



# Poll Everywhere

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## How's HW2 going?

- A. Finished ;)
- B. Working on part C
- C. Working on part B
- D. Working on part A
- E. I've read through the spec and looked at the starter code
- F. Haven't started yet ;(

# CSE333 Systems Programming

## C++ References, Const, Classes

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# Adminis...trivia?

- ★ Homework 2 due a week from Thursday (4/30)
  - File system crawler, indexer, and search engine
  - ★ Note: libhw1.a (yours or ours) and the .h files from hw1 need to be in right directory (~yourgit/hw1/)
  - Note: use Ctrl-D to exit searchshell, test on directory of small self-made files
  
- ★ Office hours are your friend (:)

# Lecture Outline

- ❖ C++ References

- ❖ const in C++

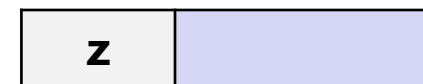
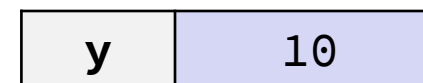
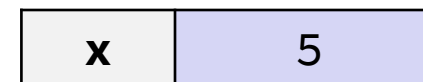
- ❖ C++ Classes Intro

# Pointers Reminder (1/6)

Note: Arrow points to *next* instruction.

- ❖ A **pointer** is a variable containing an address
  - Modifying the pointer *doesn't* modify the variable it points to, but you can access/modify what it points to by *dereferencing*
  - These work the same in C and C++

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int* z = &x;  
  
    *z += 1;  
    x += 1;  
  
    z = &y;  
    *z += 1;  
  
    return EXIT_SUCCESS;  
}
```



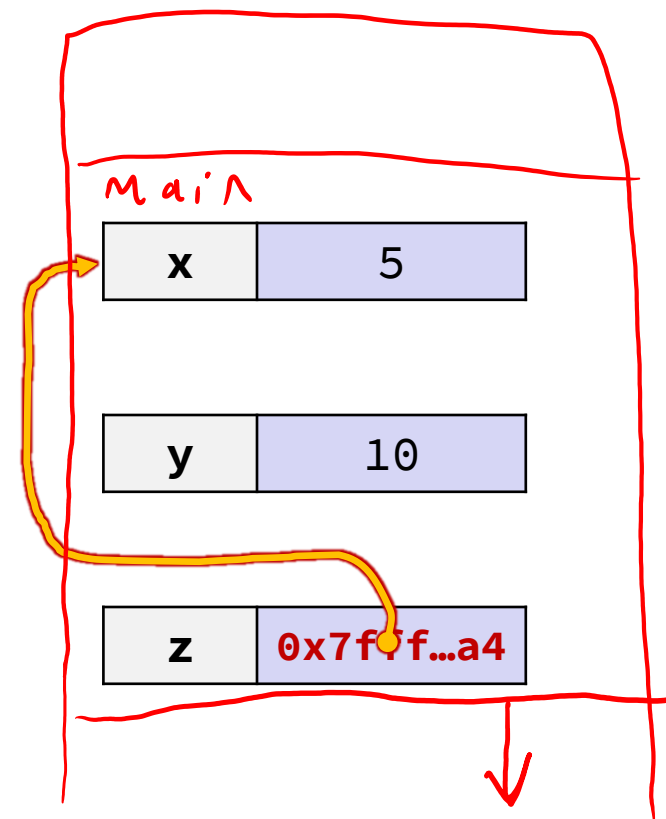
pointer.cc

# Pointers Reminder (2/6)

- ❖ A **pointer** is a variable containing an address
  - Modifying the pointer *doesn't* modify the variable it points to, but you can access/modify what it points to by *dereferencing*
  - These work the same in C and C++

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int* z = &x;  
  
    *z += 1;  
    x += 1;  
  
    z = &y;  
    *z += 1;  
  
    return EXIT_SUCCESS;  
}
```

