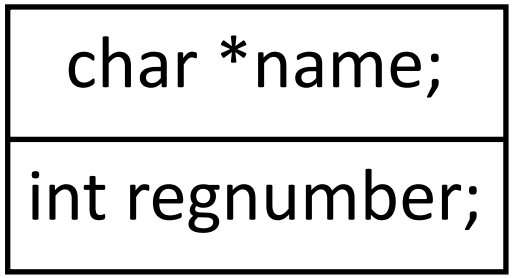
ECS 36A, May 16, 2024

Announcements

- Grades for the midterm are posted
- Thursday and Friday discussion sections will go through the midterm
- Homework 3 is out now

Structures

- Data structure used to group elements of a different type together
- Example: student registration number database
  - See element below



type of structure

field

```
struct student {
    char *name;      /* student name */
    int regnumber;  /* registration number */
};
```

Referring to a Structure

Here's how you declare a variable of the structure:

```
struct student xyzzy, *pxyzzy;
```

It's clumsy to write that, so you can define an alias for the type:

```
typedef struct student STUDENT;
```

The latter essentially produces a new type, STUDENT, that can be used wherever struct student can:

```
STUDENT xyzzy, *pxyzzy;
```

Another Declarations

```
struct student {
      char *name;       /* student name */
      int regnumber;    /* registration number */
} xyzzy, *pxyzzy;
```

- Declares type `struct student` with 2 fields, `xyzzy` (an instance of `struct student`) and `pxyzzy` (a pointer to an instance of `struct student`)

And Now, With a Typedef

```
typedef struct student {
      char *name;       /* student name */
      int regnumber;    /* registration number */
} STUDENT;
STUDENT xyzzy, *pxyzzy;
```

This defines a new type, `STUDENT`, which is the same as the type struct student. Here `xyzzy` is a variable of type `STUDENT` and `pxyzzy` is a pointer to an instance of `STUDENT`.

But Be Careful

- `typedef` defines an alias for a type
- `#define` does textual substitution

```
typedef int *PINT;
PINT a, b, c;
```

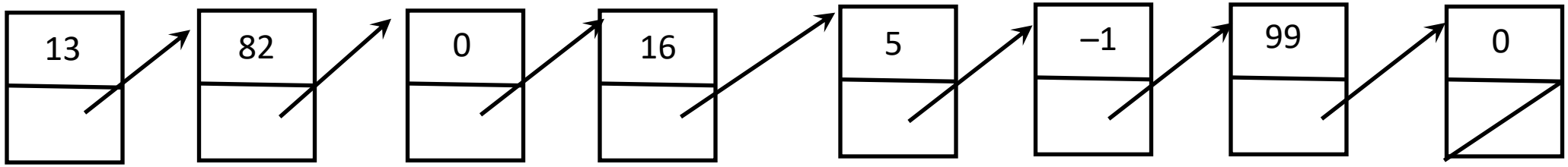
- Now `a`, `b`, and `c` are all pointers to integers

```
#define PINT int *
PINT a, b, c;     /* becomes int * a, b, c; */
```

- Now `a` is a pointer to an integer, and `b` and `c` are integers

Linked List

- A list composed of instantiations of structures
  - One element is whatever is to be sorted (int, for us)
  - Another element is a pointer to the next element; NULL if none



Structure for This List

```
struct node {
    int num;
    struct node *next;
};
struct node *list;
```

This holds the integer that you read in

This holds the pointer to the next element in the linked list; it's NULL at the end

This points to the first element of the list

Changing How Memory Is Allocated

- Now you can allocate memory one element (“node”) at a time
- Insertion at beginning is like this (see ”linked.c”, ll. 72–76):

```
new->next = first;
list = new;
```

