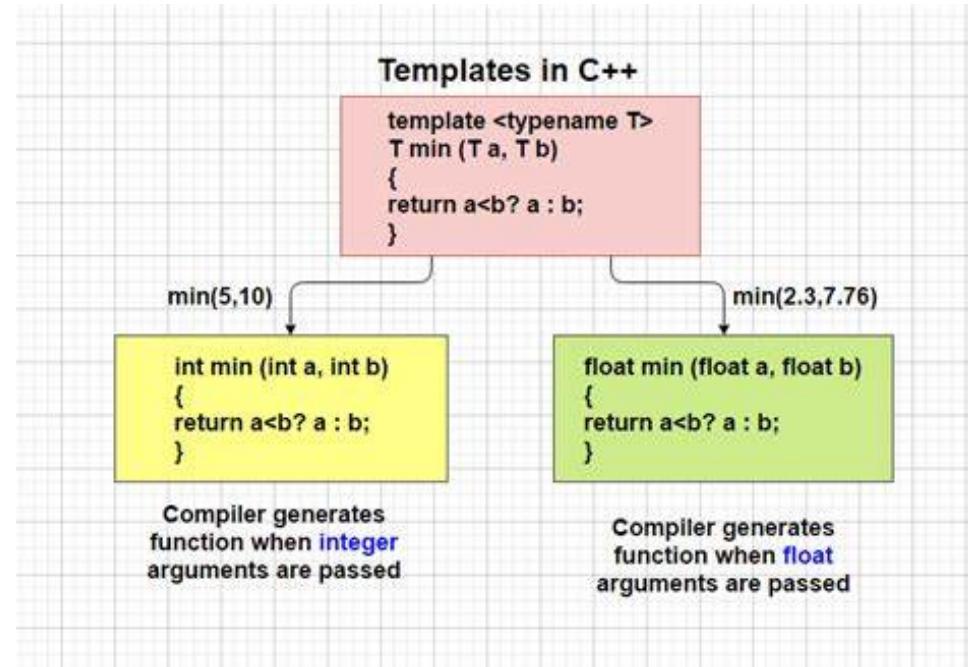
At the bottom of the slide, there is footer text: 'Programming Design – C++ Strings, File I/O, and Header Files' on the left, '53 / 62' in the center, and 'Ling-Chieh Kung (NTU IM)' on the right.

The screenshot shows a presentation slide with a dark background and a blue title 'Including a header and a source file'. Below the title is a bulleted list of points:

- When your main program also wants to include a self-defined source file, the include statement needs not be changed.
  - `#include "myMax.h"`
- We add a source file myMax.cpp.
  - In the source file, we **implement** those functions declared in the header file.
  - The main file names of the header and source files can be different.
- The two **source files** (main.cpp and myMax.cpp) must be **compiled together**.
  - Each environment has its own way.

At the bottom of the slide, there is footer text: 'Programming Design – C++ Strings, File I/O, and Header Files' on the left, '58 / 62' in the center, and 'Ling-Chieh Kung (NTU IM)' on the right.

# Templates



Templates      The standard library <vector>      Exception handling

## Template declaration

- To declare a type parameter, use the keywords `template` and `typename`.
 

```
template<typename T>
class TheClassName
{
    // T can be treated as a type inside the class definition block
};
```

  - Some old codes write `class` instead of `typename`. Both are fine.
- We then do this to all member functions:

|                                                                                                                     |                                                                                                                                |
|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <code>template&lt;typename T&gt; T TheClassName&lt;T&gt;::f(T t) {     // t is a variable whose type is T };</code> | <code>template&lt;typename T&gt; void TheClassName&lt;T&gt;::f(int i) {     // follow the rule even if T is not used };</code> |
|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|

Programming Design – Templates, Vectors, and Exceptions      7 / 55      Ling-Chieh Kung (NTU IM)