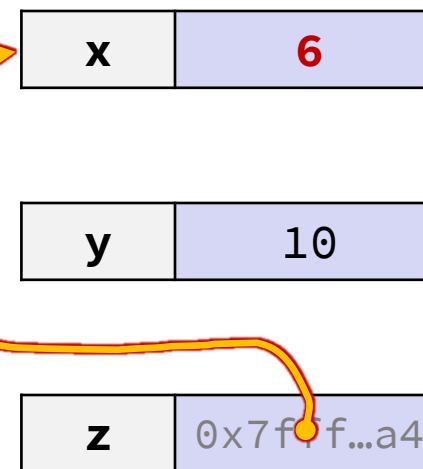
pointer.cc



# Pointers Reminder (3/6)

- ❖ A **pointer** is a variable containing an address
  - Modifying the pointer *doesn't* modify the variable it points to, but you can access/modify what it points to by *dereferencing*
  - These work the same in C and C++

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int* z = &x;  
  
    *z += 1; // sets x to 6  
    x += 1;  
  
    z = &y;  
    *z += 1;  
  
    return EXIT_SUCCESS;  
}
```

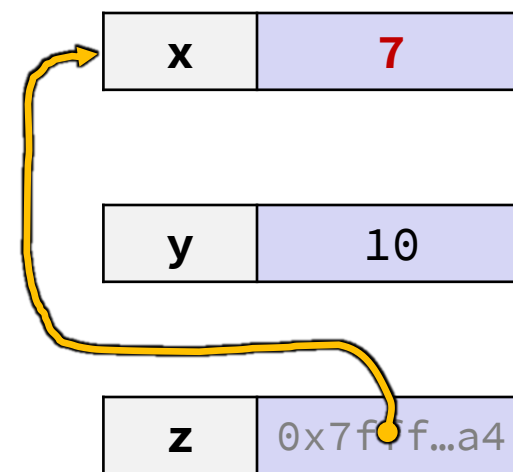


pointer.cc

# Pointers Reminder (4/6)

- ❖ A **pointer** is a variable containing an address
  - Modifying the pointer *doesn't* modify the variable it points to, but you can access/modify what it points to by *dereferencing*
  - These work the same in C and C++

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int* z = &x;  
  
    *z += 1; // sets x to 6  
    x += 1; // sets x (and *z) to 7  
  
    z = &y;  
    *z += 1;  
  
    return EXIT_SUCCESS;  
}
```

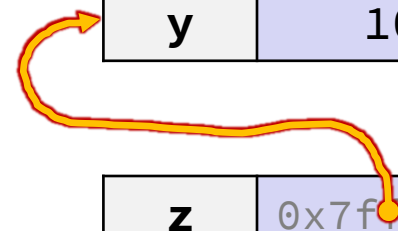
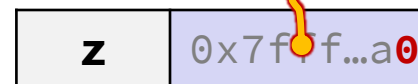
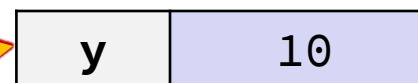
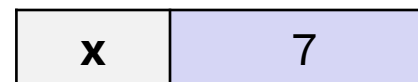


pointer.cc

# Pointers Reminder (5/6)

- ❖ A **pointer** is a variable containing an address
  - Modifying the pointer *doesn't* modify the variable it points to, but you can access/modify what it points to by *dereferencing*
  - These work the same in C and C++

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int* z = &x;  
  
    *z += 1; // sets x to 6  
    x += 1; // sets x (and *z) to 7  
  
    z = &y; // sets z to the address of y  
    *z += 1;  
  
    return EXIT_SUCCESS;  
}
```

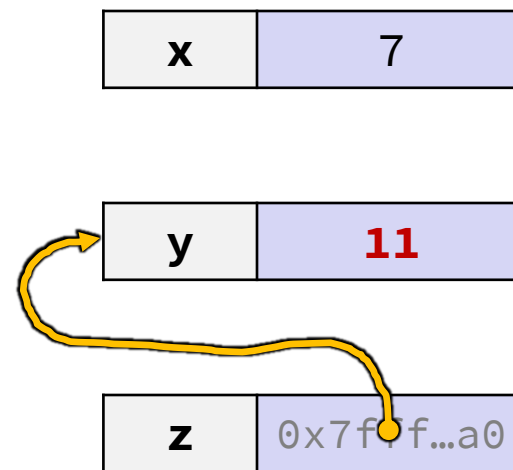


pointer.cc

# Pointers Reminder (6/6)

- ❖ A **pointer** is a variable containing an address
  - Modifying the pointer *doesn't* modify the variable it points to, but you can access/modify what it points to by *dereferencing*
  - These work the same in C and C++

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int* z = &x;  
  
    *z += 1; // sets x to 6  
    x += 1; // sets x (and *z) to 7  
  
    z = &y; // sets z to the address of y  
    *z += 1; // sets y (and *z) to 11  
  
    return EXIT_SUCCESS;  
}
```



