CSE 333
Section 4

HW2 Overview, C++ Intro

Logistics

- Exercise 5
  - Due **Thursday (10/19) by 10pm**
- Midterm
  - Next **Friday (10/27) 11:30 - 12:20 pm @ Kane 110**
- Homework 2
  - Due **Monday (10/30) @ 10:00 pm**
  - Indexing files to allow for searching
  - Bigger and longer than Homework 1!

Agenda

- Makefiles
- HW2 overview
- C++ Intro review
- Exercise 1
- Objects and const methods review
- Exercise 2

Makefiles

```
target: src1 src2 … srcN
    command/commands
```

Makefiles are used to manage project recompilation. Project structure / dependencies can be represented as a DAG, which a Makefile encodes to recursively build the minimum number of files for a target.

Makefiles

- In practice, these can often be written automatically or by following common target patterns
    - In 333, we will ask you to submit Makefiles along with a few of your exercises, but you can adapt existing rules from provided examples
    - It is more important that you understand the concepts behind them and can read and understand target rules from a given Makefile
- Exercise 3 on your worksheet is provided for practice on your own time; solutions will be released with the rest of the worksheet solutions

Homework 2 Overview

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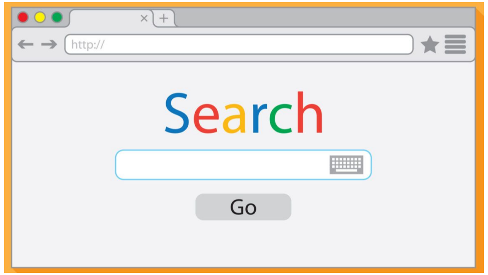
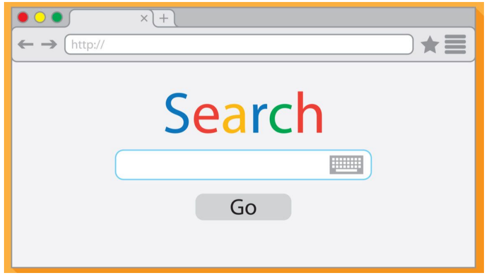


- Build a search engine for a collection of files
  - User **inputs a text query** (one or more words)
  - The search engine **outputs a ranked list of files** (decreasing order) within the collection that match the query

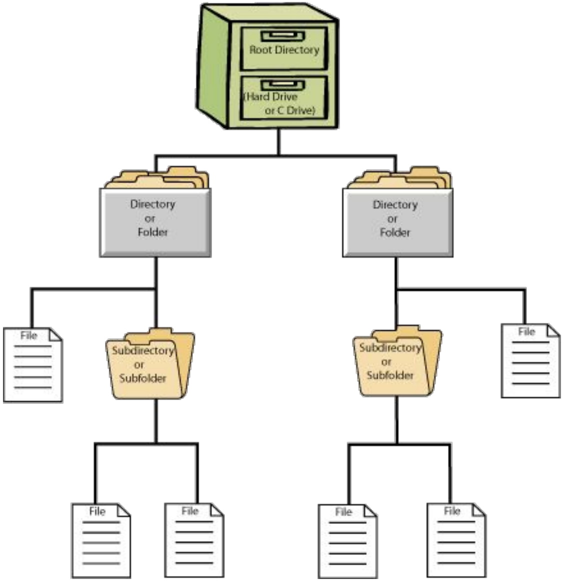
Homework 2 Overview



- Build a search engine for a collection of files
  - User **inputs a text query** (one or more words)
  - The search engine **outputs a ranked list of files** (decreasing order) within the collection that match the query
- More details:
  - Our collection of files will be the contents of a specified local directory (including the contents of its subdirectories)
  - Naive **matching**: any file that contains all words in the query
  - Naive **ranking**: sum of the counts of *all* words in the query
    - Files in search results with equal ranking can be displayed in any order

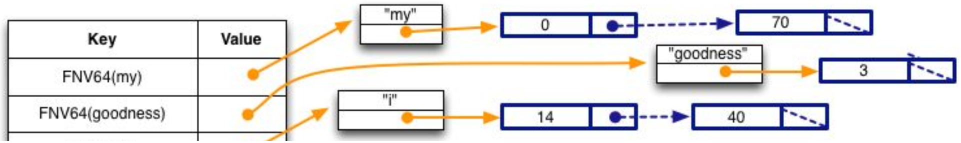
Search Engine Implementation Overview

- Major components:
  - The **directory crawler** recursively finds the “regular” files in the specified collection/corpus

