Contemporary C++: Learning Modern C++ in a Modern Way

الماس فناوری ابری پاسارگاد- آلفا

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Agenda 4/24

Session 4 .Constants, Pointers, References, Functions and Introduction to the Standard Containers (Part I)

- Working with unknown number of data
- Constants
- Pointers & References
- Null pointers and nullptr
- C++ standard library: standard array
- Range-based for loop
- More on Autos: Automatic type deduction
- C as a Procedural Programming Language
- Functions
- Writing simple functions
- Inline functions
- Q & A

150 min (incl. Q & A)

Declarations in for statements

```
{
  int i; // decl., def., uninitialized
  for (i = 1; i <= n; ++i) { // assignment
    // …
  }
}
```

just Assignment

decl., def. & init.

```
for (int i = 1; i <= n; ++i) { // good

}
```

• Scope of i: Outside of the for statement. i is not local.

• Scope of i: until the end of for statement. i is local.

• If the final value of an index needs to be known after exit from a for loop, the index variable must be declared outside the for loop.

Language-technical rule:

Locality is good.

Initialization, default initialization

- Initialization: giving an object an initial value.

```
int sum1 = 0;
```

- When we do not specify an initial value for a variable we are implicitly relaying on default initialization.

default initialization → implicit initialization

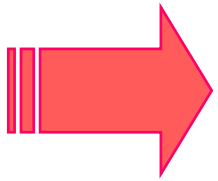
implicit initialization →
- For objects of class type: constructor
- For global variables of fundamental types: Zero initialized.
- For local variables of fundamental types: *undefined*

```
int i; // i = 0;
double d; // d = 0.0
int main()
{
  std::string s; // s is initialized by constructor
  int k; // k does not have well-defined value
  bool b = false; // explicitly initialized
  char c = 'a'; // explicitly initialized
}
```

- Important rule: Every declaration with an initializer is a definition.

Simple computation, simple programs

• Compute n!: Get n from input and compute n * (n – 1) * (n – 2) * …* 1. Note that: 0! = 1 and 1! = 1. Handle input for negative numbers.



```
#include <iostream>
int main()
{
  std::cout << "Enter an integer number: (-1 for exit) ";
  int n;
  std::cin >> n;
  if (n == -1) {
    return 0;
  }
  if (n == 0) {
    std::cout << n << "! = " << 1 << '\n';
    return 0;
  }
  long int Fact = 1; // must be explicitly initialized
  for (int i = n; i > 0; --i) {
    Fact *= i;
  }
  std::cout << n << "! = " << Fact << '\n';

  return 0;
}
```

Selection statements: the Switch statement

Selection statements: the Switch statement

- Selection statement
  - if statement
  - switch statement

```
if (condition)
  statement
```

```
if (condition)
  statement1
else
  statement2
```

```
switch (condition)
  statement
```

- The switch statement causes control to be transferred to one of several statements depending on the value of a condition.

- A **switch**-statement tests a value against a set of constants. Those constants, called **case**-labels, must be distinct, and if the value tested does not match any of them, the **default** is chosen. If the value doesn't match any case-label and no default is provided, no action is taken.