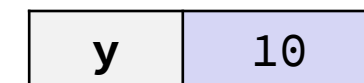
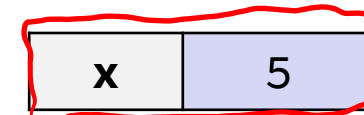
pointer.cc

# References (1/6)

Note: Arrow points to *next* instruction.

- ❖ A **reference** is an alias for another variable
  - *Alias*: another name that is bound to the aliased variable
    - Mutating a reference *is* mutating the aliased variable
  - Introduced in C++ as part of the language

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int& z = x;  
  
    z += 1;  
    x += 1;  
  
    z = y;  
    z += 1;  
  
    return EXIT_SUCCESS;  
}
```



reference.cc

# References (2/6)

- ❖ A **reference** is an alias for another variable
  - *Alias*: another name that is bound to the aliased variable
    - Mutating a reference *is* mutating the aliased variable
  - Introduced in C++ as part of the language

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int& z = x; // binds the name "z" to x  
    z += 1;  
    x += 1;  
  
    z = y;  
    z += 1;  
  
    return EXIT_SUCCESS;  
}
```

x, z	5
------	---

y	10
---	----

reference.cc

# References (3/6)

- ❖ A **reference** is an alias for another variable
  - *Alias*: another name that is bound to the aliased variable
    - Mutating a reference *is* mutating the aliased variable
  - Introduced in C++ as part of the language

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int& z = x; // binds the name "z" to x  
  
    z += 1; // sets z (and x) to 6  
    x += 1;  
  
    z = y;  
    z += 1;  
  
    return EXIT_SUCCESS;  
}
```

x, z	6
------	---

y	10
---	----

reference.cc

# References (4/6)

- ❖ A **reference** is an alias for another variable
  - *Alias*: another name that is bound to the aliased variable
    - Mutating a reference *is* mutating the aliased variable
  - Introduced in C++ as part of the language

```
int main(int argc, char** argv) {
    int x = 5, y = 10;
    int& z = x; // binds the name "z" to x

    z += 1; // sets z (and x) to 6
    x += 1; // sets x (and z) to 7

    → z = y;
    z += 1;

    return EXIT_SUCCESS;
}
```

x, z	7
------	---

y	10
---	----

reference.cc

# References (5/6)

- ❖ A **reference** is an alias for another variable
  - *Alias*: another name that is bound to the aliased variable
    - Mutating a reference *is* mutating the aliased variable
  - Introduced in C++ as part of the language

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int& z = x; // binds the name "z" to x  
  
    z += 1; // sets z (and x) to 6  
    x += 1; // sets x (and z) to 7  
  
    z = y; // sets z (and x) to the value of y  
    z += 1;  
  
    return EXIT_SUCCESS;  
}
```

x, z	10
------	----

y	10
---	----

reference.cc

# References (6/6)

- ❖ A **reference** is an alias for another variable
  - *Alias*: another name that is bound to the aliased variable
    - Mutating a reference *is* mutating the aliased variable
  - Introduced in C++ as part of the language

```
int main(int argc, char** argv) {  
    int x = 5, y = 10;  
    int& z = x; // binds the name "z" to x  
    int& a = z; // binds the name "a" to z  
    z += 1; // sets z (and x) to 6  
    x += 1; // sets x (and z) to 7  
  
    z = y; // sets z (and x) to the value of y  
    z += 1; // sets z (and x) to 11  
  
    return EXIT_SUCCESS;  
}
```

x, z, a	11
---------	----

y	10
---	----

reference.cc

# Pass-By-Reference (1/6)

Note: Arrow points to *next* instruction.