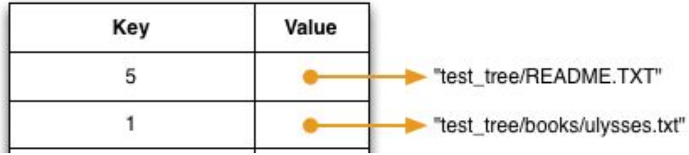


Search Engine Implementation Overview

- Major components:
  - The **directory crawler** recursively finds the “regular” files in the specified collection/corpus
  - As files are found, the **file parser** adds the words and their locations into heap-allocated data structures
    - This uses the `LinkedList` and `HashTable` implementations from HW1 – need `libhw1.a` to be in the `hw1/` directory



Key	Value
FNV64(my)	●
FNV64(goodness)	●



Key	Value
5	●
1	●

Search Engine Implementation Overview

- Major components:
  - The **directory crawler** recursively finds the “regular” files in the specified collection/corpus
  - As files are found, the **file parser** adds the words and their locations into heap-allocated data structures
    - This uses the `LinkedList` and `HashTable` implementations from HW1 – need `libhw1.a` to be in the `hw1/` directory
  - The **searchshell** (*i.e.*, search engine) reads in user queries and uses the built up data structures to return the search results
    - Finish the infinite loop by using Ctrl-D

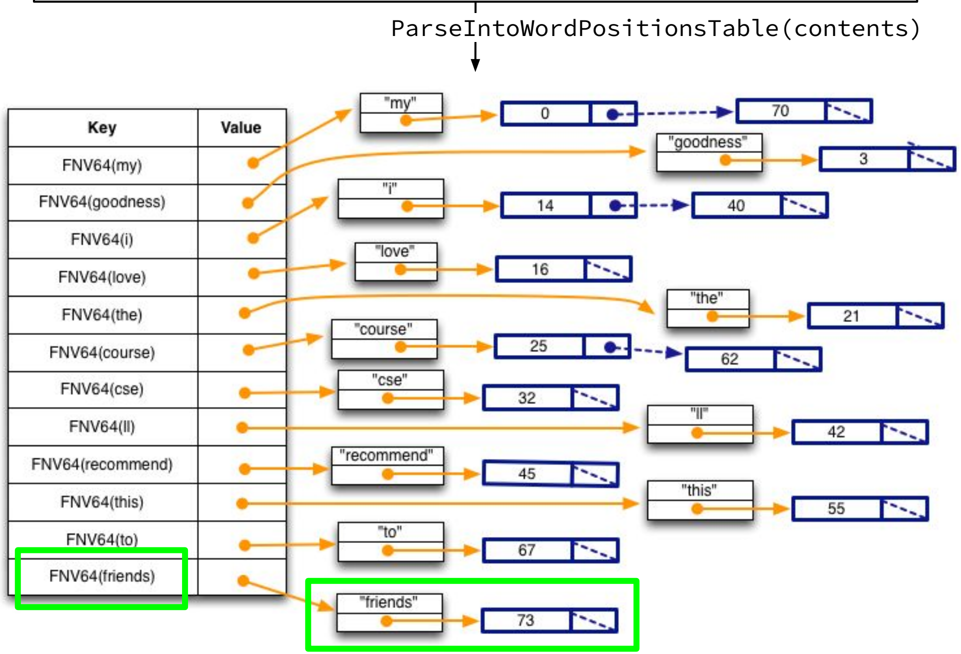
Part A: File Parsing

Read a file and generate a `HashTable` of `WordPositions`

- The words are “normalized” – lowercase and broken by non-alphabetic characters
- HashTable key is the hashed normalized word
- `WordPositions` has heap-allocated copy of the word and a LinkedList of its position(s) in the file.

somefile.txt

```
My goodness! I love the course CSE333.\n
I'll recommend this course to my friends.\n
```



Key	Value
FNV64(my)	
FNV64(goodness)	
FNV64(i)	
FNV64(love)	
FNV64(the)	
FNV64(course)	
FNV64(cse)	
FNV64(ll)	
FNV64(recommend)	
FNV64(this)	
FNV64(to)	
FNV64(friends)	

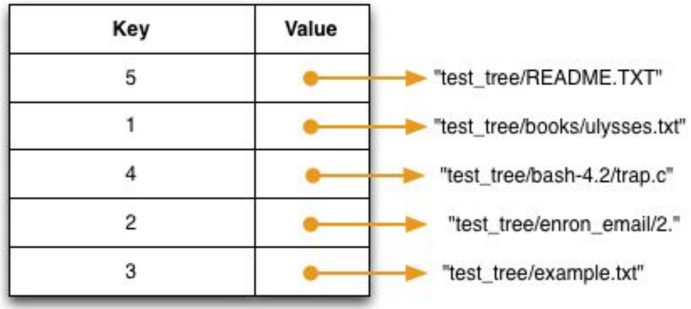
```
typedef struct {
 char       *word;      // in heap (owned)
 LinkedList *positions; // DocPositionOffset_t
} WordPositions;
```