Selection statements: if vs. Switch statement

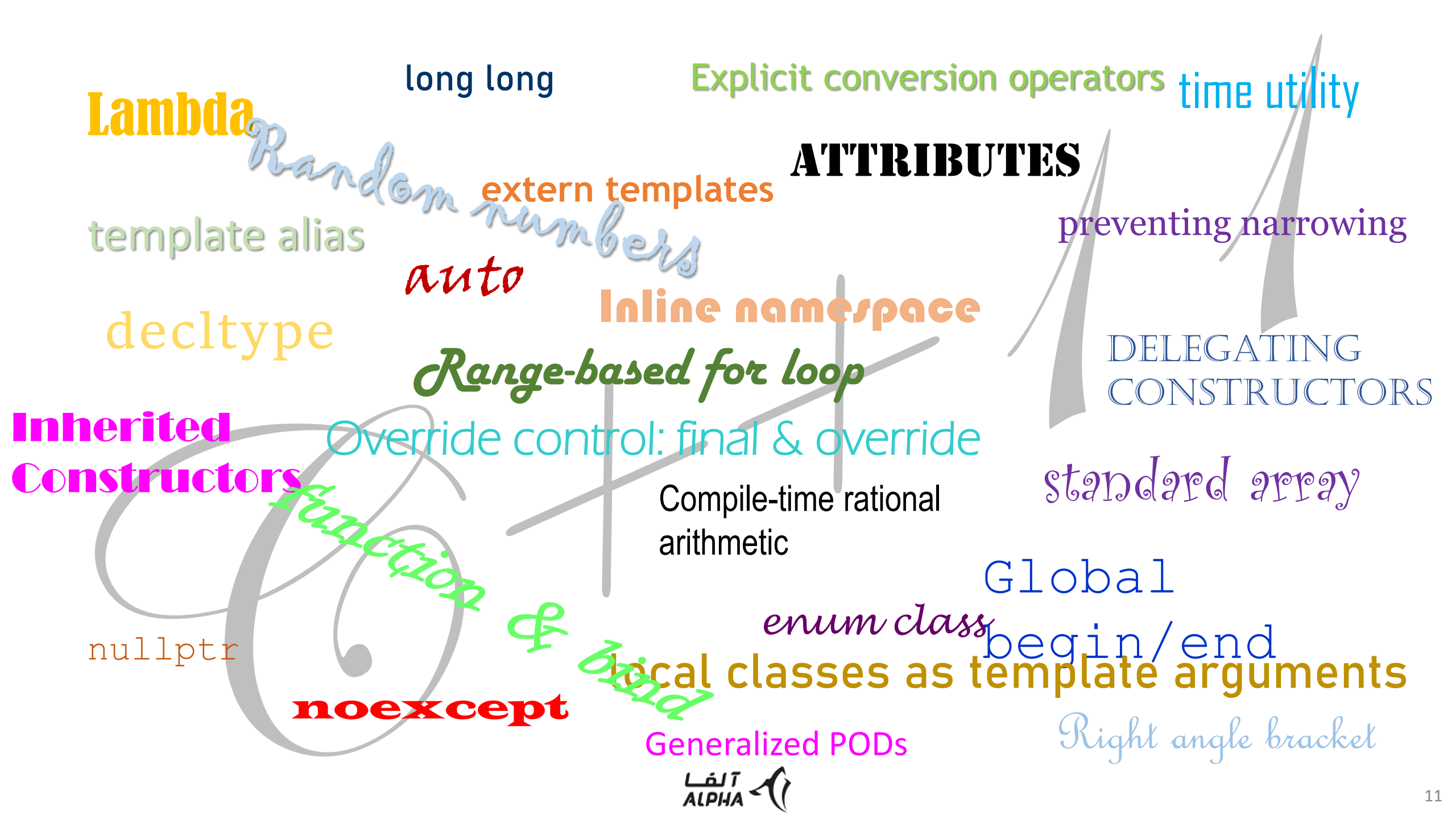
```
bool accept()
{
    cout << "Do you want to proceed (y or n )? "; // write question
    char answer;
    cin >> answer; // read answer
    if (answer == ´y´)
        return true;
    return false;
}
```

```
bool accept2()
{
    cout << "Do you want to proceed (y or n)?\n"; // write question
    char answer = 0; // initialize to a value that will not appear on input
    cin >> answer; // read answer
    switch (answer) {
    case 'y':
        return true;
    case 'n':
        return false;
    default:
        cout << "I'll take that for a no.\n";
        return false;
    }
}
```