- ❖ C++ allows you to use real *pass-by-reference*
  - Client passes in an argument with normal syntax
    - Function uses reference parameters with normal syntax
    - Modifying a reference parameter modifies the caller's argument!

```
void Swap(int& x, int& y) {  
    int tmp = x;  
    x = y;  
    y = tmp;  
}  
  
int main(int argc, char** argv) {  
    int a = 5, b = 10;  
    Swap(a, b);  
    cout << "a: " << a << "; b: " << b << endl;  
    return EXIT_SUCCESS;  
}
```

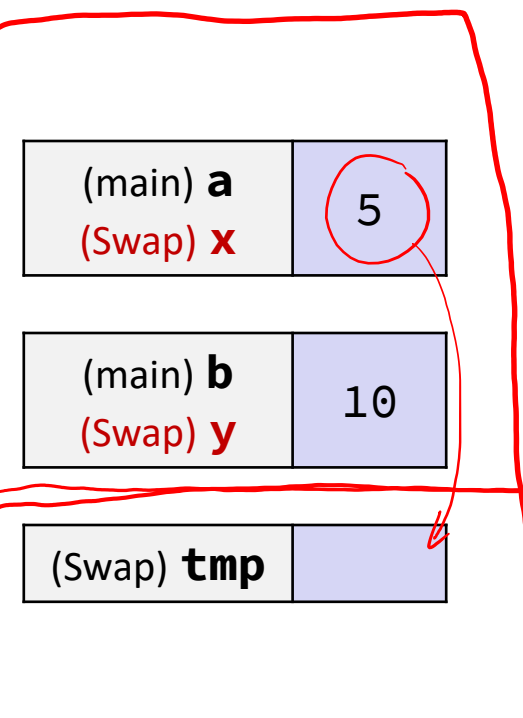
(main) <b>a</b>	5
-----------------	---

(main) <b>b</b>	10
-----------------	----

# Pass-By-Reference (2/6)

- ❖ C++ allows you to use real *pass-by-reference*
  - Client passes in an argument with normal syntax
    - Function uses reference parameters with normal syntax
    - Modifying a reference parameter modifies the caller's argument!

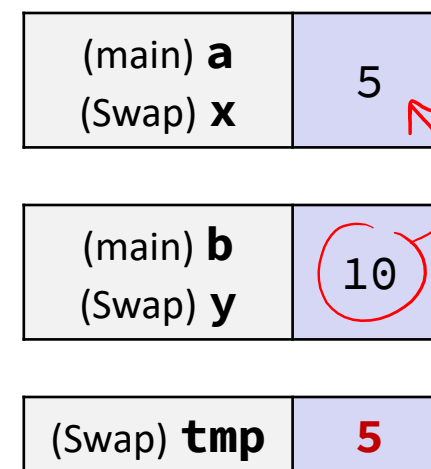
```
void Swap(int& x, int& y) {  
→ int tmp = x;  
  x = y;  
  y = tmp;  
}  
  
int main(int argc, char** argv) {  
  int a = 5, b = 10;  
  
  Swap(a, b);  
  cout << "a: " << a << "; b: " << b << endl;  
  return EXIT_SUCCESS;  
}
```



# Pass-By-Reference (3/6)

- ❖ C++ allows you to use real *pass-by-reference*
  - Client passes in an argument with normal syntax
    - Function uses reference parameters with normal syntax
    - Modifying a reference parameter modifies the caller's argument!

```
void Swap(int& x, int& y) {  
    int tmp = x;  
    x = y;  
    y = tmp;  
}  
  
int main(int argc, char** argv) {  
    int a = 5, b = 10;  
  
    Swap(a, b);  
    cout << "a: " << a << "; b: " << b << endl;  
    return EXIT_SUCCESS;  
}
```



# Pass-By-Reference (4/6)

- ❖ C++ allows you to use real *pass-by-reference*
  - Client passes in an argument with normal syntax
    - Function uses reference parameters with normal syntax
    - Modifying a reference parameter modifies the caller's argument!

```
void Swap(int& x, int& y) {  
    int tmp = x;  
    x = y;  
    y = tmp;  
}  
  
int main(int argc, char** argv) {  
    int a = 5, b = 10;  
  
    Swap(a, b);  
    cout << "a: " << a << "; b: " << b << endl;  
    return EXIT_SUCCESS;  
}
```