Part B: Directory Crawling – DocTable

Recursively search directories and parse files to build out a `DocTable` and `MemIndex` for the collection of files

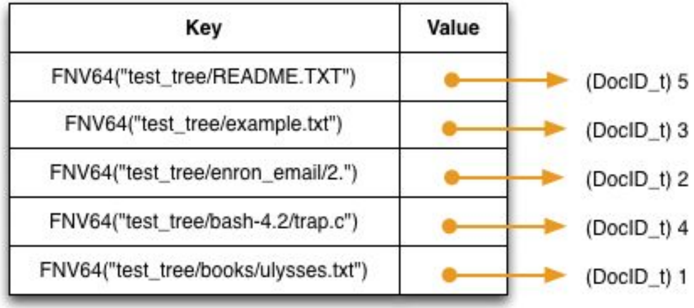
- `DocTable` maps document names to IDs (in both directions) via `HashTables`

```
struct doctable_st {
 HashTable *id_to_name;  // mapping doc id to doc name
 HashTable *name_to_id;  // mapping docname to doc id
 DocID_t    max_id;      // max docID allocated so far
};
DocID_t DocTable_Add(DocTable *table, char *doc_name);
```



Key	Value
5	"test_tree/README.TXT"
1	"test_tree/books/ulysses.txt"
4	"test_tree/bash-4.2/trap.c"
2	"test_tree/enron_email/2."
3	"test_tree/example.txt"

docid_to_docname



Key	Value
FNV64("test_tree/README.TXT")	(DocID_t) 5
FNV64("test_tree/example.txt")	(DocID_t) 3
FNV64("test_tree/enron_email/2.")	(DocID_t) 2
FNV64("test_tree/bash-4.2/trap.c")	(DocID_t) 4
FNV64("test_tree/books/ulysses.txt")	(DocID_t) 1

docname_to_docid

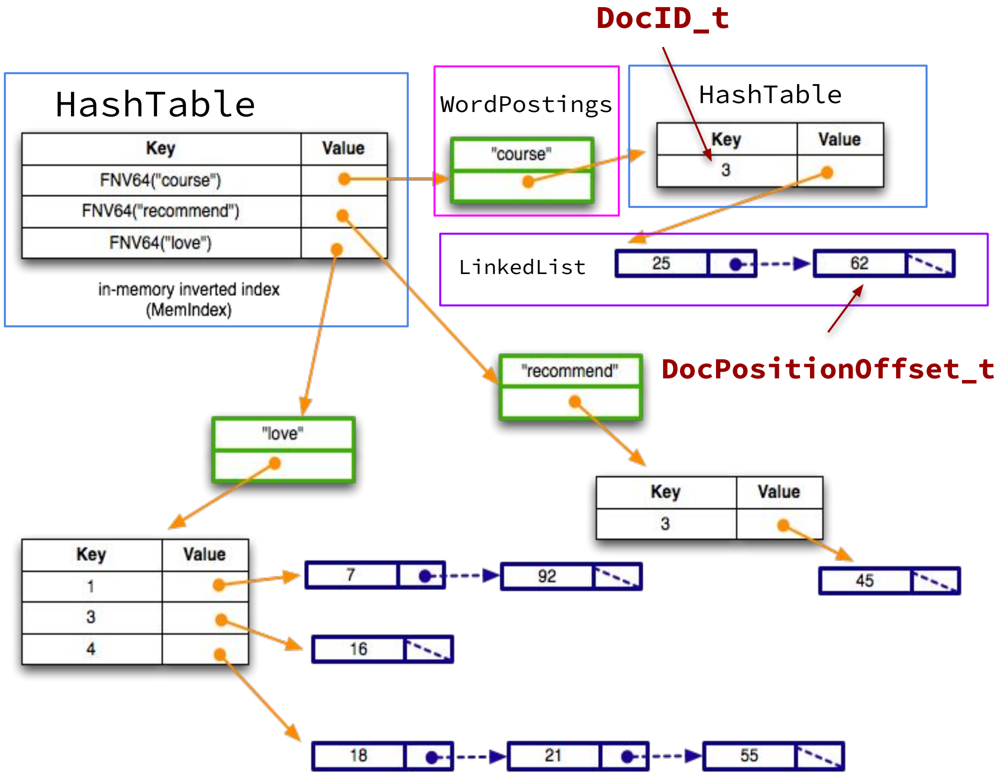
Part B: Directory Crawling – MemIndex

```
typedef struct {
 char          *word;
 HashTable     *postings;
} WordPostings;
```

- MemIndex indexes individual words to their locations in the collection of files via a HashTable of WordPostings.

