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# CSE 374

# Programming Concepts & Tools

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Winter 2017

Lecture 19 – Introduction to C++

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# C++

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C++ is an *enormous* language:

- All of C
- Classes and objects (kind of like Java, some crucial differences)
- Many more little conveniences (I/O, new/delete, function overloading, pass-by-reference, bigger standard library)
- Namespaces (kind of like Java packages)
- Stuff we won't do: const, different kinds of casts, exceptions, templates, multiple inheritance, ...
- We will focus on a couple themes rather than just a "big bag of new features to memorize" ...

# Our focus

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Object-oriented programming in a C-like language may help you understand C and Java better?

- We can put objects on the stack or the heap; an object is not a pointer to an object
- Still have to manage memory manually
- Still lots of ways to HCBWKMSCOD\*
- Still distinguish header files from implementation files
- Allocation and initialization still separate concepts, but easier to “construct” and “destruct”
- Programmer has more control on how method-calls work (different defaults from Java)

\*hopefully crash, but who knows – might silently corrupt other data

# References

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- Lectures and sample code will have enough to get by for cse374
- Beyond that, best place to start: *C++ Primer*, Lippman, Lajoie, Moo, 5<sup>th</sup> ed., Addison-Wesley, 2013
- Every serious C++ programmer should also read:  
*Effective C++*, Meyers, 3<sup>rd</sup> ed., Addison-Wesley, 2005
  - Best practices for standard C++
- *Effective Modern C++*, Meyers, O'Reilly, 2014
  - Additional “best practices” for C++11/C++14
- Good online source: [cplusplus.com](http://cplusplus.com)

# Hello World

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```
#include <iostream>
int main() {
    // Use standard output stream cout
    // and operator << to send "Hello World"
    // and a newline (end line) to stdout
    std::cout << "Hello World" << std::endl;
    return 0;
}
```

- Differences from C: “new-style” headers (no .h), namespace access (::), I/O via stream operators, ...
- Differences from Java: not everything is in a class, any code can go in any file, ...
  - Can write procedural programs if that’s what you want

# Compiling

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- Need a different compiler than for C; use g++ on Linux. Example:

```
g++ -Wall -g -std=c++11 -o hello hello.cc
```

- The .cc extension is a convention (just like .c for C), but less universal (also common: .cpp, .cxx, .C, ...)
- Uses the C preprocessor (no change there)
- Now: A few “niceties” before our real focus (classes and objects)

# I/O

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- Operator << takes a “ostream” and (various things) and outputs it; returns the stream, which is why this works:  
`std::cout << 3 << "hi" << f(x) << '\n' ;`
  - Easier and safer than printf (type safe)
- Operator >> takes “istream” and (various things) and inputs into it
  - Easier and safer than scanf. Does not use pointers

```
int x; std::cin >> x;
```

## >> and <<

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- Can “think of” >> and << as keywords, but they are not:
  - Operator overloading redefines them for different pairs of types
    - In C and core C++ they mean “left-shift” and “right-shift” (of bits); undefined for non-numeric types
  - Lack of address-of for input (`cin>>x`) done with call-by-reference (coming soon)

# Namespaces

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- In C, all non-static functions in the program need different names
  - Even operating systems with tens of millions of lines
- Namespaces (cf. Java packages) let you group top-level names:  
`namespace thespace { ... definitions ... }`
  - Of course, then different namespaces can have the same function names and they are totally different functions
  - Can nest them
  - Can reuse the same namespace in multiple places
    - Particularly common: in the .h and the .cc
- Example, the whole C++ standard library is in `namespace std`
- To use a function/variable/etc. in another namespace, do  
`thespace::some_fun()` (not . like in Java)

# Using

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- To avoid having to always write namespaces and :: use a *using declaration*
- Example:

```
#include <iostream>
using namespace std;
int main() {
    cout << "Hello World" << endl;
    return 0;
}
```

# Onto Classes and Objects

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Like Java:

- Fields vs. methods, static vs. instance, constructors
- Method overloading (functions, operators, and constructors too)

Not quite like Java:

- access-modifier (e.g., private) syntax and default
- declaration separate from implementation (like C)
- funny constructor syntax, default parameters (e.g., ... = 0)

Nothing like Java:

- Objects vs. pointers to objects
- Destructors and copy-constructors
- virtual vs. non-virtual (to be discussed)

# Stack vs. heap

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- Java: cannot stack-allocate an object (only a pointer to one; all objects are dynamically allocated on the heap)
- C: can stack-allocate a struct, then initialize it
- C++: stack-allocate and call a constructor (where `this` is the object's address, as always, except `this` is a pointer)

```
Thing t(10000);
```
- Java: `new Thing(...)` calls constructor, returns heap-allocated pointer
- C: Use `malloc` and then initialized, must free exactly once later, untyped pointers
- C++: Like Java, `new Thing(...)`, but can also do `new int(42)`. Like C must deallocate, but must use `delete` instead of `free`. (**never mix malloc/free with new/delete!**)

# Destructors

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- An object's destructor is called just before the space for it is reclaimed
- A common use: Reclaim space for heap-allocated things pointed to (first calling their destructors)
  - But not if there are other pointers to it (aliases)?!
- Meaning of `delete x`: call the destructor of pointed-to heap object, then reclaim space
- Destructors also get called for stack-objects (when they leave scope)
- Advice: Always make destructors virtual (learn why soon)

# Arrays

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Create a heap-allocated array of objects: `new A[10]` ;

- Calls *default* (zero-argument) constructor for each element
- Convenient if there's a good default initialization

Create a heap-allocated array of pointers to objects:

`new A* [10]` ;

- More like Java (but not initialized?)
- As in C, `new A()` and `new A[10]` have type `A*`
- `new A*` and `new A* [10]` both have type `A**`
- Unlike C, to delete a non-array, you must write `delete e`
- Unlike C, to delete an array, you must write `delete [] e`
- Else HYCSBWK – `delete` must be told when it is deleting an array (otherwise it tries to delete a single element)

# Digression: Call-by-reference

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- In C, we know function arguments are copies
  - But copying a pointer means you still point to the same (uncopied) thing
- Same also works in C++; but can also use a “reference parameter” (& character before var name)
- Function definition: `void f(int& x) {x = x+1; }`
- Caller writes: `f(y)`
- But it's as though the caller wrote `f(&y)` and every occurrence of `x` in the function really said `*x`.
- So that little & has a big meaning.

# Copy Constructors

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- In C, we know `x=y` or `f(y)` copies `y` (if a struct, then member-wise copy)
- Same in C++, unless a copy-constructor is defined, then do whatever the copy-constructor says
- A copy-constructor by definition takes a reference parameter (else we'd need to copy, but that's what we're defining) of the same type
- Copy constructor vs. assignment
  - Copy constructor *initializes* a new bag of bits (new variable or parameter)
  - Assignment (=) *replaces* an existing value with a new one – may need to clean up old state (free heap data?)

# const

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- **const** can appear in many places in C++ code
  - Basically means “doesn’t change” or “won’t change”, but there are subtleties
- Examples:

```
const int default_length = 125; // don't use #define
void examine (const thing &t); // won't change t
int getX() const; // won't change *this
```

- “const correctness” is important in real C++ code
  - Learn it if you do any non-trivial C++

# Still to come

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- So far we have classes and objects (class instances)
  - Enough for many interesting types, particularly small concrete types like strings, complex, date, time, etc
- For full object-oriented programming we still need (and have) subclassing, inheritance, and related things
  - Many similarities with Java, but more options and different defaults