Modular Code Structure

- module implementation, e.g, thread.c
  - contains:
    - function implementations
    - global variable declarations
    - `#includes` of headers needed by implementation
    - definitions needed (only) by implementation
    - static vs. regular global variables and functions
  - static vs. regular functions and global variables
- module interface, e.g., thread.h
  - `#included` by code that needs to use threads
  - contains
    - prototypes of (public) thread functions
    - declarations of data structures and constants used by the interface

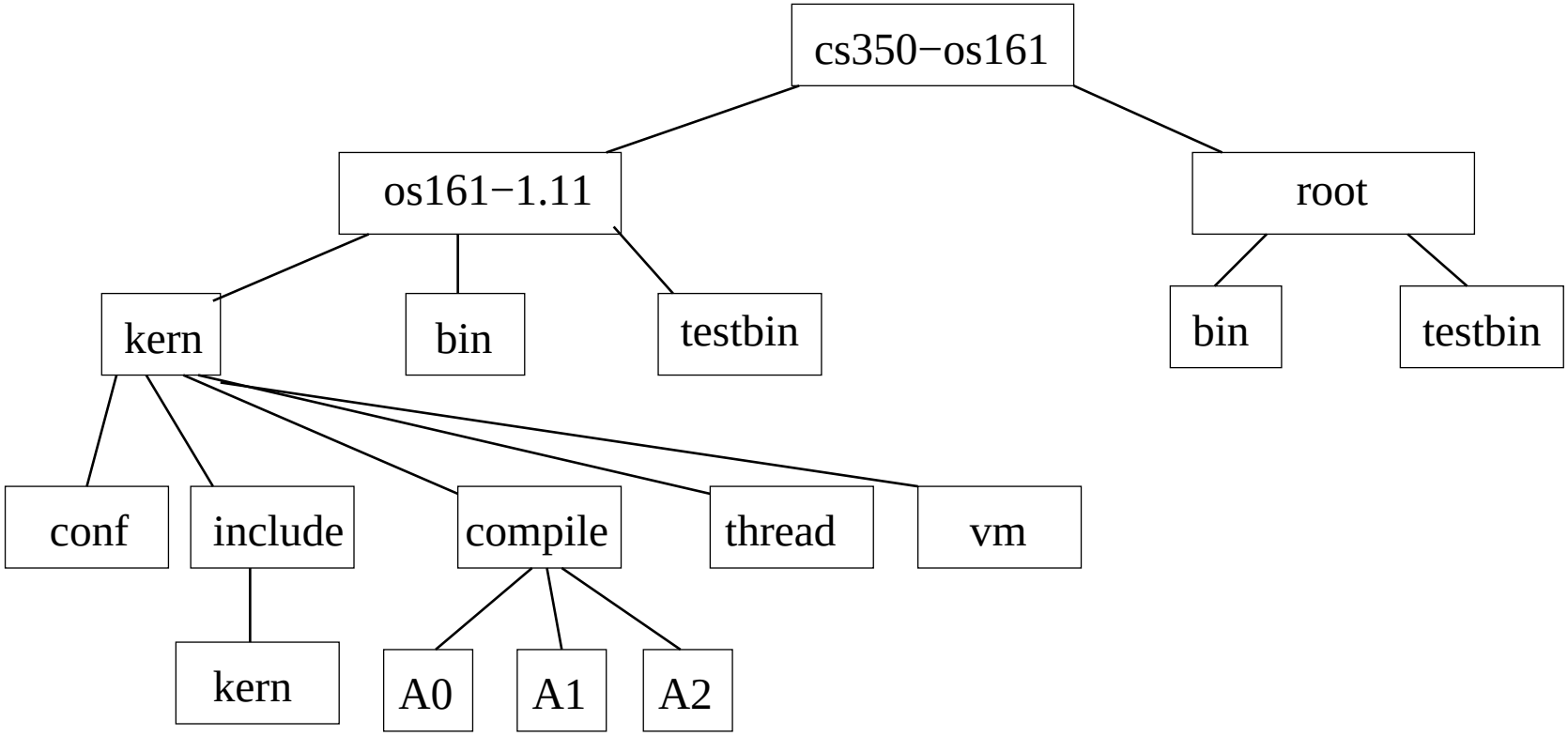
Other Code Structuing Issues

- some header files are not tied to specific modules
  - example: `include/types.h`
- order of inclusion of header files is signficant