Let's examine the word "course":

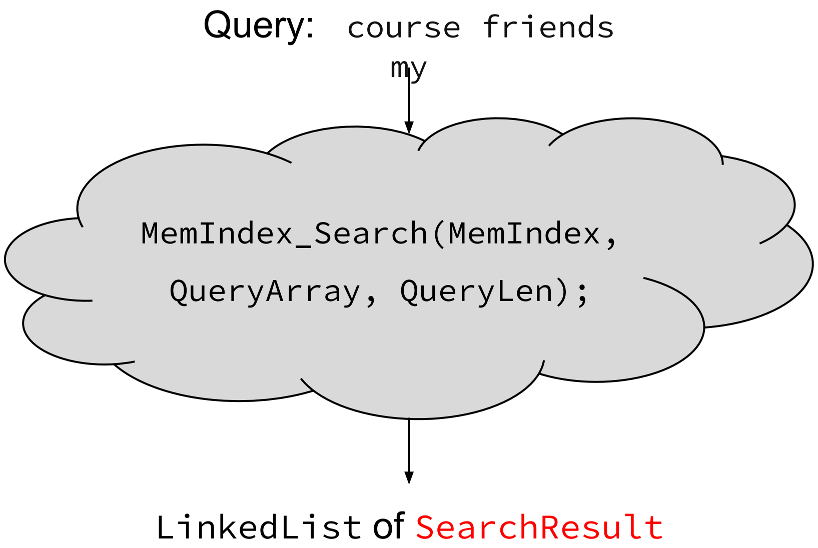
- The WordPostings' HashTable has single key, so only DocID/file 3 contains "course"
- The LinkedList shows it appears at characters 25 and 62 in DocID 3



Part C: Searchshell

Parse user queries, use MemIndex to generate search results, then output to list with ranks

- Formatting should match example output, other than ordering of ties
- Fairly open-ended – the exact implementation is up to you!



Query: `course friends my`

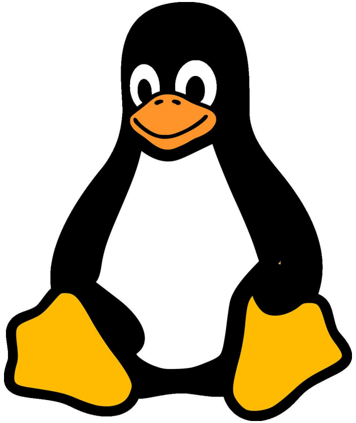
`MemIndex_Search(MemIndex, QueryArray, QueryLen);`

`LinkedList` of `SearchResult`

```
typedef struct SearchResult {
 uint64_t docid;  // matching document
 uint32_t rank;   // rank quantifier
} SearchResult;
```

Hints

- Read the `.h` files for documentation about functions!
- Understand the high level idea and data structures before getting started
- Follow the suggested implementation steps given in the HW2 spec
- Debug on very small sets of short text files
  - You can create your own directory and files!



C++ introduction review: Pointers, References, & Const

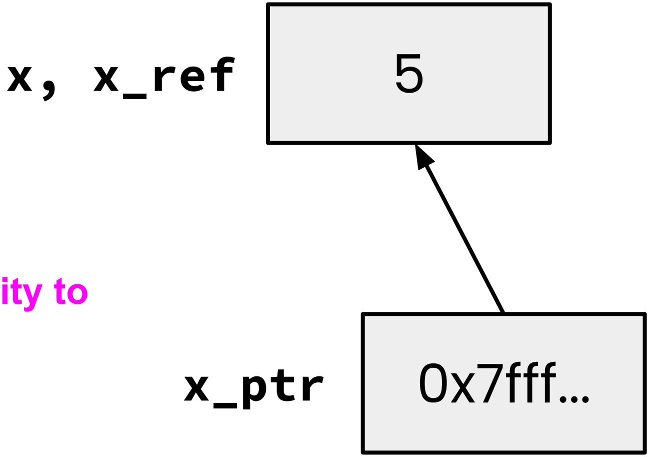
Example

Consider the following code:

```
int x = 5;
int& x_ref = x;
int* x_ptr = &x;
```

Note syntactic similarity to pointer declaration

Still the address-of operator!



When would it be a good idea to use to references instead of pointers?