switch statement and Break

```
bool accept3()
{
    cout << "Do you want to proceed (y or n)?\n"; // write question
    char answer = 0; // initialize to a value that will not appear on input
    cin >> answer; // read answer
    bool result =
    switch (answer) {
    case 'y':
    case 'Y':
        result = true;
        break;
    case 'n':
    case 'N':
        result = false;
        break;
    default:
        cout << "I'll take that for a no.\n";
        return false;
    }
}
```


long long
Explicit conversion operators
time utility
Lambda
Random numbers
ATTRIBUTES
extern templates
template alias
preventing narrowing
auto
Inline namespace
decltype
DELEGATING CONSTRUCTORS
Range-based for loop
Inherited Constructors
Override control: final & override
standard array
Compile-time rational arithmetic
function & bind
Global begin/end
enum class
nullptr
Local classes as template arguments
noexcept
Generalized PODs
Right angle bracket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ALPHA

Attributes

- Attributes specify additional information for various source constructs such as types, variables, names, blocks, or translation units.
- Attributes provide the unified standard syntax for implementation-defined language extensions, such as the GNU and IBM language extensions __attribute__((...)), Microsoft extension __declspec(), etc.
- A construct [[…]] is called an attribute and can be placed just about anywhere in the C++ syntax.
  - C++11 attributes
    - noreturn
    - carries_dependency: C++ memory model
  - C++14 attributes: deprecated

static_assert

[[fallthrough]]

fold expression

Hexadecimal floating-point literals

Structured Bindings

string_view

template <auto>

Inline variable

Nested namespace

Class template argument deduction

Selection statements with initializer

Byte type

if constexpr

static_assert

[[fallthrough]]

fold expression

Hexadecimal floating-point literals

Structured Bindings

string_view

template <auto>

Inline variable

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Selection statements with initializer

Byte type

if constexpr

Fallthrough

- The use of a fallthrough statement is intended to suppress a warning that an implementation might otherwise issue for a case or default label that is reachable from another case or default label along some path of execution.

```
void f(int n) {
    void g(), h(), i();
    switch (n) {
    case 1:
    case 2:
        g();
        [[fallthrough]];
    case 3: // warning on fallthrough discouraged
        h();
    case 4: // implementation may warn on fallthrough
        i();
        [[fallthrough]]; // ill-formed
    }
}
```

Working with unknown number of data

- Input loop:

```
while (cin >> x) { /* … */ }
```

```
cin >> x; // return cin
```

- attempt to read from `cin` (input stream) until hit the end of file or read invalid object for the type of x.

```
if (cin >> x) { /* … */ }
```

→

```
cin >> x;
if (cin) { /* … */ }
```

- test the condition and read a value as a side effect.
- End-of-file signal:
  - MS Windows operating system : *Control* key + z
  - Unix and Linux operating systems: *Control* key + d
- Read unknown number of characters and write them.

```
#include <iostream>
int main()
{
  char x;
  while (std::cin >> x)
    std::cout << x << '\n';
  return 0;
}
```

Simple computation, simple programs

- Read some “integers” and compute 1. number of inputs 2. sum and 3. average of numbers.


```
#include <iostream>

int main()
{
  using namespace std;
  int n;
  int count = 0;
  int sum = 0;
  int average;
  while (cin >> n) { // standard input loop
    ++count;
    sum += n;
  }

  average = sum / count; // integer division
  cout << count << '\t' << sum << '\t' << average << '\n';

  return 0;
}
```

Simple computation, simple programs

• Prime numbers. Read some “integers” and determine which are prime numbers. The numbers should be greater than equal 1. A positive integer p is called *prime*, if it has just two divisors, namely 1 and p. By convention 1 is not prime.

```
#include <iostream>

int main()
{
  using namespace std;

  for (;;) {
    cout << "X =  (0 for exit) ";
    int x;
    if (cin >> x) {
      if (x <= 0) {
        cout << "Invalid number!";
        break;
      }
      else if (x == 1)
        cout << x << " isn't prime." << endl;
      else { // x >= 2
        bool is_prime = true;
      // inefficient and naïve implementation
      for (int i = 2; (i <= x / 2) && (is_prime = (x % i != 0)); ++i) ;
// to be continued on next page
```