Compiler internally generates and adds below code

```
template <typename T>
T myMax(T x, T y)
{
    return (x > y)? x: y;
}

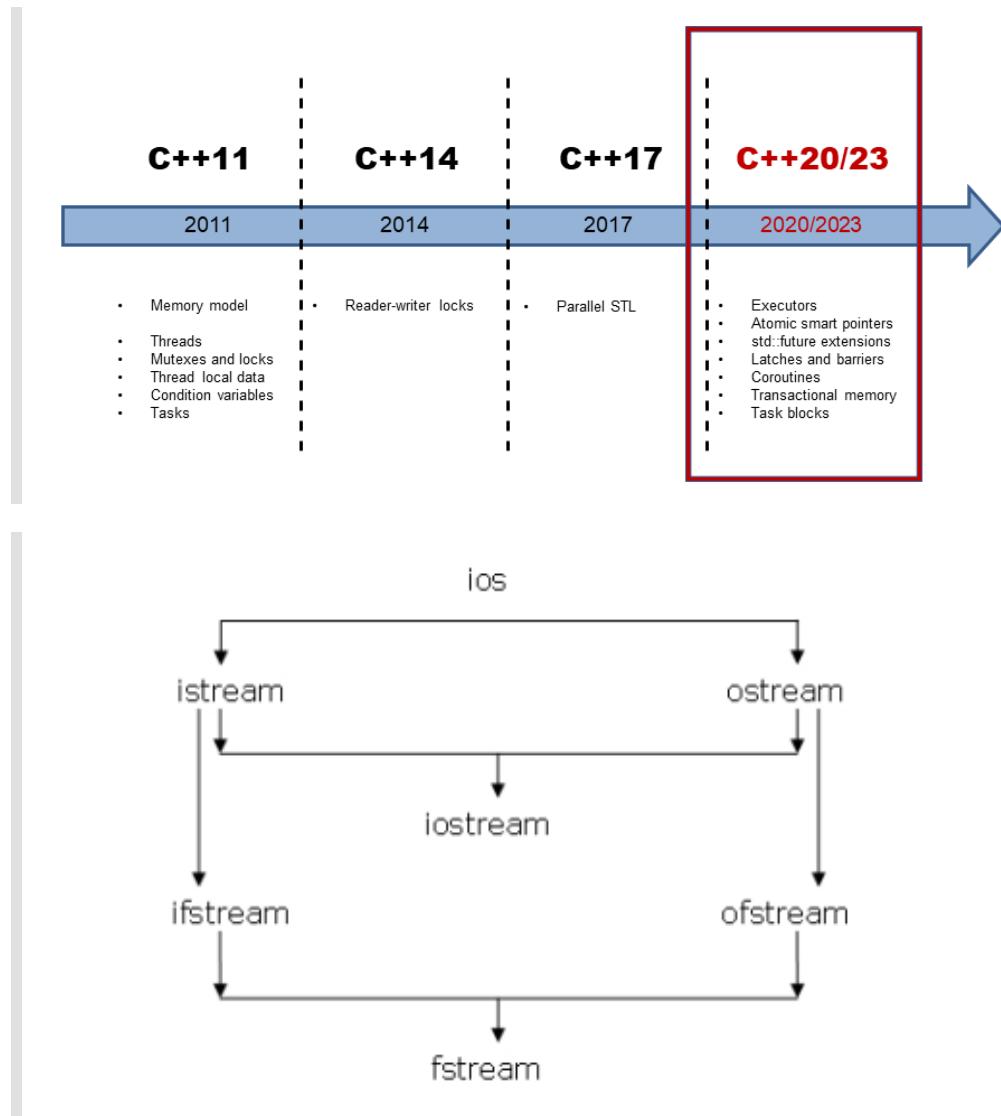
int main()
{
    cout << myMax<int>(3, 7) << endl;
    cout << myMax<char>('g', 'e') << endl;
    return 0;
}
```

Compiler internally generates and adds below code.