Pointers vs. References

Pointers

- Can move to different data via reassignment/pointer arithmetic
- Can be initialized to **nullptr**
- Useful for output parameters:
  `MyClass* output`

References

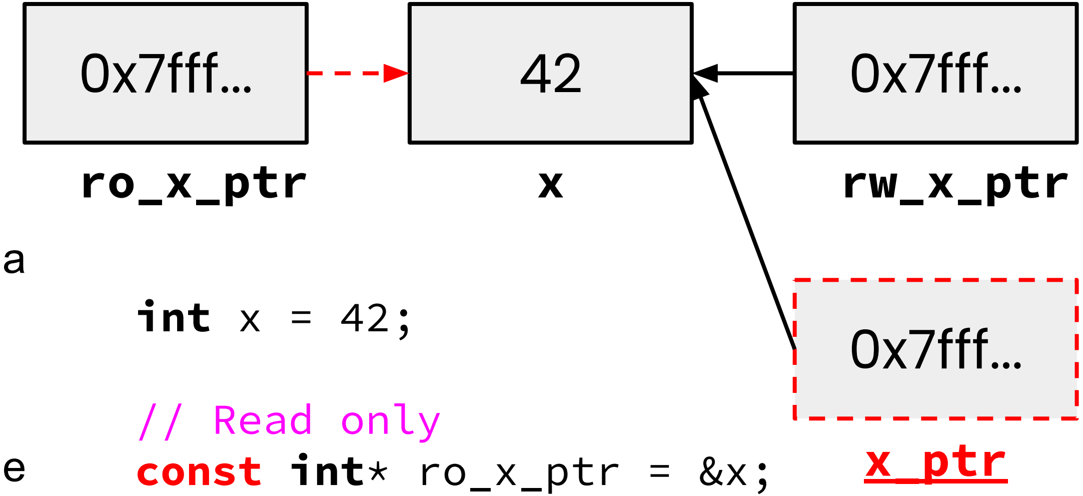
- References the same data for its entire lifetime - *can't reassign*
- No sensible "default reference," must be an alias
- Useful for input parameters:
  `const MyClass& input`

Pointers, References, Parameters

- **`void Func(int& arg)`** vs. **`void Func(int* arg)`**
- Use references when you don't want to deal with pointer semantics
  - Allows real pass-by-reference
  - Can make intentions clearer in some cases
- **STYLE TIP:** use references for input parameters and pointers for output parameters, with the output parameters declared last
  - Note: A reference can't be `NULL/nullptr`

Const

- Mark a variable with `const` to make a compile time check that a variable is never reassigned
- Does not change the underlying write-permissions for this variable



```
int x = 42;

// Read only
const int* ro_x_ptr = &x;

// Can still modify x with
rw_x_ptr!
int* rw_x_ptr = &x;

// Only ever points to x
int* const x_ptr = &x;
```