Forever loop, logical operators, …

- Logical operators:
  - &&

    expr1 && expr2: if both expressions are true, it returns true, otherwise it returns false.
  - ||

    expr1 || expr2: if both expressions are false, it returns false, otherwise it returns true.
- *Short-circuit evaluation*
- Logical operators: && (logical and), and || (logical or) guarantee that their left-hand operand is evaluated before their right-hand operand.

```
// continued from last page
        if (is_prime)
            cout << x << " is prime." << endl;
        else
            cout << x << " is composite." << endl;
        }
    }
  }
  return 0;
}
```

```
if (i < 0 || i >= max) // …
```

```
if (i >= 0 && i < max) // …
```

- “infinite” loop

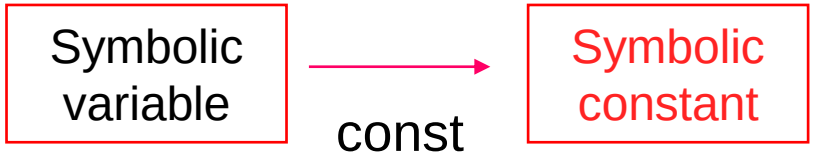
```
for (;;) // …
```

```
while (true) // …
```

Operator	Function	Use
&&	Logical and	expr && expr
||	Logical or	expr || expr

Constants

- The keyword const can be added to the declaration of an object to make the object declared a constant.
- Constants must be initialized.
- Constants can't be assigned.




```
const float PI = 3.14; // PI is r-value
const int light_speed = 3 * 100000000; // m/s
const double cm_per_inch; // error: no initializer
PI++; // ++ needs lvalue
const char vowel[5] = { 'A', 'E', 'I', 'O', 'U' };
```

- (Obviously) you can assign a const to a non-const but not a non-const to a const.

- Constants → maintainable code
- Constants → more localized information
- Use symbolic constants to avoid *magic numbers*.

```
const int max = 128;
int v[max];
```

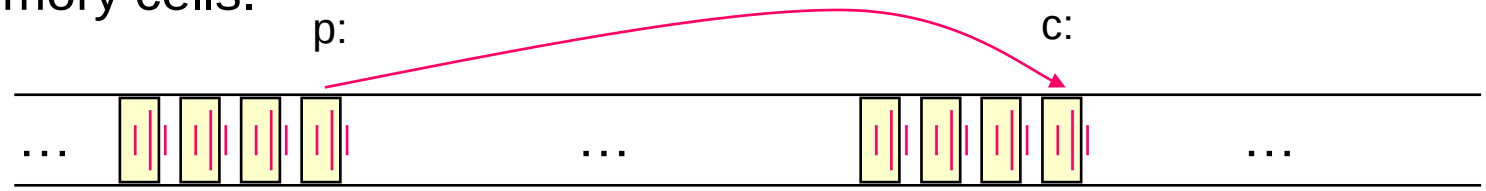
```
for (int i = 0; i < BUF_SIZE; i++)
  // …
```

CentimeterInchConversionProg.

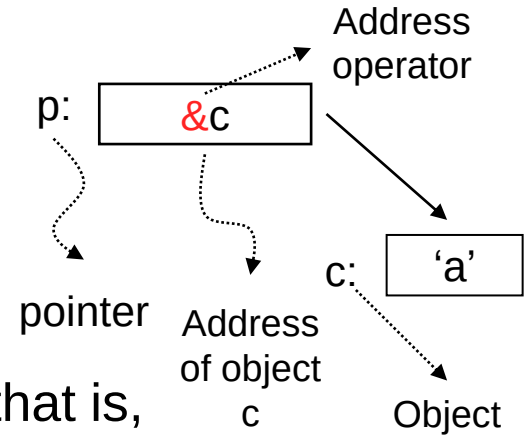
CentimeterInchConversion2Prog.