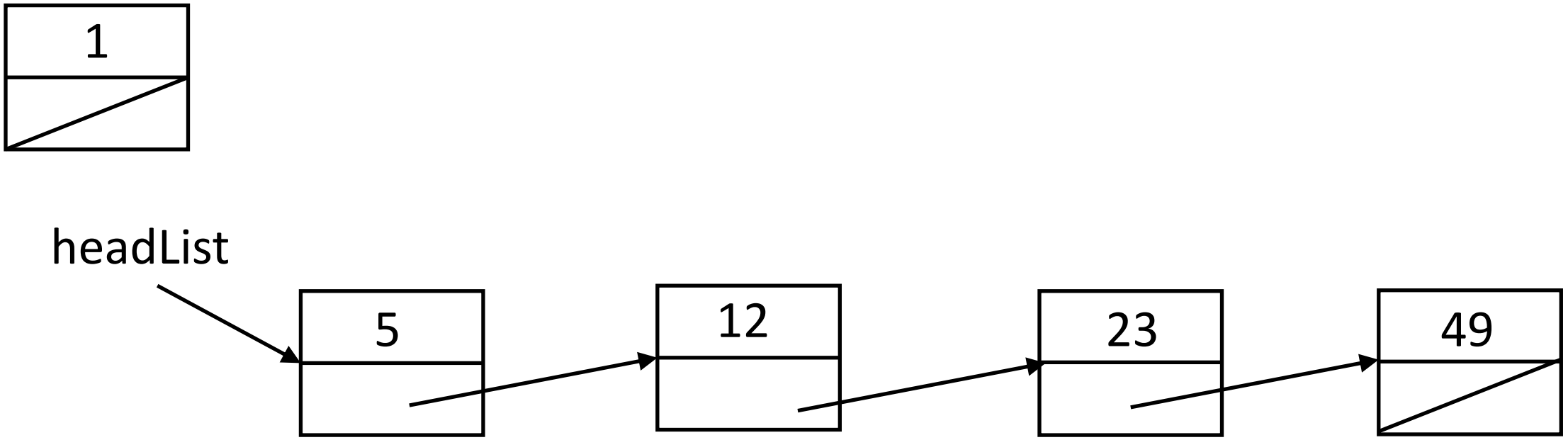
- Insertion in the middle between *prev* and *succ* is (see “linked.c”, ll. 78–97):

```
new->next = succ;
prev->next = new;
```

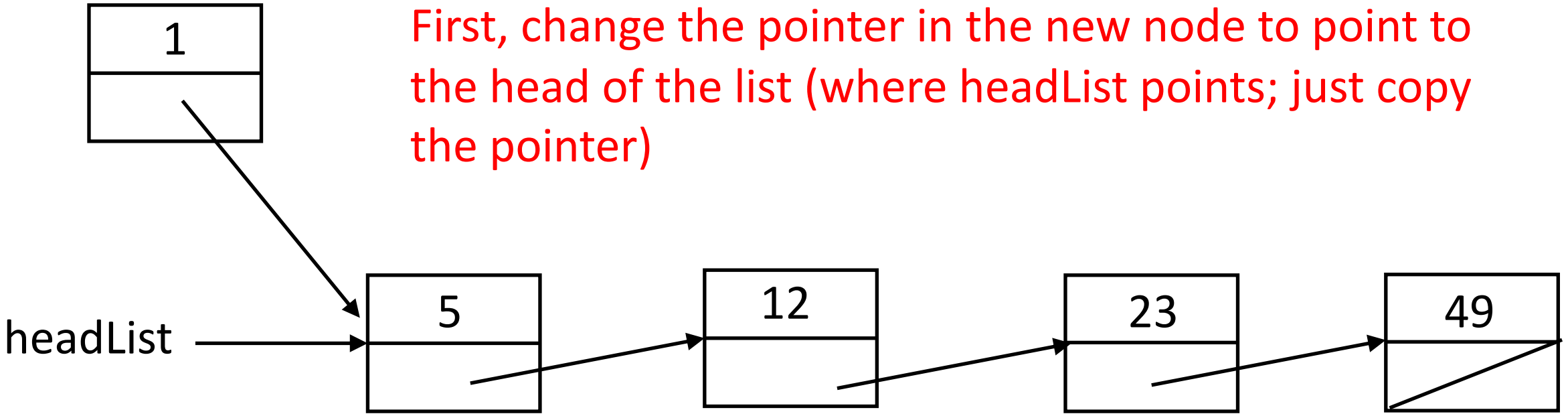
- Insertion at the end, after last (see “linked.c”, same lines as above) :

```
last->next = new;
```