Legend

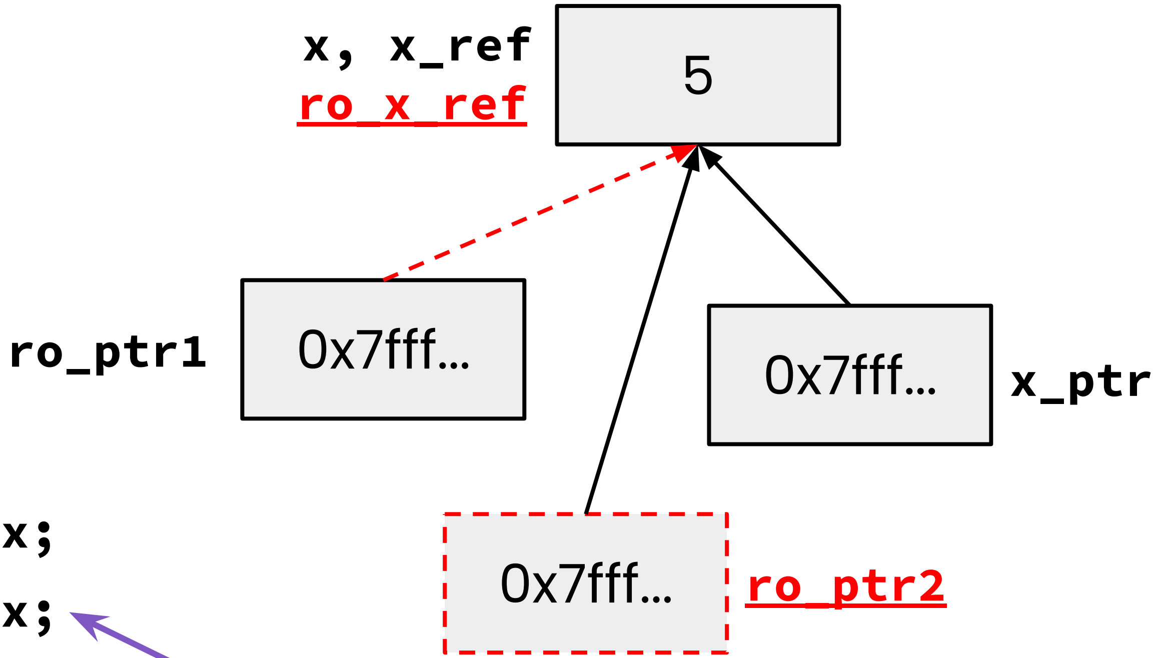
Red = can't change box it's next to

Black = read and write

Exercise 1

Exercise 1

```
int x = 5;
int& x_ref = x;
int* x_ptr = &x;
const int& ro_x_ref = x;
const int* ro_ptr1 = &x;
int* const ro_ptr2 = &x;
```



“Pointer to a const int”

“Const pointer to an int”

Tip: Read the declaration “right-to-left”

Legend

Red = can’t change box it’s next to

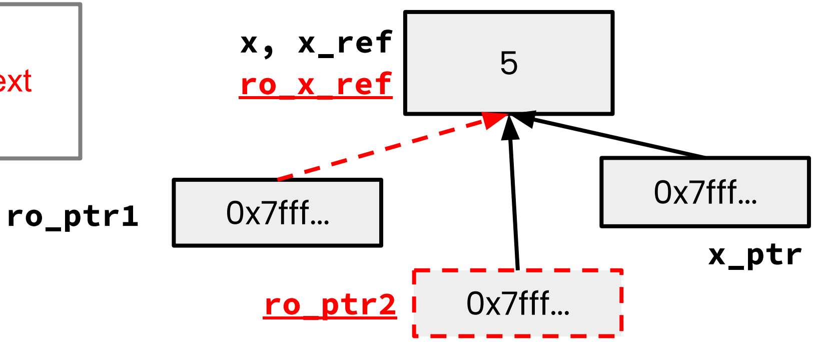
Black = read and write

Exercise 1

Legend

Red = can’t change box it’s next to

Black = “read and write”



```
void Foo(const int& arg);
void Bar(int& arg);

int x = 5;
int& x_ref = x;
int* x_ptr = &x;
const int& ro_x_ref = x;
const int* ro_ptr1 = &x;
int* const ro_ptr2 = &x;
```

Which lines result in a compiler error?

✔ OK ❌ ERROR

- ✔ `Bar(x_ref);`
- ❌ `Bar(ro_x_ref);` ro_x_ref is const
- ✔ `Foo(x_ref);`
- ✔ `ro_ptr1 = (int*) 0xDEADBEEF;`
- ❌ `x_ptr = &ro_x_ref;` ro_x_ref is const
- ❌ `ro_ptr2 = ro_ptr2 + 2;` ro_ptr2 is const
- ❌ `*ro_ptr1 = *ro_ptr1 + 1;` (*ro_ptr1) is const

Exercise 1

When would you prefer `void Func(int &arg);` to `void Func(int *arg);`?

Expand on this distinction for other types besides int.

- When you don’t want to deal with pointer semantics, use references
- When you don’t want to copy stuff over (doesn’t create a copy, especially for parameters and/or return values), use references
- Style wise, we want to use **references for input parameters** and **pointers for output parameters**, with the output parameters declared last

Objects and `const` Methods

```
#ifndef POINT_H_
#define POINT_H_

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

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

#endif  // POINT_H_
```

Cannot mutate the object it’s called on.

Trying to change x_ or y_ inside will produce a compiler error!

A **`const`** class object can only call member functions that have been declared as **`const`**

Exercise 2

Exercise 2

Which *lines* of the snippets of code below would cause compiler errors?