Pointers

• A typical machine has an array of consecutively numbered or addressed memory cells.



- For a type *T* , *T* * is the type "pointer to *T* ." That is, a variable of type *T* * can hold the address of an object of type *T*.
- *Pointer* is an object which its value represents the address of another object or 0.
- If you can access an object, you can obtain its address, and vice versa.




```
char c = 'a';
char *p = &c; // p holds the address of c
```

- The fundamental operation on pointer is *dereferencing*, that is, referring to the object pointed to by the pointer. This operation is also called *indirection*.

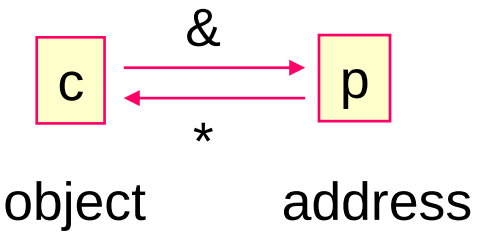
```
char c2 = *p; // c2 == 'a'
```

Dereference operator

Pointers ... cont.

- Indirection operators:

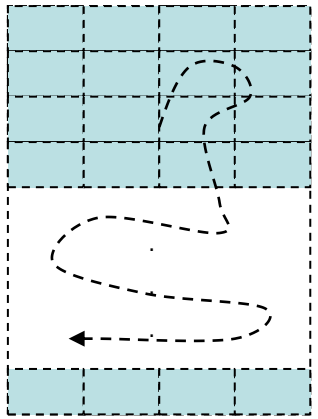
Operator	Function	Use
&	address of	&lvalue
*	dereference	*expr




```
int     x; // x is an object of type int
int     *p; // *p has type int
int*    p; // p has type int*
```