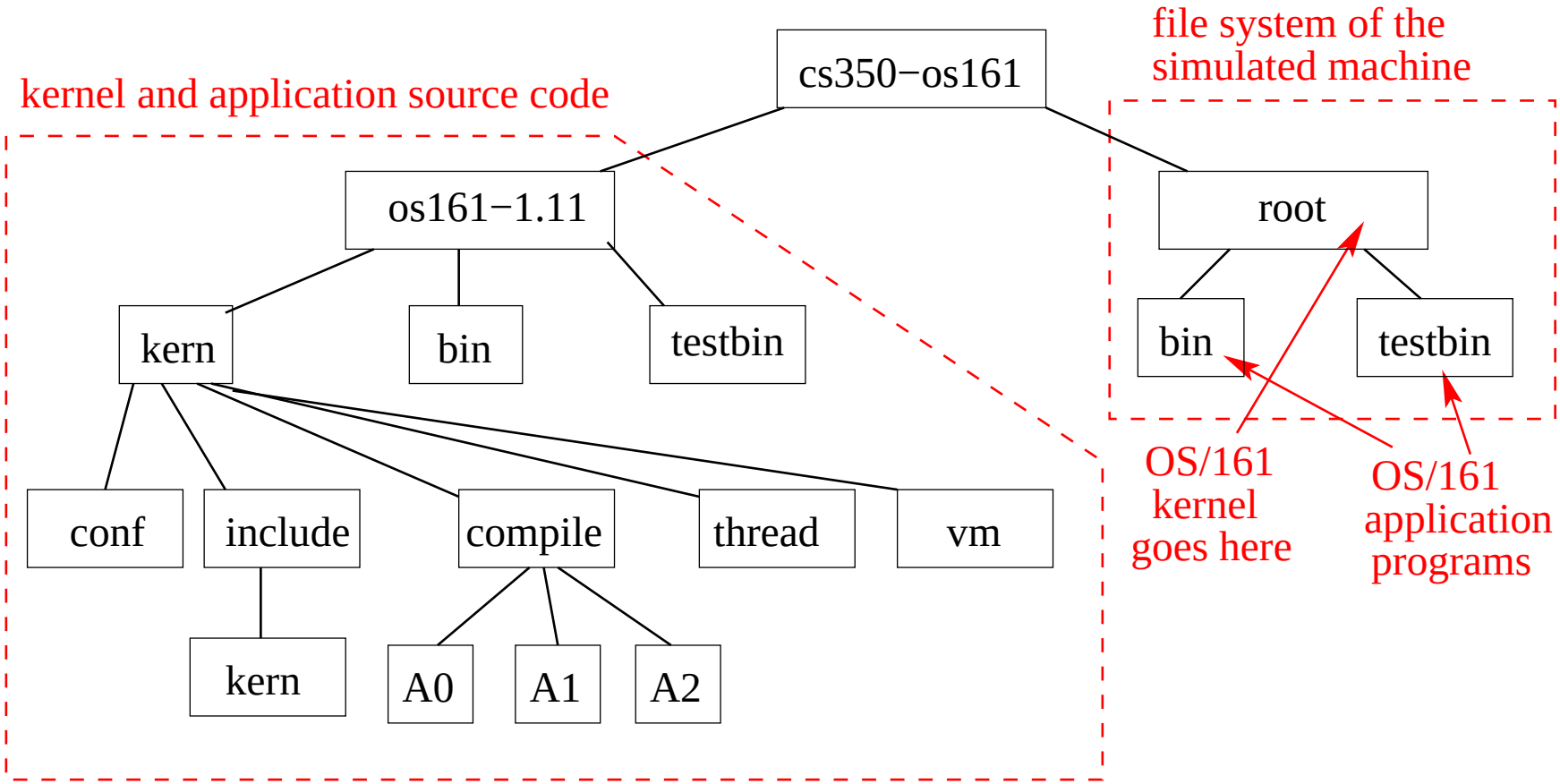
```
#include <types.h>
#include <lib.h>
#include <kern/errno.h>
#include <array.h>
#include <machine/spl.h>
#include <machine/pcb.h>
#include <thread.h>
...
```