✔ OK ❌ ERROR

```
class MultChoice {
  public:
    MultChoice(int q, char resp) : q_(q), resp_(resp) { }  // 2-arg ctor
    int get_q() const { return q_; }
    char get_resp() { return resp_; }
    bool Compare(MultChoice &mc) const;  // do these MultChoice's match?

  private:
    int  q_;      // question number
    char resp_;  // response: 'A','B','C','D', or 'E'
};  // class MultChoice
```

```
     const MultChoice m1(1,'A');
     MultChoice m2(2,'B');
❌   cout << m1.get_resp();
✔    cout << m2.get_q();
```

```
     const MultChoice m1(1,'A');
     MultChoice m2(2,'B');
✔    m1.Compare(m2);
❌   m2.Compare(m1);
```

What would you change about the class declaration to make it better?

```
class MultChoice {
  public:
    MultChoice(int q, char resp) : q_(q), resp_(resp) { }  // 2-arg ctor
    int get_q() const { return q_; }
    char get_resp() { return resp_; }
    bool Compare(MultChoice &mc) const;  // do these MultChoice's match?

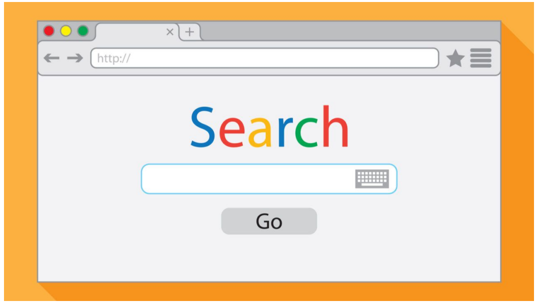
  private:
    int  q_;     // question number
    char resp_;  // response: 'A','B','C','D', or 'E'
};  // class MultChoice
```

```
class MultChoice {
  public:
    MultChoice(int q, char resp) : q_(q), resp_(resp) { }  // 2-arg ctor
    int get_q() const { return q_; }
    char get_resp() { return resp_; }
    bool Compare(MultChoice &mc) const;  // do these MultChoice's match?

  private:
    int  q_;     // question number
    char resp_;  // response: 'A','B','C','D', or 'E'
};  // class MultChoice
```

- make get_resp() const
- make the parameter to Compare() const

Homework 2



- Main Idea: Build a search engine for a file system
  - It can **take in queries** and **output a list of files** in a directory that has that query
  - The query will be **ordered** based on the number of times the query is in that file
  - Should handle **multiple word queries** (*Note: all words in a query have to be in the file*)

- What does this mean?
  - Part A: **Parsing a file** and reading all of its contents into heap allocated memory
  - Part B: **Crawling a directory** (reading all regular files recursively in a directory) and building an index to query from
  - Part C: **Build a searchshell** (search engine) to query your index for results

Note: It will use the **LinkedList** and **HashTable** implementations from **HW1**!

Exercise 3a

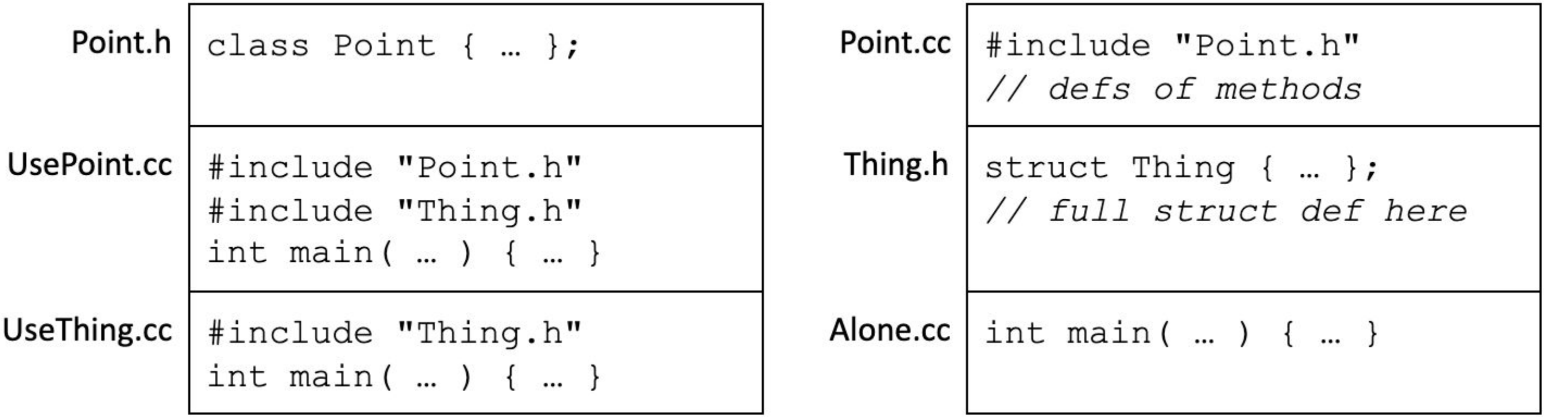
Which *lines* of the snippets of code below would cause compiler errors?

