Algorithms for GIS

Today

- More C/compiling/Makefiles
  - Working with multiple files
  - Pointer exercises

- Announcements:
  - Assignment 1 due on Tuesday
  - Assignment 2 posted, due on 9/22
  - Josh office hours: Mon 8pm
  - Need your feedback!

Header files

- Example: implement a linked list
  - **list.h**:
    - is the interface to the outside world
    - contains type definitions and signature of functions that are meant to be used by other modules
  - **list.c**:
    - implements all functions in list.h

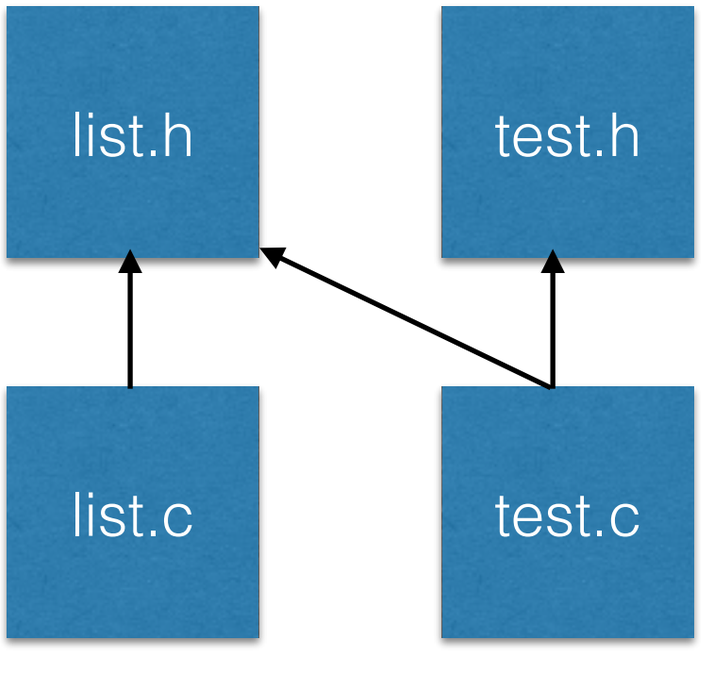
```c
/* list.h */

typedef struct node_t {
     int data;
     struct node_t* next;
}

typedef struct list_t {
     Node* head;
} List;

List* init();
…
```

list.h

list.c

```c
/* list.c */

#include “list.h”

List* init() {
   //implement init
   …
}
```

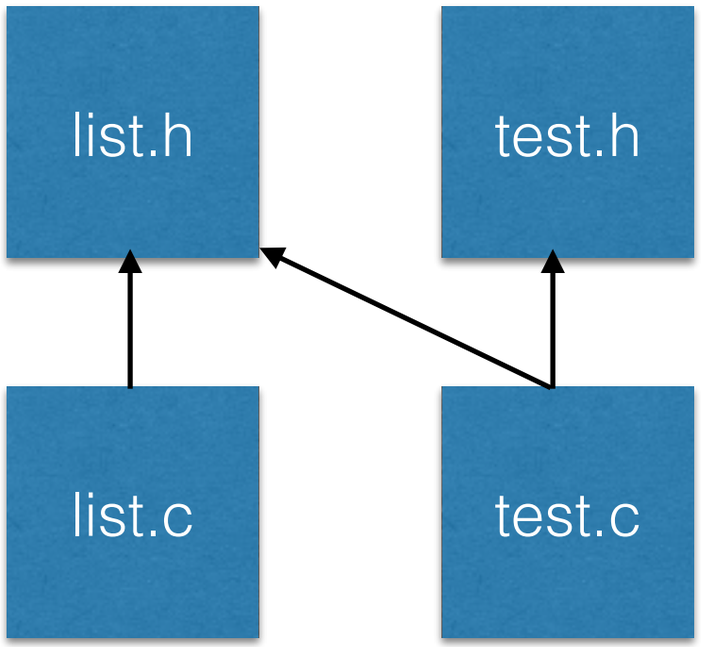
Working with multiple files




```
/* test.c */

#include “test.h”
#include “list.h”

…

int main() {
  ….
}
```