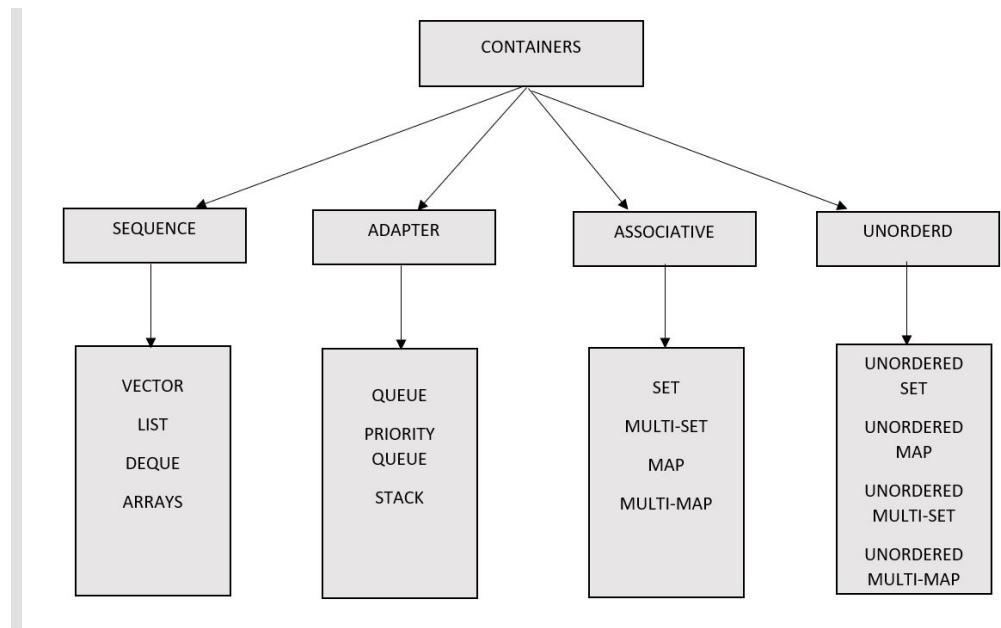
```
int myMax(int x, int y)
{
    return (x > y)? x: y;
}

char myMax(char x, char y)
{
    return (x > y)? x: y;
}
```