✓ OK ❌ ERROR

```
✓   int z = 5;
✓   const int* x = &z;
✓   int* y = &z;
✓   x = y;
❌   *x = *y;
```

```
✓   int z = 5;
✓   int* const w = &z;
✓   const int* const v = &z;
❌   *v = *w;
✓   *w = *v;
```

Exercise 3



Point.h

```
class Point { … };
```

UsePoint.cc

```
#include "Point.h"
#include "Thing.h"
int main( … ) { … }
```

UseThing.cc

```
#include "Thing.h"
int main( … ) { … }
```

Point.cc

```
#include "Point.h"
// defs of methods
```

Thing.h

```
struct Thing { … };
// full struct def here
```

Alone.cc

```
int main( … ) { … }
```

1. Draw out Point's DAG
   - ○ The direction of the arrows is not important, but be consistent

https://courses.cs.washington.edu/courses/cse333/23wi/lectures/07/07-syscalls-make_23wi.pdf#page=37

DAG

Point.h

```
class Point { … };
```

UsePoint.cc

```
#include "Point.h"
#include "Thing.h"
int main( … ) { … }
```

UseThing.cc

```
#include "Thing.h"
int main( … ) { … }
```

Point.cc

```
#include "Point.h"
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```

Thing.h

```
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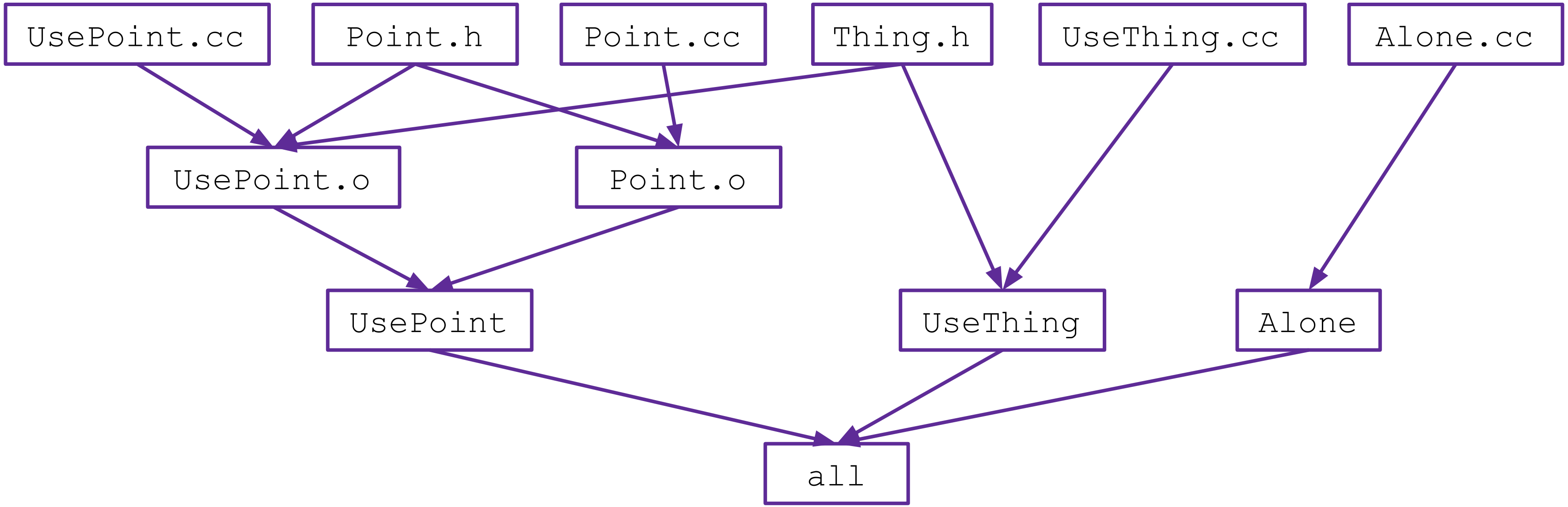
Alone.cc

```
int main( … ) { … }
```



Makefile

Variable

Phony target
Note: all first

```
CFLAGS = -Wall -g -std=c++17

all: UsePoint UseThing Alone

UsePoint: UsePoint.o Point.o
	g++ $(CFLAGS) -o UsePoint UsePoint.o Point.o

UsePoint.o: UsePoint.cc Point.h Thing.h
	g++ $(CFLAGS) -c UsePoint.cc

Point.o: Point.cc Point.h
	g++ $(CFLAGS) -c Point.cc

UseThing: UseThing.cc Thing.h
	g++ $(CFLAGS) -o UseThing UseThing.cc

Alone: Alone.cc
	g++ $(CFLAGS) -o Alone Alone.cc

clean:
	rm UsePoint UseThing Alone *.o *~
```

Q&A :-)