- If test.c needs to use some list functions
  - needs to `#include “list.h”`

Working with multiple files

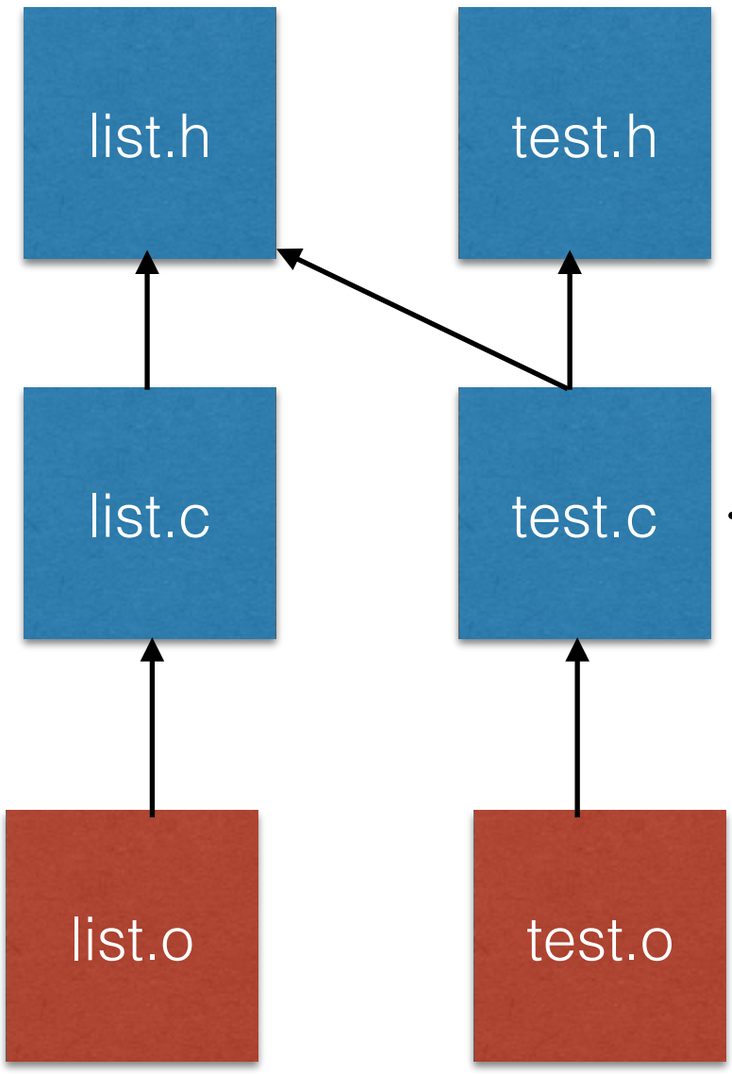



```
/* test.c */

#include “test.h”
#include “list.h”

…

int main() {
  ….
}
```

```
gcc -c list.c -o list.o
gcc -c test.c -o test.o
gcc list.o test.o -o test
./test
```

- Compilation has 2 phases
  - compile only (gcc -c): each xxx.c file ==> xxx.o file
  - for each file that contains a main():
    - link the .o files of the headers that it needs to create the executable