## C++ SL(Strandard Library)



## C++ STL(Strandard Template Library)

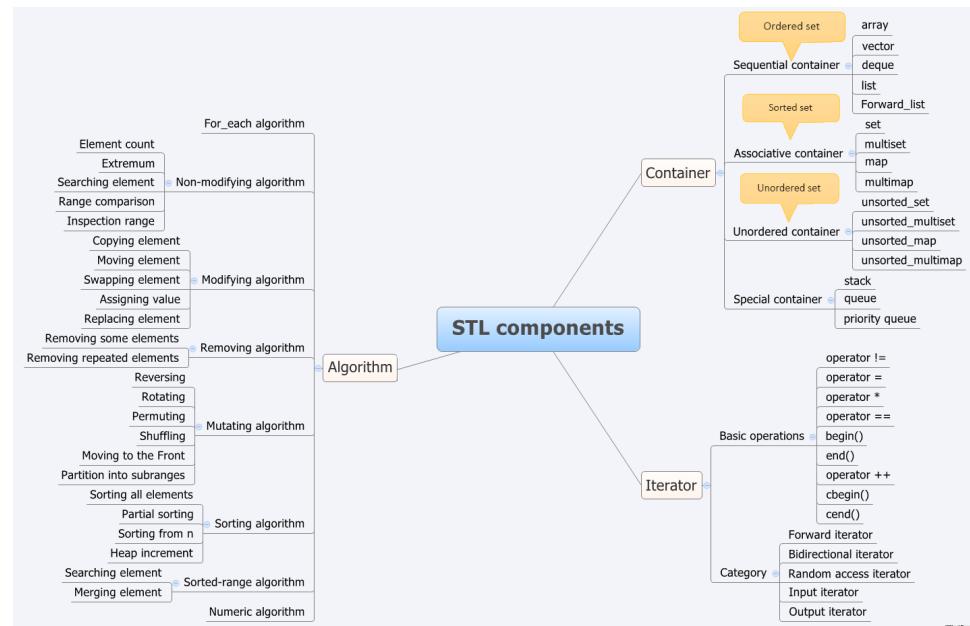


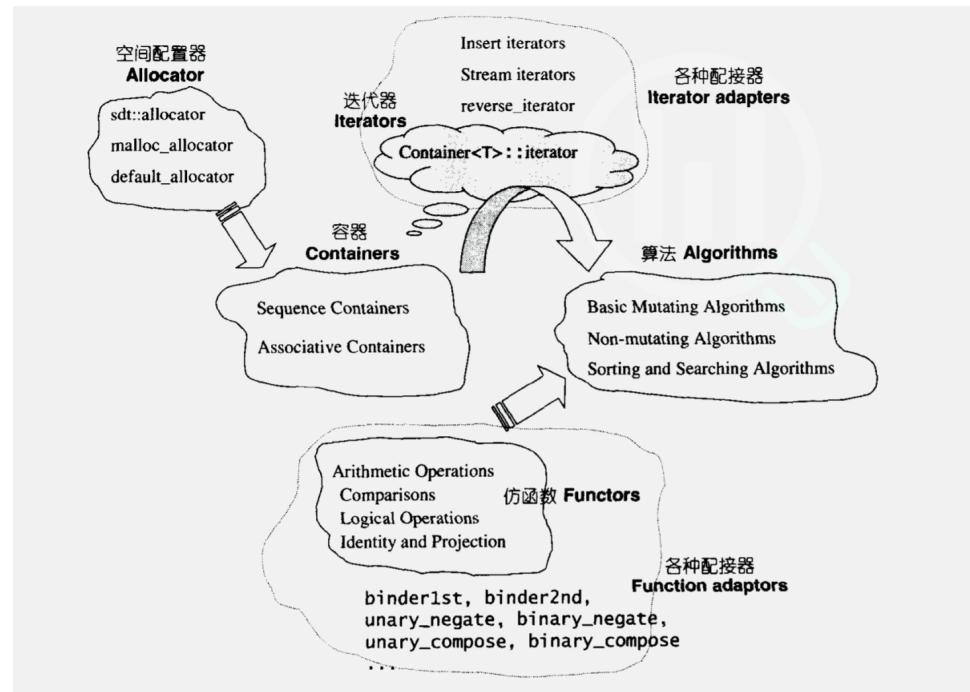
## Intro to the C++ Standard Template Library (STL)

- The STL is a collection of related software elements
  - Containers
    - Data structures: store values according to a specific organization
  - Iterators
    - Variables used to give flexible access to the values in a container
  - Algorithms
    - Functions that use iterators to access values in containers
    - Perform computations that modify values, or creates new ones
  - Function objects
    - Encapsulate a function as an object, use to modify an algorithm
- The STL makes use of most of what we've covered
  - Extensive use of function and class templates, concepts
- The STL makes use of several new ideas too
  - `typedefs`, traits, and associated types

---

### CSE 332: C++ STL containers





## Four STL Components

- **Containers**: used to manage collections of objects of a certain kind.
- **Algorithms**: act on containers.
  - E.g. initialization, sorting, searching....
- **Iterators**: used to step through the elements of collections of objects.
- **Functors** are objects that can be treated as though they are a function or function pointer.

2018/9/8

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## Vector

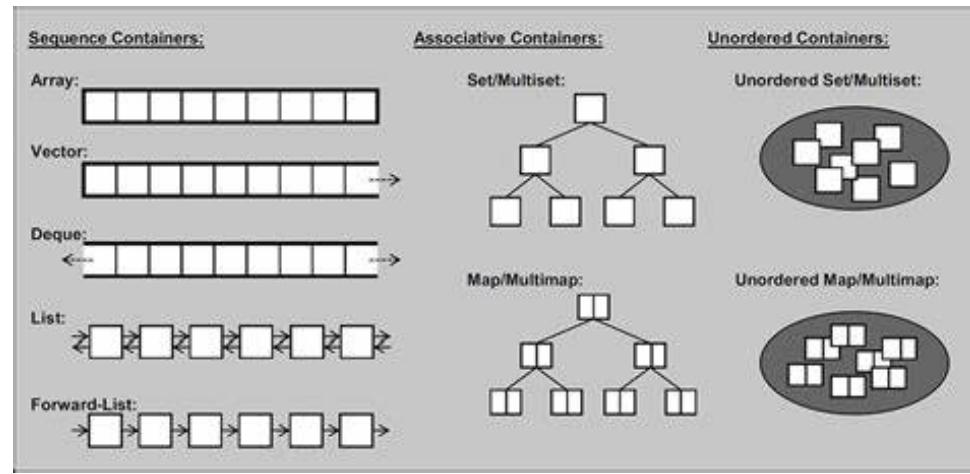
Templates      The standard library <vector>      Exception handling