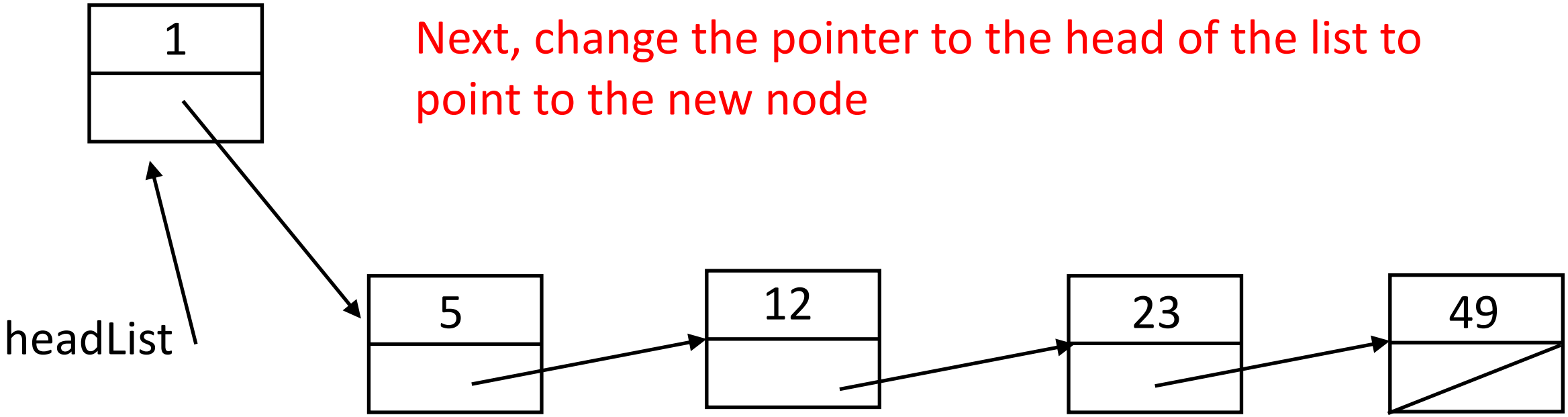
Insertion



Insertion: At the Beginning of the List



Insertion: At the Beginning of the List



Code for This

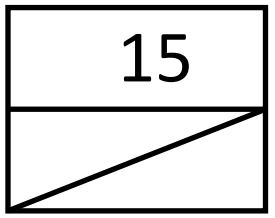
- new is a pointer to the new node, headList points to the head of the list
- First, make new point to the old head. of the list

```
new->next = headList;
```

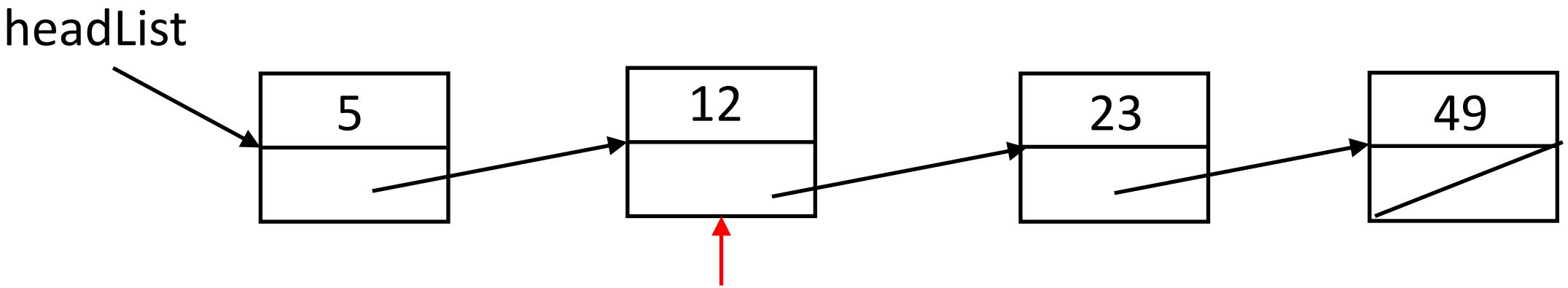
- Next, make the pointer to the head of the list point to new

```
headList = new;
```