Working with multiple files

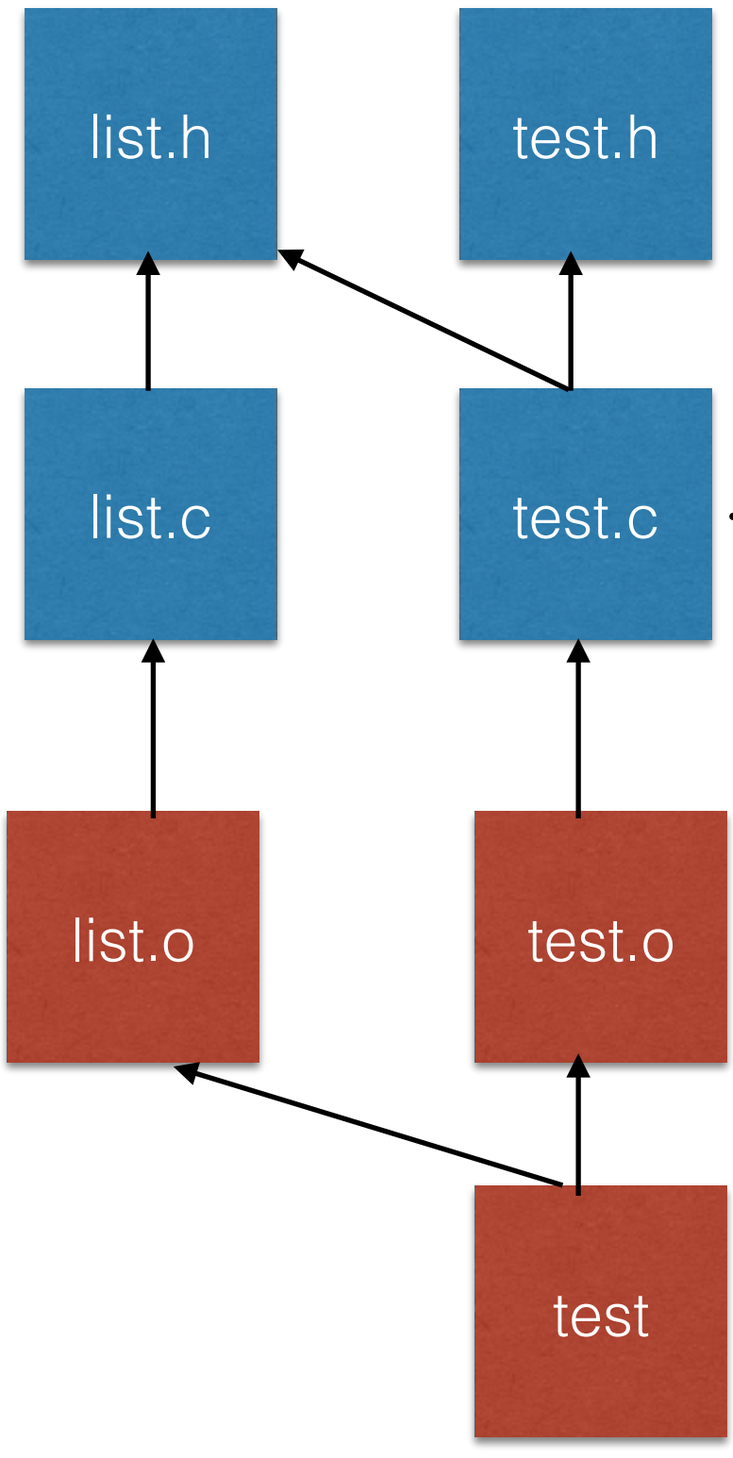



```c
/* test.c */

#include “test.h”
#include “list.h”

…

int main() {
  ….
}
```

```
gcc -c list.c -o list.o
gcc -c test.c -o test.o
gcc list.o test.o -o test
./test
```

test.o has a symbol table with external functions, but no info on where they are defined