(main) <b>a</b>	10
(Swap) <b>x</b>	10

(main) <b>b</b>	10
(Swap) <b>y</b>	10

(Swap) <b>tmp</b>	5
-------------------	---

# Pass-By-Reference (5/6)

- ❖ C++ allows you to use real *pass-by-reference*
  - Client passes in an argument with normal syntax
    - Function uses reference parameters with normal syntax
    - Modifying a reference parameter modifies the caller's argument!

```
void Swap(int& x, int& y) {  
    int tmp = x;  
    x = y;  
    y = tmp;  
}  
  
int main(int argc, char** argv) {  
    int a = 5, b = 10;  
  
    Swap(a, b);  
    cout << "a: " << a << "; b: " << b << endl;  
    return EXIT_SUCCESS;  
}
```

(main) <b>a</b>	10
(Swap) <b>x</b>	10

(main) <b>b</b>	5
(Swap) <b>y</b>	5

(Swap) <b>tmp</b>	5
-------------------	---

# Pass-By-Reference (6/6)

- ❖ C++ allows you to use real *pass-by-reference*
  - Client passes in an argument with normal syntax
    - Function uses reference parameters with normal syntax
    - Modifying a reference parameter modifies the caller's argument!

```
void Swap(int& x, int& y) {  
    int tmp = x;  
    x = y;  
    y = tmp;  
}  
  
int main(int argc, char** argv) {  
    int a = 5, b = 10;  
  
    Swap(a, b);  
    cout << "a: " << a << "; b: " << b << endl;  
    return EXIT_SUCCESS;  
}
```

(main) <b>a</b>	10
-----------------	----

(main) <b>b</b>	5
-----------------	---



# Poll Everywhere

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poll1.cc

```

void Foo(int& x, int* y, int z) {
    z = *y;
    x += 2;
    y = &x;
}

int main(int argc, char** argv) {
    int a = 1;
    int b = 2;
    int& c = a;

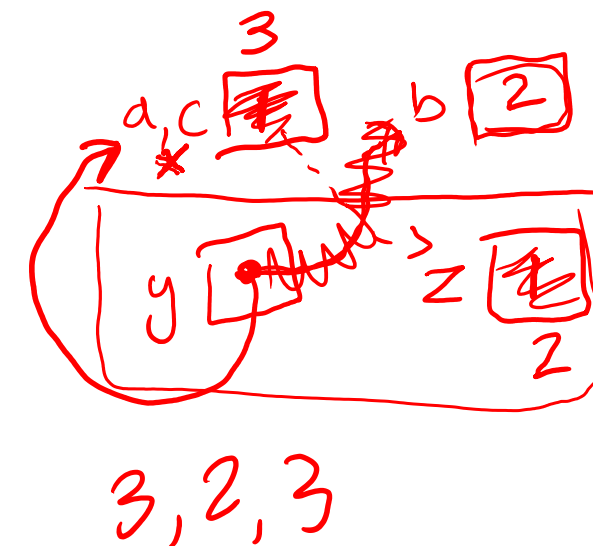
    Foo(a, &b, c);
    std::cout << "(" << a << ", " << b
    << ", " << c << ")" << std::endl;

    return EXIT_SUCCESS;
}

```

## What will happen when we try to compile and run this code?

- A. Output "(1,2,3)"
- B. Output "(3,2,3)"
- C. Output "(3,2,2)"
- D. Compiler error
- E. We're lost...



# Lecture Outline

- ❖ C++ References
- ❖ **const in C++**
- ❖ C++ Classes Intro

# const

- ❖ **const**: this cannot be changed/mutated
  - Used *much* more in C++ than in C
  - Signal of intent to compiler; meaningless at hardware level
    - Results in compile-time errors

```
void BrokenPrintSquare(const int& i) {  
    i = i*i; // compiler error here!  
    std::cout << i << std::endl;  
}  
  
int main(int argc, char** argv) {  
    int j = 2;  
    BrokenPrintSquare(j);  
    return EXIT_SUCCESS;  
}
```

x ~ x

brokenpassbyrefconst.cc

# const and Pointers

❖ Pointers can change data in two different contexts:

- 1) You can change the value of the pointer  
(i.e., address stored)
- 2) You can change the thing the pointer points to  
(via dereference)

❖ `const` can be used to prevent either/both of these behaviors!