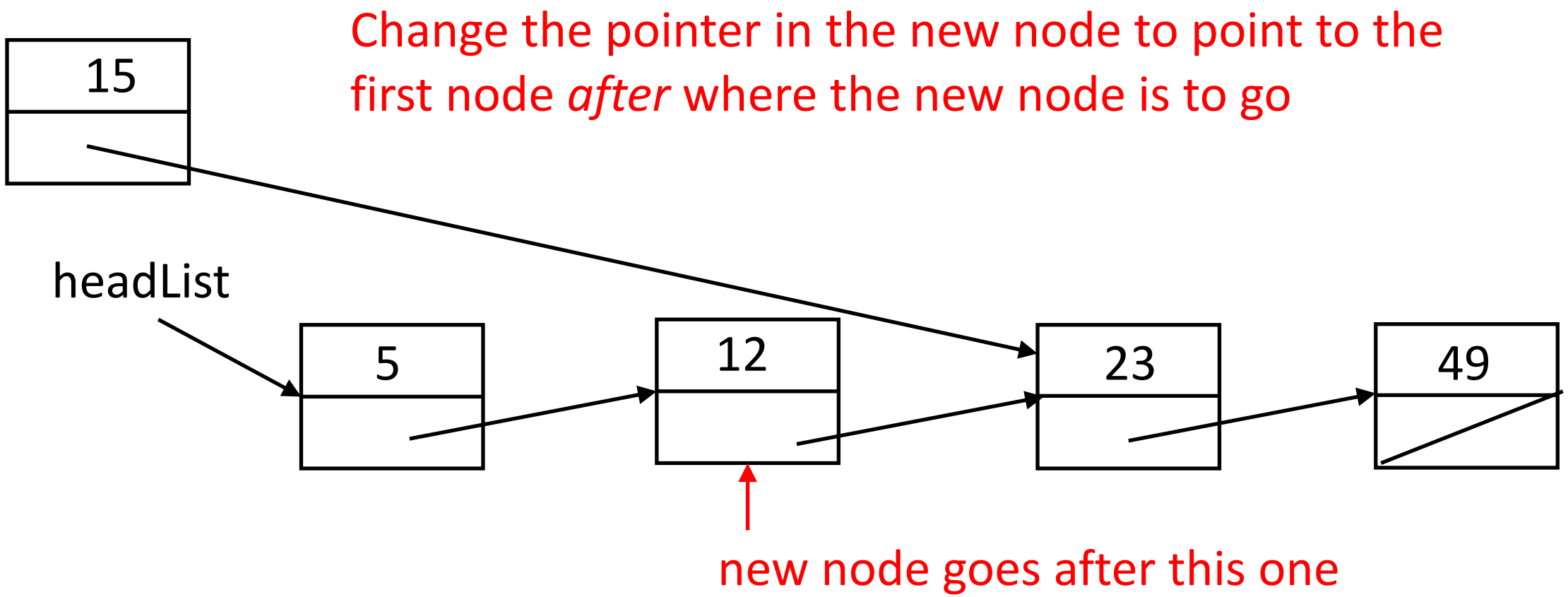
Insertion: In the Middle of the List



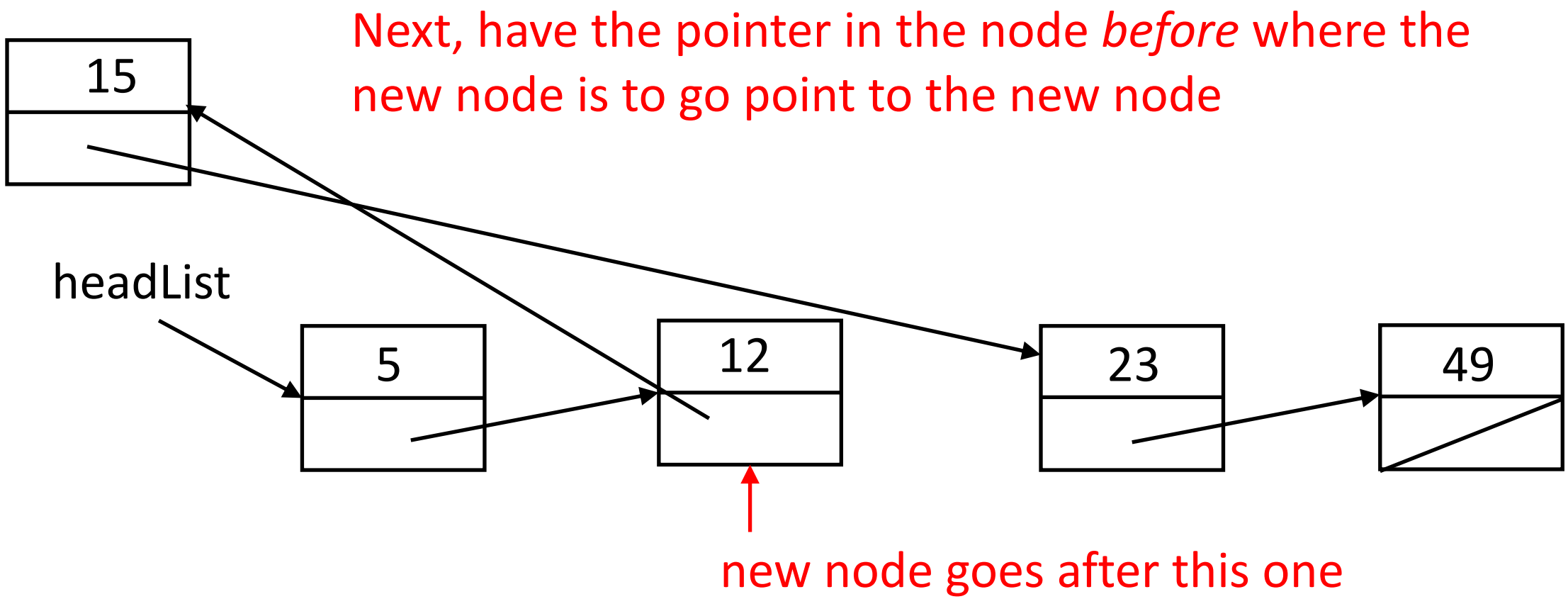
First, scan down the list until you reach the node before which the new node goes.



