Getting Deeper into

C++ Semantics

EECS 230

Spring 2016
The plan

- On language technicalities
- Declarations
  - definitions
  - headers
  - scope
- Functions
  - declarations & definitions
  - formal and actual parameters
  - pass by value, reference, and const reference
- Namespaces
  - using declarations
Language technicalities

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Language technicalities

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- Evil: because language details can distract from our main task: programming
- Necessary: because you can’t program without a language

This week we learn grammar and vocabulary
Technicalities

● Like in natural language (e.g., English):
  ▶ Don’t get hung up on minor issues
  ▶ There’s more than one way to say everything

● Most design and programming concepts are universal, but technicalities are particular
Declarations

A declaration introduces a *name* into a *scope* (region of code):

- gives a type for the named object
- sometimes includes an initializer
- must come before use
Declarations

A declaration introduces a *name* into a *scope* (region of code):

- gives a type for the named object
- sometimes includes an initializer
- must come before use

Examples:

- `int a = 7;`
- `int b;`
- `vector<string> c;`
- `double my_sqrt(double);`
Headers

Declarations are frequently introduced through *headers*:

```c
int main()
{
    cout << "Hello, world!\n";
}
```

Error: unknown identifier `cout`
Declarations are frequently introduced through *headers*:

```c
#include "eecs230.h"

int main()
{
    cout << "Hello, world!\n";
}
```

*eecs230.h* has declarations for *cout*, *operator<<*, etc.
Definitions

A declaration that (also) fully specifies the declarandum is a *definition*.
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Examples:

```c
int a = 5;
```
Definitions

A declaration that (also) fully specifies the declarandum is a definition.

Examples:

```c
int a = 5;
int b;  // but why?
```
Definitions

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Examples:

```cpp
int a = 5;
int b;     // but why?
vector<double> v;
```
Definitions

A declaration that (also) fully specifies the declarandum is a definition.

Examples:

```cpp
int a = 5;
int b;  // but why?
vector<double> v;
double square(double x) { return x * x; }
```
Definitions

A declaration that (also) fully specifies the declarandum is a definition.

Examples:

```c
int a = 5;
int b;     // but why?
vector<double> v;
double square(double x) { return x * x; }
struct Point { int x, y; };
```

Definitions

A declaration that (also) fully specifies the declarandum is a definition.

Examples:

```c
int a = 5;
int b;       // but why?
vector<double> v;
double square(double x) { return x * x; }
struct Point { int x, y; }
```

Examples of non-definition declarations:

```c
extern int b;
double square(double);
struct Point;
```
Declarations and definitions

<table>
<thead>
<tr>
<th></th>
<th>declarations</th>
<th>definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>may be repeated</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>must come before use</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>
Why both?

To refer to something, we need only its declaration.
We can hide its definition, or save it for later.
In large programs, declarations go in header files to ease sharing.
double my_sqrt(double input, double epsilon)
{
    
}

int main()
{
    ... my_sqrt(d, eps) ...
}
int main()
{
    ... my_sqrt(d, eps) ...    // unknown identifier
}

double my_sqrt(double input, double epsilon)
{
    ...
    :
    :
}

Declaration example

double my_sqrt(double, double epsilon);

int main()
{
    · · · my_sqrt(d, eps) · · ·
}

double my_sqrt(double input, double epsilon)
{
    · · ·
}
Library declaration example

In my_math.h:

```c
double my_sqrt(double, double epsilon);
```

In my_math.cpp:

```c
#include "my_math.h"

double my_sqrt(double input, double epsilon)
{
    // Function implementation
}
```

In some other .cpp source file:

```c
#include "my_math.h"

int f() { ... my_sqrt(d, eps) ... }
```
Scope

A scope is a region of program text:

- global scope (outside any language construct)
- [namespace scope (outside everything but a namespace)]
- [class scope (inside a class or struct)]
- local scope (between { and } braces; includes function scope)
- statement scope (loop variable in a <for>)

They nest!
Scope

A scope is a region of program text:

- global scope (outside any language construct)
- [namespace scope (outside everything but a namespace)]
- [class scope (inside a class or struct)]
- local scope (between `{` and `}` braces; includes function scope)
- statement scope (loop variable in a `<for>`)  

They nest! Useful because:

- Declarations from outer scopes are visible in inner scopes
- Declarations from inner scopes are not visible in outer scopes
- (Exception: `<class>` stuff)
Scope example

```cpp
int number_of_bees = 0;  // global scope — visible everywhere
void increase_bees();     // also global scope

void buzz(int n)          // buzz is global, n is local to buzz
{
    if (number_of_bees > n) {
        cout << 'b';

        for (int i = 0;    // i has statement scope
            i < number_of_bees;
            ++i)
            cout << 'z';
    }

    increase_bees();
}
```
Scope example

```cpp
int number_of_bees = 0;  // global scope — visible everywhere
void increase_bees();    // also global scope

void buzz(int n)         // buzz is global, n is local to buzz
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    if (number_of_bees > n) {
        cout << 'b';

        for (int i = 0; i < number_of_bees; ++i) {
            cout << 'z';
        }
    }

    increase_bees();
}
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        for (int i = 0; // i has statement scope
             i < number_of_bees;
             ++i)
            cout << 'z';
    }

    increase_bees();
}
```
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             ++i)
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    increase_bees();
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```
Scope example

```c++
int number_of_bees = 0;  // global scope — visible everywhere
void increase_bees();  // also global scope

void buzz(int n)  // buzz is global, n is local to buzz
{
    if (number_of_bees > n) {
        cout << 'b';
        for (int i = 0; // i has statement scope
            i < number_of_bees;
                 ++i)
            cout << 'z';
    }

    increase_bees();
}
```
Local scope is local

Variable names declared in different scopes refer to different objects:

```plaintext
bool is_even(int n) { return n % 2 == 0; }
bool is_odd(int n)  { return n % 2 == 1; }
void swap(int& a, int& b)
{
    int n = a;
    a = b;
    b = n;
}
```
Local scope is local

Variable names declared in different scopes refer to different objects:

```cpp
bool is_even(int n) { return n % 2 == 0; }

bool is_odd(int m) { return m % 2 == 1; }

void swap(int& a, int& b)
{
    int n = a;
    a = b;
    b = n;
}
```

There are three unrelated objects named n above
Local scope is local

Variable names declared in different scopes refer to different objects:

```cpp
bool is_even(int n) { return n % 2 == 0; }
bool is_odd(int m) { return m % 2 == 1; }
void swap(int& a, int& b)
{
    int temporary = a;
    a = b;
    b = temporary;
}
```

There are three unrelated objects named n above
Local scope is local

Variable names declared in different scopes refer to different objects:

```c
bool is_even(int n) { return n % 2 == 0; }

bool is_odd(int m) { return m % 2 == 1; }

void swap(int& n, int& m)
{
    int temporary = n;
    n = m;
    m = temporary;
}
```

There are three unrelated objects named `n` above
Guidelines for scope

- Declare variables in the smallest possible scope
- Global variables:
  - In general: avoid if you can
  - In EECS 230: avoid (because you can)
Recap: Why functions?

- Chunk a program into manageable pieces ("divide and conquer")
- Map to our understanding of the problem domain
- Make the program easier to read
- Facilitate code reuse
- Ease testing and distribution of labor
Function syntax

Declaration:

```
return_type fun_name(type1 formal1, type2 formal2, ...);
```

(You can omit formal argument names in a declaration)
Function syntax

Declaration:

```
return_type fun_name(type1 formal1, type2 formal2, …);
```

(You can omit formal argument names in a declaration)

Definition:

```
return_type fun_name(type1 formal1, type2 formal2, …)
{
    stm; …
    return expr;
}
```
Function syntax

Declaration:

```plaintext
return_type fun_name(type1 formal1, type2 formal2, ...);
```

(You can omit formal argument names in a declaration)

Definition:

```plaintext
return_type fun_name(type1 formal1, type2 formal2, ...)
{
    stm; 
    ...  
    return expr;
}
```
Using a function

If a function is defined thus:

\[ \text{ret } f(\text{type1 formal1, type2 formal2, } \ldots ) \text{ body} \]

(where \textit{body} is a block or \textit{try}-\textit{catch} block)
Using a function

If a function is defined thus:

```
ret f(type1 formal1, type2 formal2, ...) body
```

(where `body` is a block or `try`-`catch` block)

then calling it as `f(actual1, actual2, ...)` means:

1. run its `body` with `actual1` copied to `formal1`, `actual2` copied to `formal2`, etc.
2. replace the function call with the value returned by the function
Example of using a function

double square(double f) { return f * f; }  
double dist(double x1, double y1, double x2, double y2)  
  { return sqrt(square(x1 - x2) + square(y1 - y2)); }
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << dist(1, 2, 4, -2) << ' \n ';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(square(x1 - x2) + square(y1 - y2));
    } ) << '\n';
}
Example of using a function

```c
double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(square(1 - x2) + square(y1 - y2));
    } ) << '\n';
}
```
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2) {
    return sqrt(square(x1 - x2) + square(y1 - y2));
}