### The standard library <vector>

- A vector is very easy to use.
  - To create a vector, indicate the type of items:
 

```
vector<int> v1; // integer vector
vector<double> v2; // double vector
vector<Warrior> v3; // Warrior vector
```
- Member functions that modifies a vector:
  - `push_back()`, `pop_back()`, `insert()`, `erase()`, `swap()`, etc.
- Member functions for one to access a vector element:
  - `[]`, `front()`, `back()`, etc.
- Member functions related to the capacity:
  - `size()`, `max_size()`, `resize()`, etc.

Programming Design – Templates, Vectors, and Exceptions      28 / 55      Ling-Chieh Kung (NTU IM)



## Exception Handling

### Object Oriented Programming in C++

#### Exception Handling in C++

- The process of converting system error messages into user friendly error message is known as **Exception handling**. This is one of the powerful feature of C++ to handle run time error and maintain normal flow of C++ application.
- **Exception**
- An exception is an event, which occurs during the execution of a program, that disrupts the normal flow of the program's Instructions.

Lecture Slides By Adil Aslam

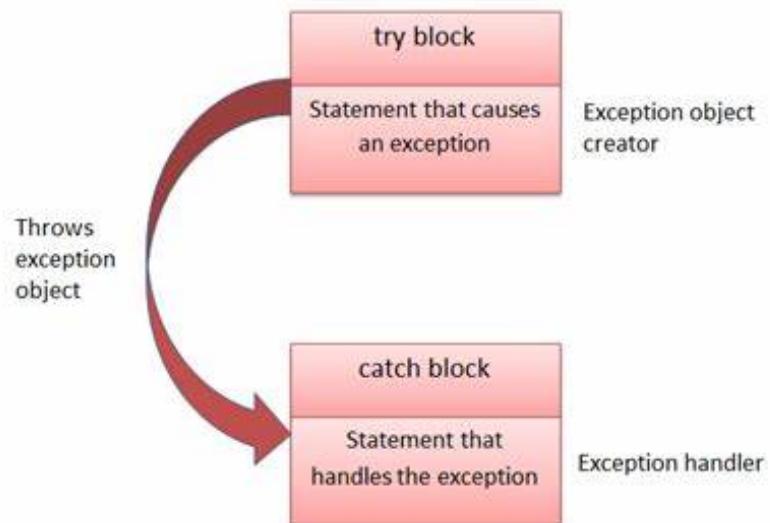
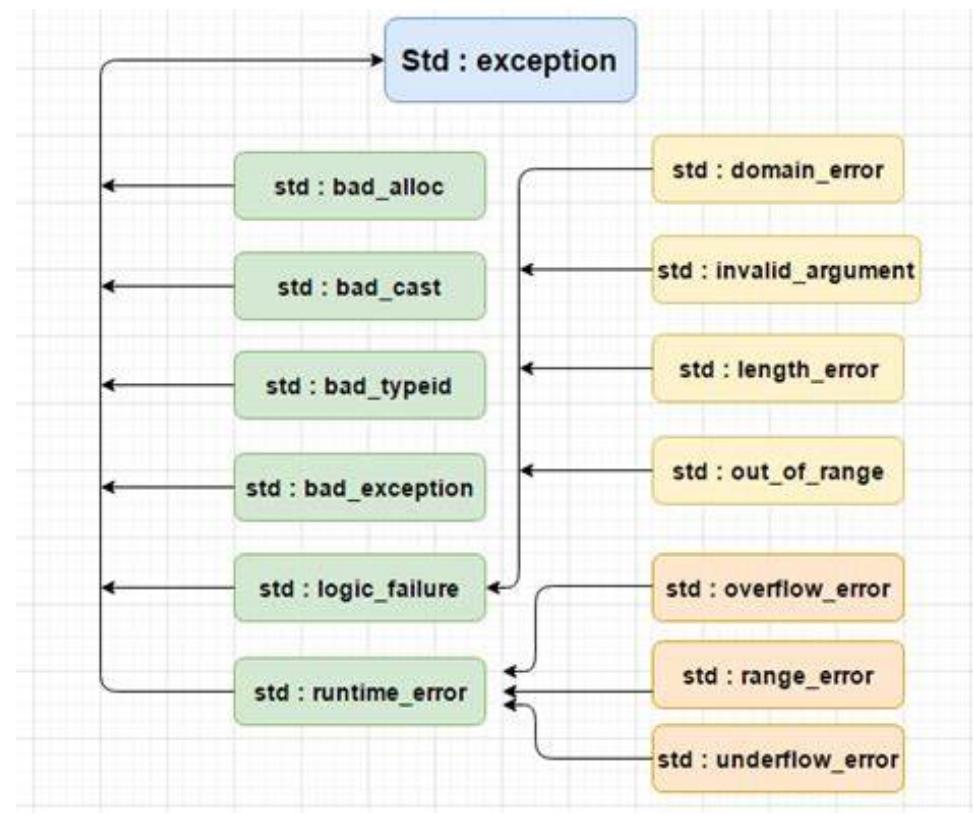