OS/161 convention is that `types.h` should always be included first

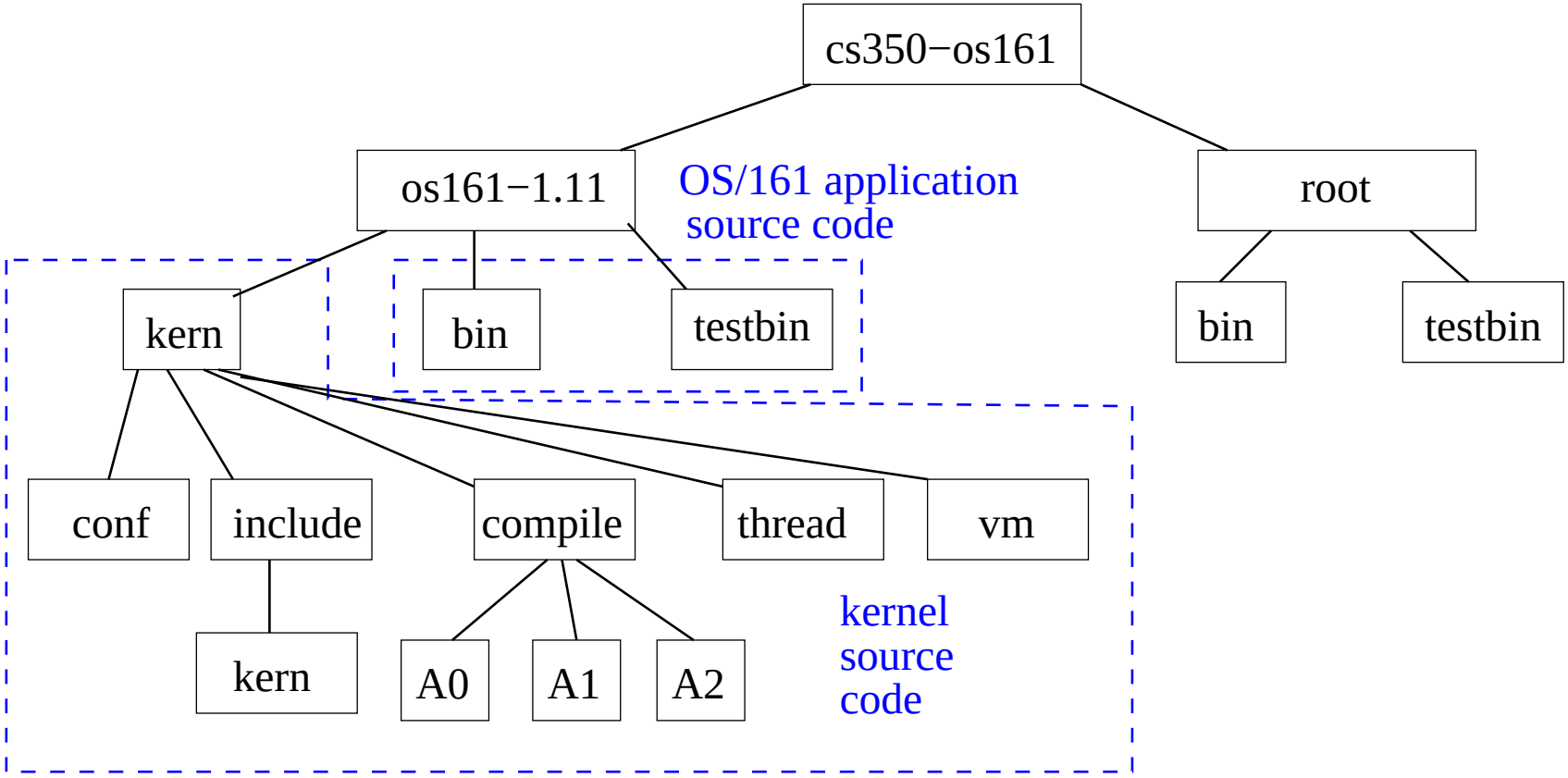
OS/161 Directory Structure (1 of 4)