Working with multiple files




```
/* test.c */

#include “test.h”
#include “list.h”

…

int main() {
  ….
}
```

```
gcc -c list.c -o list.o
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./test
```
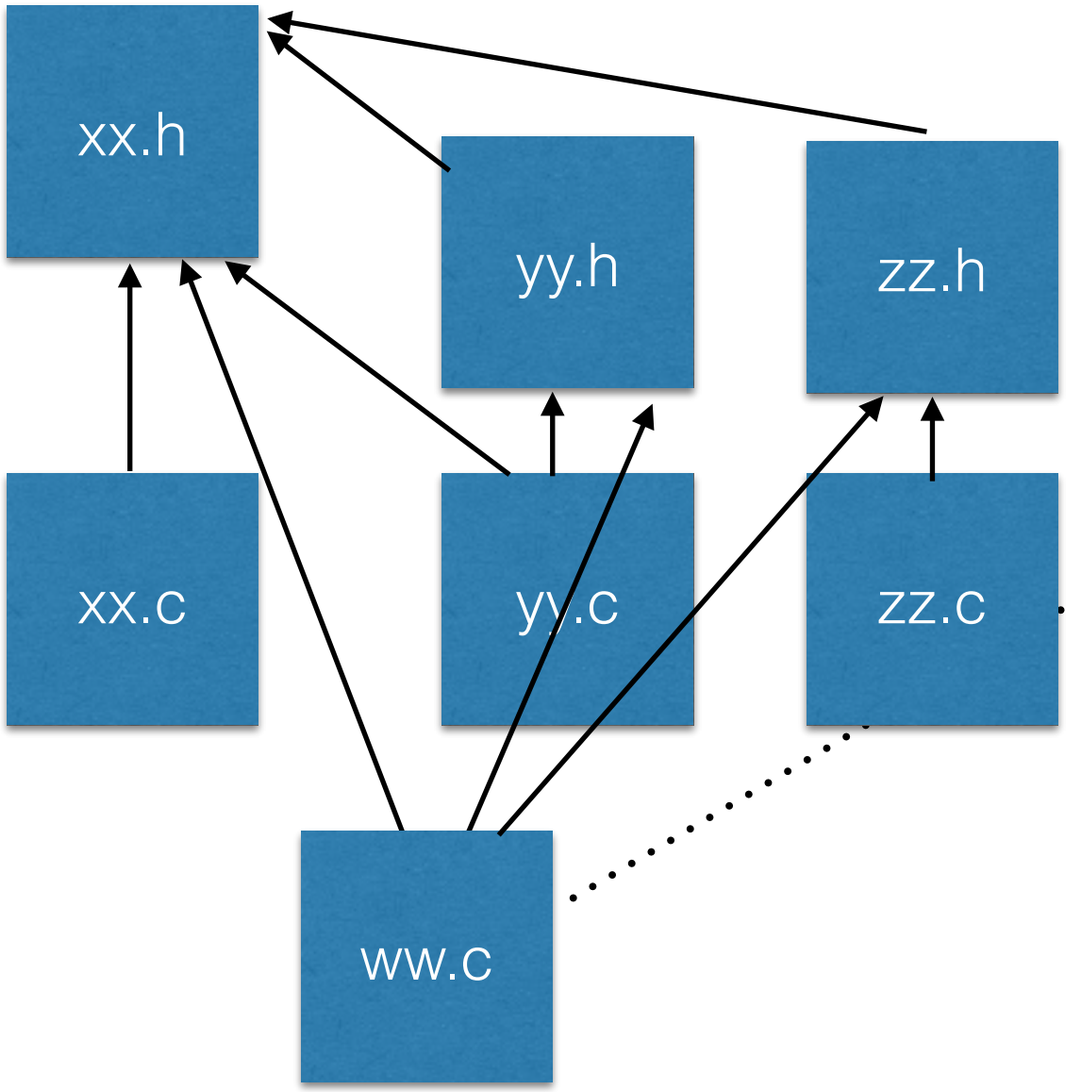

test.o has a symbol table with external functions, but no info on where they are defined

link phase links the files together and fills in the addresses of functions in the symbol table

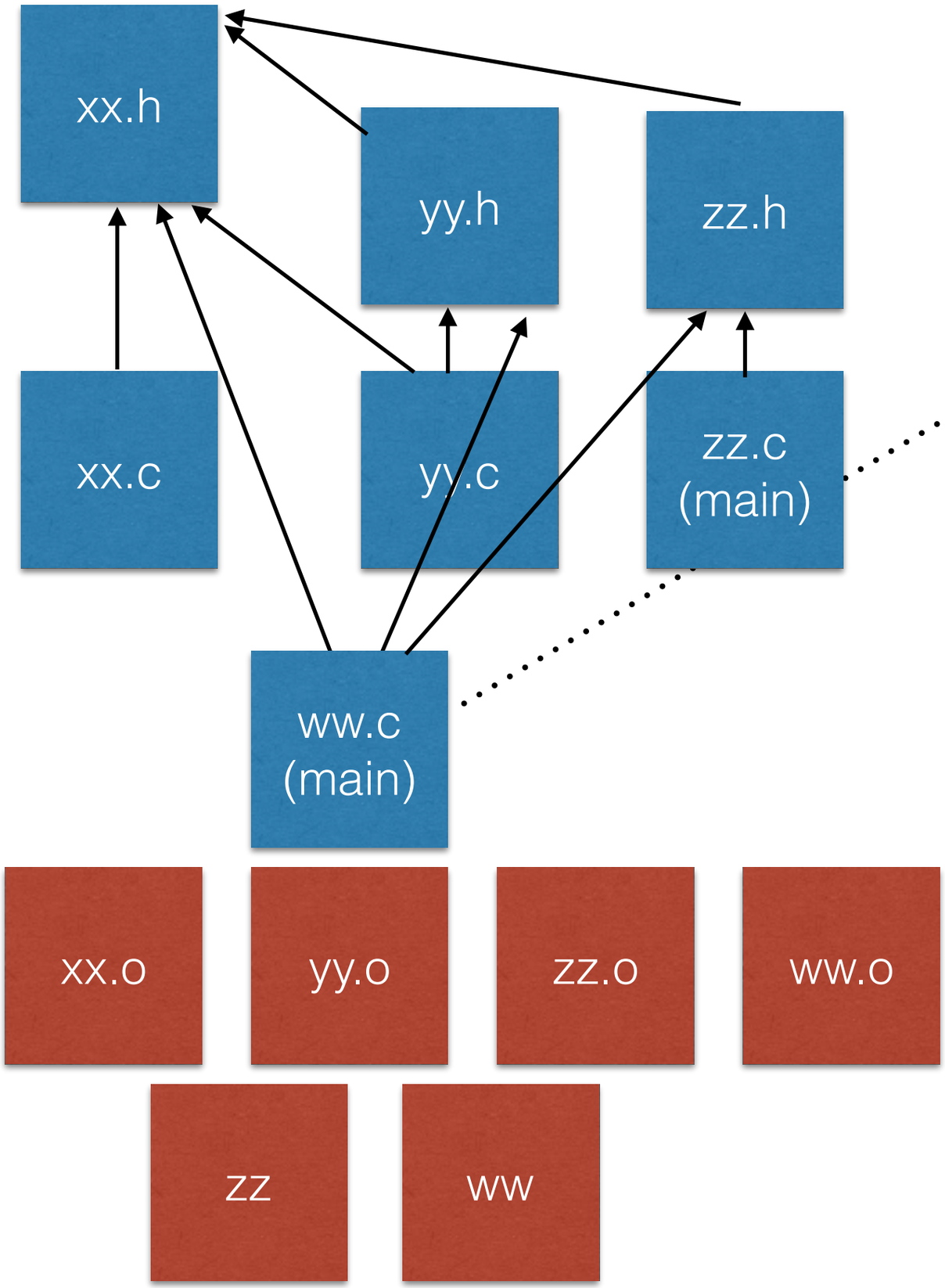
Complex dependency graph




```
/* ww.c */

#include “xx.h”
#include “yy.h”
#include “zz.h”

…
```