Fig: Exception Handling Mechanism



Templates      The standard library <vector>      Exception handling

## Standard exception classes

- In the C++ standard library, we have the following standard exception classes:
  - Inheritance and polymorphism!

```
try {
    g(s, i);
}
// this also works
catch(logic_error e) {
    cout << "...\\n";
}
```

- Include <`stdexcept`> to use them.

```
exception
logic_error
domain_error
invalid_argument
length_error
out_of_range
runtime_error
range_error
overflow_error
underflow_error
```

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Templates      The standard library <vector>      Exception handling

## Throwing an exception

- Let the client `catch` the exception:

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

void f(int a[], int n) throw(logic_error)
{
    int i = 0;
    cin >> i;
    if(i < 0 || i > n)
        throw logic_error("...");
    a[i] = 1;
}
```

```
int main()
{
    int a[5] = {0};
    try {
        f(a, 5);
    }
    catch(logic_error e) {
        cout << e.what();
    }
    for(int i = 0; i < 5; i++)
        cout << a[i] << " ";
    return 0;
}
```

- `what()` returns the message generated when throwing an exception.

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Templates      The standard library <vector>      Exception handling

## Modifying the function header

- Functions that throw an exception may have a `throw clause` at the end of their headers.
  - This restricts the exceptions that a function can throw.
  - Omitting a `throw` clause allows a function to throw any exception.
- To allow multiple types of exceptions:

```
void f(int a[], int n) throw(type1, type2)
```

- The documentation of a function (or method) should indicate any exception it might throw.

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

void f(int a[], int n)
    throw(logic_error)
{
    int i = 0;
    cin >> i;
    if(i < 0 || i > n)
        throw logic_error("...");
    a[i] = 1;
}
```

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Templates      The standard library <vector>      Exception handling

## Functions that do not(?) throw exception

- If a function will **never** throw an exception, one may **indicate this explicitly**.
- For example, (in C++ 11) the function **length()** of the class **string** is actually defined as:

```
size_t length() const noexcept;
```

- This means that this function never throws an exception.
- When one calls a function, it is good to know that it may (or will never) throw an exception.
- Therefore, indicate this if you know that is true.
- It is the programmer's responsibility make sure that the function indeed does not throw an exception; the compiler does not check anything.

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Templates      The standard library <vector>      Exception handling

## Defining your own exception classes

- C++ Standard Library supplies a number of exception classes.
- You may also want to define **your own exception class**.
  - This helps your program communicate better to your clients.
  - Your own exception classes should **inherit from standard exception classes** for a standardized exception working interface.

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

class MyException : public exception
{
public:
    MyException(const string& msg = "") : exception(msg.c_str()) {}
};
```

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-- Memo End --