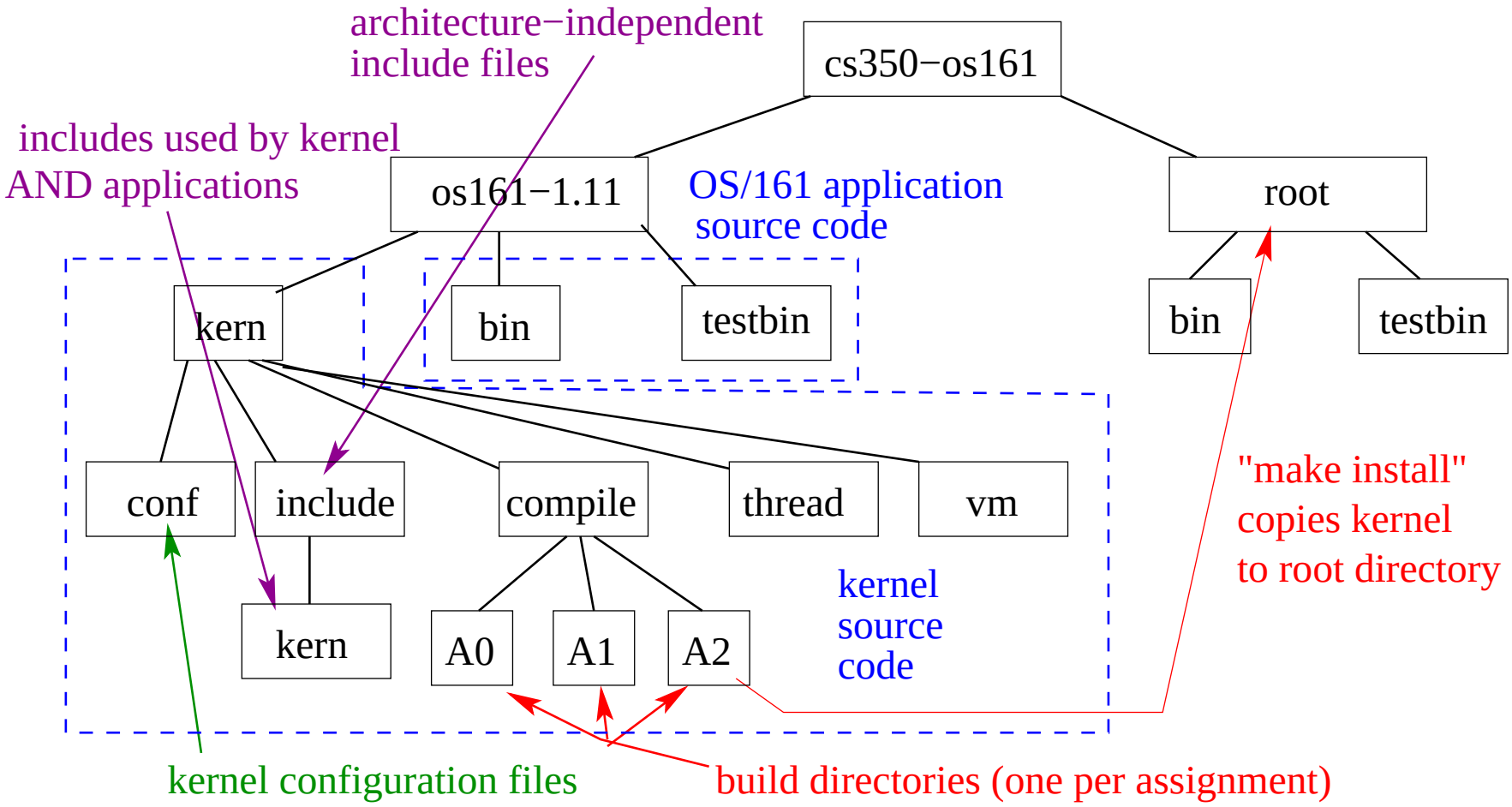
OS/161 Directory Structure (2 of 4)



OS/161 Directory Structure (3 of 4)



OS/161 Directory Structure (4 of 4)



Kernel's Standard Library

- User-level C applications can use the C standard library
- The OS/161 kernel also has a library, similar to the user-level standard library, e.g.,
  - dynamic memory management (`kmalloc`, `kfree`)
  - string functions
  - input/output (`kprintf`,`kgets`,`putch`
  - data movement (`copyin`,`copyout`)
- kernel library is not identical to the user-level library, e.g.,
  - `kmalloc` vs. `malloc`
  - `kstrdup` vs. `strdup`
  - `kprintf` vs. `printf`

  Why??

Pointers and Arrays

```
static char *bowls;

int
initialize_bowls(unsigned int bowlcount) {
  unsigned int i;
  bowls = kmalloc(bowlcount*sizeof(char));
  if (bowls == NULL) {
    panic("initialize_bowls: unable to allocate
           space for %d bowls\n",bowlcount);
  }
  /* initialize bowls */
  for(i=0;i<bowlcount;i++) {
    bowls[i] = '-';
  }
  ...
```

Dynamic Memory Allocation

```
struct semaphore *
sem_create(const char *namearg, int initial_count) {
  struct semaphore *sem;
  sem = kmalloc(sizeof(struct semaphore));
  if (sem == NULL) { return NULL; }
  sem->name = kstrdup(namearg);
  if (sem->name == NULL) {
     kfree(sem);
     return NULL;   }
  sem->count = initial_count;
  return sem;
}
```

What does a `semaphore` look like?

`volatile` Variables

```
struct semaphore {
  char *name;
  volatile int count;
};

void P(struct semaphore *sem)
{
....
  while (sem->count==0) { thread_sleep(sem); }
  assert(sem->count>0);
  sem->count--;
....
}
```

`volatile` indicates that the value of a program variable may change "spontaneously"

`const` Variables

- from `kern/lib/kheap.c`:

```
#define NSIZES 8
static const size_t
  sizes[NSIZES] = {16,32,64,128,256,512,1024,2048};
```

- from `kern/include/lib.h`:

```
int strcmp(const char *, const char *);
char *strcpy(char *, const char *);
```

`const` indicates that the value of a program variable should never change. In the case of a pointer variable, `const` indicates that the thing pointed to should never change.