- `const` next to pointer name means you can't change the value of the pointer
- `const` next to data type pointed to means you can't use this pointer to change the thing being pointed to
- Tip: read variable declaration from *right-to-left*

# const and Pointers Examples

- ❖ The syntax with pointers is confusing:

```
int main(int argc, char** argv) {
    int x = 5;
    const int y = 6;
    y++;
    const int* z = &y;
    *z += 1;
    z++;
    int* const w = &x;
    *w += 1;
    w++;
    const int* const v = &x;
    *v += 1;
    v++;
    return EXIT_SUCCESS;
}
```

*Handwritten annotations:*

- Red arrows point to `y++`, `*z += 1`, `z++`, `*w += 1`, `w++`, `*v += 1`, and `v++`.
- Red text next to `const int* z = &y;` says: *pointer to a int that's const*
- Red text next to `int* const w = &x;` says: *const pointer to an int*
- Red text next to `const int* const v = &x;` says: *const pointer to an int that's const*

# const and Pointers Examples: In Words

- ❖ The syntax with pointers is confusing:

```
int main(int argc, char** argv) {
    int x = 5;           // int
    const int y = 6;    // (const int)
    y++;

    const int* z = &y;  // pointer to a (const int)
    *z += 1;
    z++;

    int* const w = &x;  // (const pointer) to a (variable int)
    *w += 1;
    w++;

    const int* const v = &x; // (const pointer) to a (const int)
    *v += 1;
    v++;

    return EXIT_SUCCESS;
}
```

# const and Pointers Examples: With Outcomes

- ❖ The syntax with pointers is confusing:

```
int main(int argc, char** argv) {
    int x = 5;           // int
    const int y = 6;    // (const int)
    y++;                // compiler error

    const int* z = &y;  // pointer to a (const int)
    *z += 1;           // compiler error
    z++;              // ok

    int* const w = &x;  // (const pointer) to a (variable int)
    *w += 1;           // ok
    w++;              // compiler error

    const int* const v = &x; // (const pointer) to a (const int)
    *v += 1;           // compiler error
    v++;              // compiler error

    return EXIT_SUCCESS;
}
```

# const Parameters

- ❖ A const parameter *cannot* be mutated inside the function
  - Therefore it does not matter if the argument can be mutated or not
- ❖ A non-const parameter *may* be mutated inside the function
  - Compiler won't let you pass in const parameters

pointer to an int  
that's const  
Make parameters const when you can!



```
void Foo(const int* y) {
    std::cout << *y << std::endl;
}

void Bar(int* y) {
    std::cout << *y << std::endl;
}

int main(int argc, char** argv) {
    const int a = 10;
    int b = 20;
    Foo(&a); // OK
    Foo(&b); // OK
    Bar(&a); // not OK - error
    Bar(&b); // OK

    return EXIT_SUCCESS;
}
```

UNmodified!

# Poll Everywhere

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const pointer to  
an int

poll2.cc

```
void Foo(int* const x, int& y,
         int z) {
    *x += 1;
    y *= 2;
    z -= 3;
}

int main(int argc, char** argv) {
    const int a = 1;
    int b = 2, c = 3;
    Foo(&a, b, c);
    std::cout << "(" << a << "," << b
              << "," << c << ")" << std::endl;
    return EXIT_SUCCESS;
}
```

## What will happen when we try to compile and run this code?

A. Output "(2,4,0)"

B. Output "(2,4,3)"

C. Compiler error about call to Foo (in main)

D. Compiler error about body of Foo

E. Lost lost lost...



# When to Use References?

- ❖ A stylistic choice, not mandated by the C++ language
- ❖ Google C++ style guide suggests:
  - Input parameters:
    - Either use values (for primitive types like `int` or small structs/objects)
    - Or use `const` references (for complex struct/object instances)
  - Output parameters:
    - Use `const` pointers
      - Unchangeable pointers referencing changeable data
  - Ordering:
    - List input parameters first, then output parameters last

```
size_t StringBefore(const string& input, const string& search,
                   string* const result) {
    *result = input.substr(0, input.find(search));
    return input.find(search);
}
```