declarator

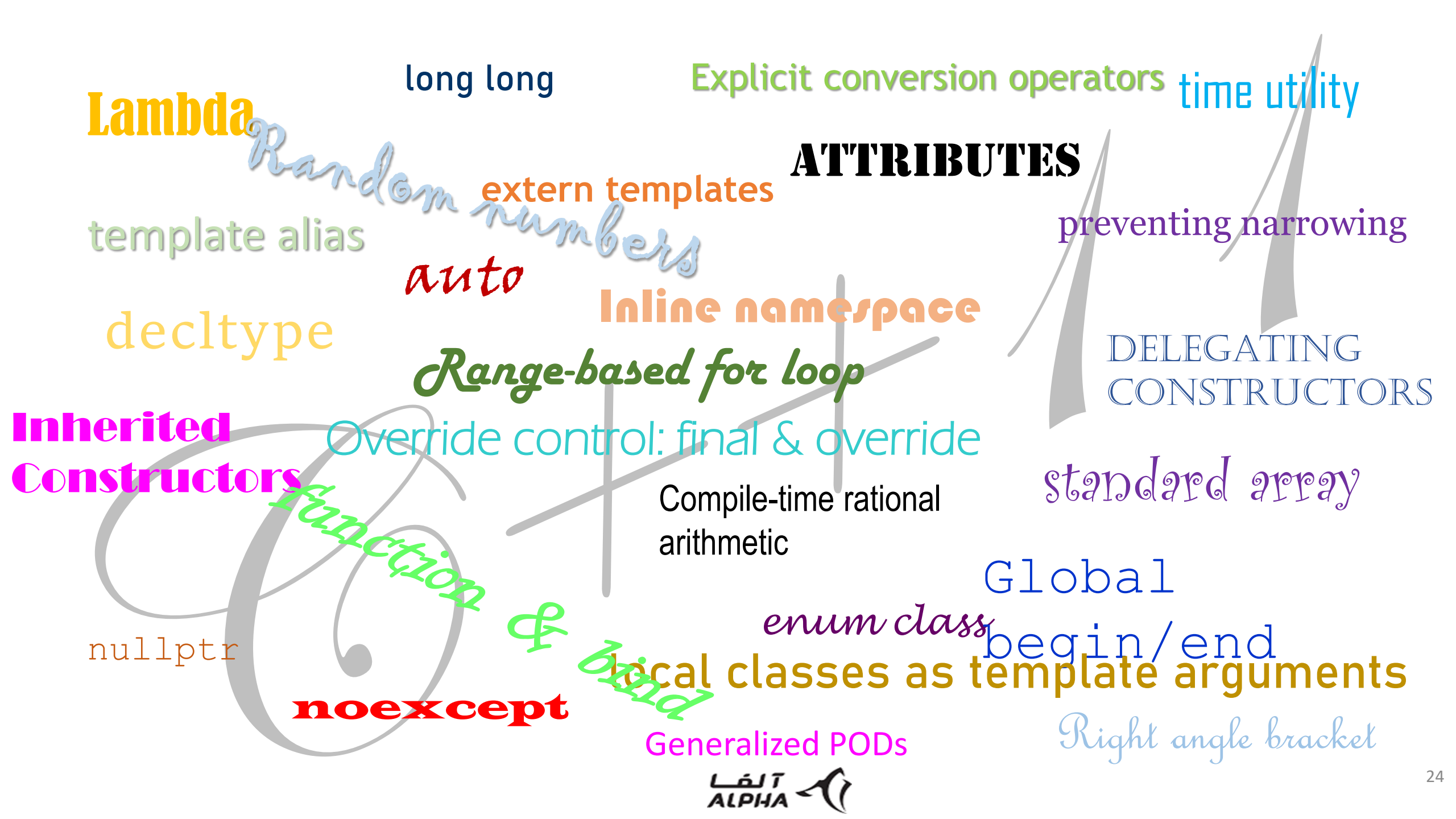
Type specifier



- Zero (0) is an `int`.
  - Standard conversion
  - No object is allocated with the address 0.
- Every pointer has an associated type.

```
void g()
{
  int i = 1024;
  int* pi = i; // error: initialize with rvalue
  double* pd = pi; // error: type mismatch
}
```

```
void f()
{
  int* p; // points to nowhere
  p = 0; // pointer literal
  int x = 1;
  p = &x; // p points to x
  (*p)++; // () is necessary!
}
```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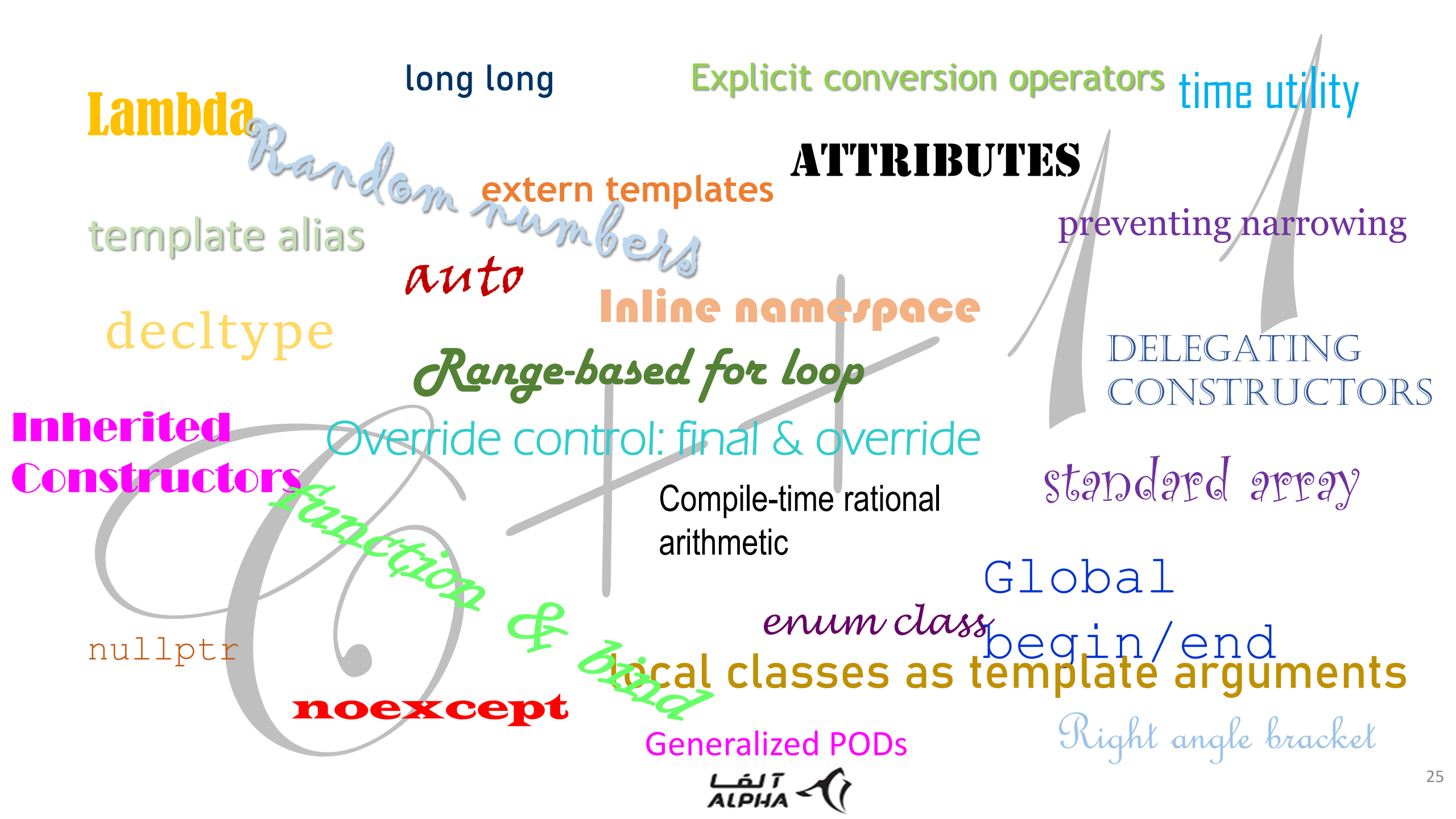
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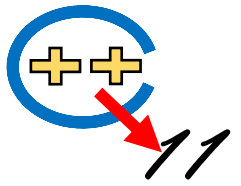
Null pointers in C and C++



- Pointers and null pointers

```
char c = 'a';
char* p = &c; // '*' means 'pointer to' p points to c, '&' is address operator
```

- C99 → Null pointer constant

✓An integer constant expression with the value 0, or such an expression cast to type void *, is called a null pointer constant.

- C++03 → Null pointer constant

```
// macros
#define NULL 0
#define NULL ((void *)0)
char* p = NULL;
```

✓A null pointer constant is an integral constant expression rvalue of integer type that evaluates to zero.

- Zero (0) is an int.

```
char* p = 0; // points to nowhere
             // no memory allocation yet
```

- No object is allocated with the address *0. 0 acts as a pointer literal, indicating* that a pointer doesn't refer to an object.

Nullptr: a literal for null pointers

- Problems with NULL and 0:

```
void f(int) { /* … */ }
void f(char*) { /* … */ }
f(0); // f(int) called
f(NULL); // f(int) called
```

1. *Distinguishing between null and zero.*

- There is no way to write a call to f(char*) with a null pointer value without writing an explicit cast (i.e., f((char*)0)) or using a named variable.