- Each file must include all headers it needs
- The dependency graph must be ACYCLIC!
    - If not, very weird compile errors

Complex dependency graph




```
/* ww.c */

#include “xx.h”
#include “yy.h”
#include “zz.h”

…
```

Why?

- For efficiency
  - compiling large projects is slow
  - if change one line in a file, you re-compile only the object files and executables that depend on it, directly or indirectly

- make utility
  - Makefile specifies dependencies
  - ‘make’ keeps track of when files were last modified ==> figures out what changed and what needs to be recompiled

Lessons

- C gives a lot of freedom for bad style
  - Debugging can be hell. Really.

- Program with asserts.
- Modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, modularize, …
- Write test modules for EVERYTHING

Pointers

T x;

- Any variable is stored somewhere in memory and thus has an address, which can be retrieved with operator &

  &x gives the address of variable x

- An address is called a pointer
- The address of a variable of type T is considered to have type T*

  &x has type T*;

- Given an address, we might want to know what is stored at that address. That's called dereferencing the pointer, and it's done with operator *

  T* p;

  *p is of type T, and it is the value stored at address p

- Caveat: Dereferencing an invalid address is a **BUG**.
- A bug of this type doesn't always manifest, and does not manifest in the same way. That is, it might give you a segfault. Or not. Still, your program has a bug in it and its behavior is unpredictable.

Pointers

- Rule: make sure you initialize a pointer before you dereference it
  - by assigning it the address of a variable
  - by calling malloc()
  - by assigning it the value of another valid pointer

Pointers

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- Perhaps this is boring.. Consider this.
  - You WILL get segfaults
  - You will spend a LONG time figuring it out
  - It’s ALWAYS because you break this one rule

- And remember
  - Bad memory references do not always manifest
  - The program might work fine on one computer, but not on other.

Pointer quiz

- We want to write a function to allocate an array of n element of type T
- We'll write it two ways:
  - return the array
  - take the array as parameter

Is this working?

```
//assume T is  a type

T* create(int n) {
    T* result;
    result = (T*)malloc(n*sizeof(T));
    assert(result);
    return result;
}



int n=100;
T* x;
x = create(n);
//is x an array of 100 elements?
```

```
//assume T is  a type


void create(int n, T* a) {
    a = (T*) malloc(n*sizeof(T));
    assert(a);
}



int n=100;
T* x;
create(n, x);
//is x an array of 100 elements?
```