# Lecture Outline

- ❖ C++ References
- ❖ `const` in C++
- ❖ **C++ Classes Intro**

# Classes

## ❖ Class definition syntax (in a .h file):

```
class Name {  
  public:  
  // public member definitions & declarations go here  
  
  private:  
  // private member definitions & declarations go here  
}; // class Name
```

- Members can be functions (methods) or data (variables)

*scope resolution operator*

## ❖ Class member function definition syntax (in a .cc file):

```
retType Name::MethodName(type1 param1, ..., typeN paramN) {  
  // body statements  
}
```

- (1) *define* within the class definition or (2) *declare* within the class definition and then *define* elsewhere

# Class Organization

- ❖ It's a little more complex than in C when modularizing with `struct` definition:
  - Class definition is part of interface and should go in `.h` file
    - Private members still must be included in definition (!)
  - Usually put member function definitions into companion `.cc` file with implementation details
    - Common exception: setter and getter methods
  - These files can also include **non-member functions** that use the class
- ❖ Unlike Java, you can name files anything you want
  - Typically `Name.cc` and `Name.h` for **class Name**

# const & Classes

- ❖ Like other data types, **objects** can be declared as `const`:
  - Once a `const` object has been constructed, its member variables can't be changed
  - Can only invoke member functions that are labeled `const`
- ❖ You can declare a member **function** of a class as `const`
  - This means that it cannot modify the object it was called on
    - The compiler will treat member variables as `const` inside the function at compile time
  - If a member function doesn't modify the object, mark it `const`!



# Class Definition (.h file)

Point.h

```
#ifndef POINT_H_
#define POINT_H_

class Point {
public:
    Point(const int x, const int y);    // constructor
    int get_x() const { return x_; }   // inline member function
    int get_y() const { return y_; }   // inline member function
    double Distance(const Point& p) const;    // member function
    void SetLocation(const int x, const int y); // member function

private:
    int x_; // data member
    int y_; // data member
}; // class Point

#endif // POINT_H_
```

# Class Member Definitions (.cc file)

Point.cc

```

#include <cmath>
#include "Point.h"
Point::Point(const int x, const int y) {
    x_ = x;
    this->y_ = y; // "this->" is optional unless name conflicts
}

```

*Point \* this;*

*constructor*

```

double Point::Distance(const Point& p) const {
    // We can access p's x_ and y_ variables either through the
    // get_x(), get_y() accessor functions or the x_, y_ private
    // member variables directly, since we're in a member
    // function of the same class.
    double distance = (x_ - p.get_x()) * (x_ - p.get_x());
    distance += (y_ - p.y_) * (y_ - p.y_);
    return sqrt(distance);
}

```

*const Point \* this;*

```

void Point::SetLocation(const int x, const int y) {
    x_ = x;
    y_ = y;
}

```

# Class Usage (.cc file)

usepoint.cc

```
#include <iostream>
#include <cstdlib>
#include "Point.h"

using namespace std;

int main(int argc, char** argv) {
    Point p1(1, 2); // allocate a new Point on the Stack
    Point p2(4, 6); // allocate a new Point on the Stack


    cout << "p1 is: (" << p1.get_x() << ", ";
    cout << p1.get_y() << ")" << endl;

    cout << "p2 is: (" << p2.get_x() << ", ";
    cout << p2.get_y() << ")" << endl;

    cout << "dist : " << p1.Distance(p2) << endl;
    return EXIT_SUCCESS;
}
```

constructor

# Reading Assignment

- ❖ Before next time, **read** the sections in *C++ Primer* covering class constructors, copy constructors, assignment (`operator=`), and destructors
  - Free link for UW students to the [relevant section \(§13.1.1\)](#)
    - Click “Read now” and scroll down to “ Academic user?”
  - Ignore “move semantics” for now
  - The table of contents and index are your friends...