2. *Naming null*

```
std::string s1(false); // compiles, calls char* constructor with null
std::string s2(true); // error
```

- The pointer literal is the keyword *nullptr*.

```
// macros
#define NULL 0
#define NULL ((void *)0)
char* p = NULL;
```

- C++11 → Null pointer constants

```
int x = nullptr; // error
char* pc = 0; // still good
char* pc2 = nullptr; // best
bool b = (pc == pc2); // OK: b = true
f(nullptr); // called f(long long*)
g(nullptr); // error
class Point { /* … */ } *pp = nullptr;
```

Nullptr cont.

- A null pointer constant is an integral constant expression rvalue of integer type that evaluates to *zero* or a *rvalue of type std::nullptr_t*.

```
typedef decltype(nullptr) nullptr_t;
```

- A complete example

```
#include <cstddef>
#include <iostream>
template<class F, class A> void forward(F f, A a)
{
   f(a);
}

void g(int* i)
{
   std::cout << "Function g called\n";
}

int main()
{
   g(NULL); // fine
   g(0); // fine

   forward(g, nullptr);   // fine
   forward(g, NULL);  // ERROR: No function g(int)
}
```

Reference Types

- The notation T& means *reference to T.*
- A reference is an alternative name for an object.
- Like constants, references must be initialized.

Type Specifier& Reference = Referent;

```
void f()
{
  int i = 0;
  int& ir; // error: reference should be initialized
  int& iref = i; // OK
  int& iref2 = 1; // error: should be initialized with l-value of an object
}
```

•The main use of references is for specifying arguments and return types for functions.

```
const int& ir = 5; //ok
```

```
void swap(int& x, int& y)
{
  int tmp = x; // decl. statement
  x = y;
  y = tmp;
}
```

```
int a = 0, b = 1;
swap(a, b);
```

Pointer vs. Reference

- A Reference must always refers to some object. There is no *Null Reference.*

```
int& ir = 0; // error: null reference?
int* ip = 0; // ok: null pointer
```

- A Reference should be *initialized*. Pointer doesn't have such restrictions.

```
bool& ir; // error: reference should be initialized?
int* ip; // ok: uninitialized pointer: valid but risky
```

```
void UseDouble(const double& rd)
{
  // …
}
```

```
void UseDouble(const double* pd)
  if (pd)
    // …
}
```

- You can't separate reference from referent. You can't reseat reference.

```
string s1("Hello");
string s2("Good bye");
string& rs = s1; // rs refers to s1
string* ps = &s1; // ps points to s1
rs = s2; // rs still refers to s1, but s1's value is now "Good Bye"
ps = &s2; // ps not points to s2; s1 is unchanged
```

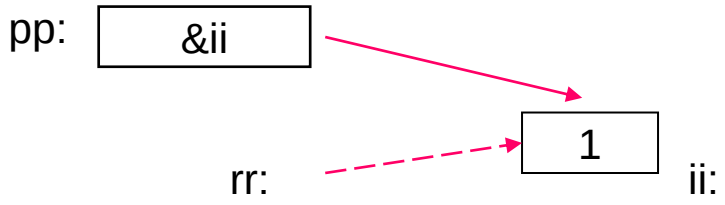
Q When should I use references, and when should I use pointers?

A Use references when you can, and pointers when you have to.

Reference implementation: An application of constant pointer

•The obvious implementation of a reference is as a (constant) pointer that is dereferenced each time it is used.

```
void g()
{
  int ii = 0;
  int& rr = ii;
  rr++; // ii is incremented to 1
  int* pp = &rr; // pp points to ii
}
```



Thanks for your patience …

A man who asks a question is a fool for minute,
The man who does not ask, is a fool for a life.
- Confucius

Learning to ask the right (often hard) questions is an essential part of learning to think as a programmer.
- Bjarne Stroustrup *programming Principles and Practice Using C++, page 4.*

There is no stupid question, but there is stupid answer.
- Howard Hinnant