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(square(1 - 4) + square(y1 - y2));
    } ) << ' \n';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(square(-3) + square(y1 - y2));
    } ) << '
';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(( {
            double f = -3; return f * f;
        } ) + square(y1 - y2));
    } ) << \
    << '
';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2) {
    return sqrt(square(x1 - x2) + square(y1 - y2));
}

int main()
{
    cout << (
    {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt((
            {
                double f = -3; return -3 * -3;
            }) + square(y1 - y2));
        }) << '\n';
    }
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(( {
            double f = -3; return 9;
        }) + square(y1 - y2));
    }) << ' \n';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(9 + square(y1 - y2));
    } ) << ' \n';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(9 + square(4));
    } ) << ' \n';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2) {
    return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << (
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(9 + 16);
    ) << ' \n';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return sqrt(25);
    } ) << '\n';
}

Example of using a function

```cpp
double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << ( {
        double x1 = 1; double y1 = 2;
        double x2 = 4; double y2 = -2;
        return 5;
    }) << ' \n';
}
```
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    cout << 5 << ' 
';
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
{ return sqrt(square(x1 - x2) + square(y1 - y2)); }

int main()
{
    // printed “5”
    cout << '\n';
}
Example of using a function

define square (double f) { return f * f; }
define dist (double x1, double y1, double x2, double y2) {
    return sqrt(square(x1 - x2) + square(y1 - y2));
}
define main ()
{
    // printed “5
    cout;
}
Example of using a function

double square(double f) { return f * f; }

double dist(double x1, double y1, double x2, double y2)
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int main()
{
    // printed “5
”
}
Parameter modes

Ordinary parameters (e.g., $f(int \ x, \ string \ s)$) get a copy of the actual argument object:

- The callee can make changes, but
- the caller won’t see them.
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Reference parameters (e.g., \( f(int& \ x, \ string& \ s) \)) get a reference to the actual argument object:

- The callee can make changes, and
- the caller \textit{will} see them.
Parameter modes

Ordinary parameters (e.g., `f(int x, string s)`) get a copy of the actual argument object:

- The callee can make changes, but
- the caller won’t see them.

Reference parameters (e.g., `f(int& x, string& s)`) get a reference to the actual argument object:

- The callee can make changes, and
- the caller will see them.

Const reference parameters (e.g., `f(const int& x, const string& s)`) get an unchangeable reference to the actual argument object:

- The callee cannot make changes, but
- no copying is necessary.
Pass by copy vs. pass by reference

```cpp
int f(int a) { a = a + 1; return a; }
int g(int& a) { a = a + 1; return a; }

int main()
{
    int x = 0; y = 0;
    cout << "f(x) = " << f(x) << '
';
    cout << "g(y) = " << g(y) << '
';
    cout << "x = " << x << '
';
    cout << "y = " << y << '
';
}
```

What gets printed?
if (the function wants to change the parameter) {
    pass by reference
} else if (the parameter is small, like an int or double) {
    pass by copy (i.e., an ordinary parameter)
} else {
    pass by const reference
}
References aren’t just for arguments

vector<string> v;

for (string s : v) ... // copies each element
for (string& s : v) ... // doesn’t copy
for (const string& s : v) ... // and doesn’t allow changes
Namespaces

What if Anne and Bob both want a function `swizzle(int)`?

```cpp
namespace anne {
    void swizzle(int);
}

namespace bob {
    void swizzle(int);
}
```
Namespaces

What if Anne and Bob both want a function `swizzle(int)`?

```cpp
namespace anne { 
void swizzle(int); 
}

namespace bob { 
void swizzle(int); 
}

From outside, we can refer to `anne::swizzle` and `bob::swizzle`
What if we almost always want `anne::swizzle` and are tired of typing `anne::` over and over?

Two options:

A ‹`using`› declaration brings one name into scope:

```cpp
using anne::swizzle;
```

A ‹`using`› directive brings a whole namespace into scope:

```cpp
using namespace anne;
```

The C++ standard library is defined in namespace `std`, so ordinarily you'd refer to `std::cout`, `std::string`, etc.

But `eecs230.h` contains a ‹`using`› namespace directive (Rude! Don’t put ‹`using`› directives in headers.)
using

What if we almost always want `anne::swizzle` and are tired of typing `anne::` over and over? Two options:

- A `<using>` *declaration* brings one name into scope:
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What if we almost always want `anne::swizzle` and are tired of typing `anne::` over and over? Two options:

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  using anne::swizzle;
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- A `<using> directive` brings a whole namespace into scope:
  ```cpp
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But `eecs230.h` contains a `using namespace std;` directive (Rude! Don’t put `using` directives in headers.)
Next time

Defining your own types!