Insertion: In the Middle of the List



Insertion: In the Middle of the List



Code for This

- new is a pointer to the new node, headList points to the head of the list, and p is a pointer to node
- First, find the node that new goes after

```
for(p = headList;
     p != NULL && p->next < new->next;
          p = p->next)
     /* do nothing */;
```

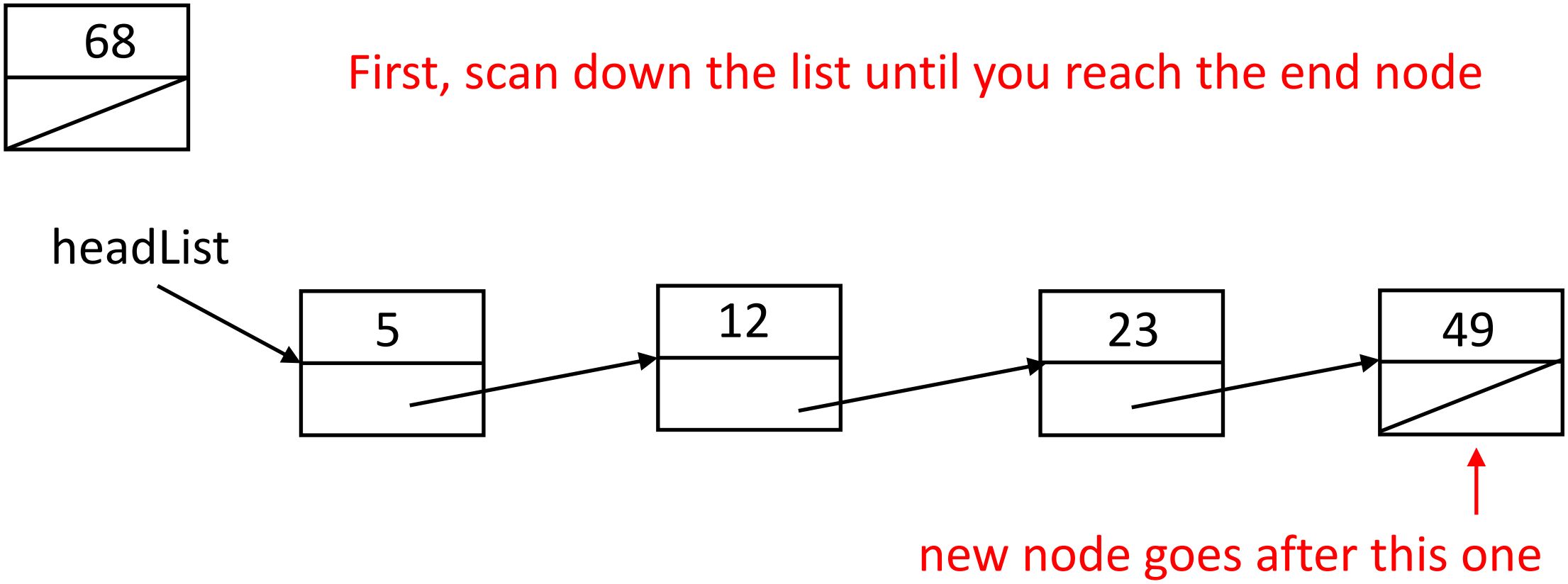
- Next, change the pointer in new to point to the node *after* where this one goes

```
new->next = p->next;
```

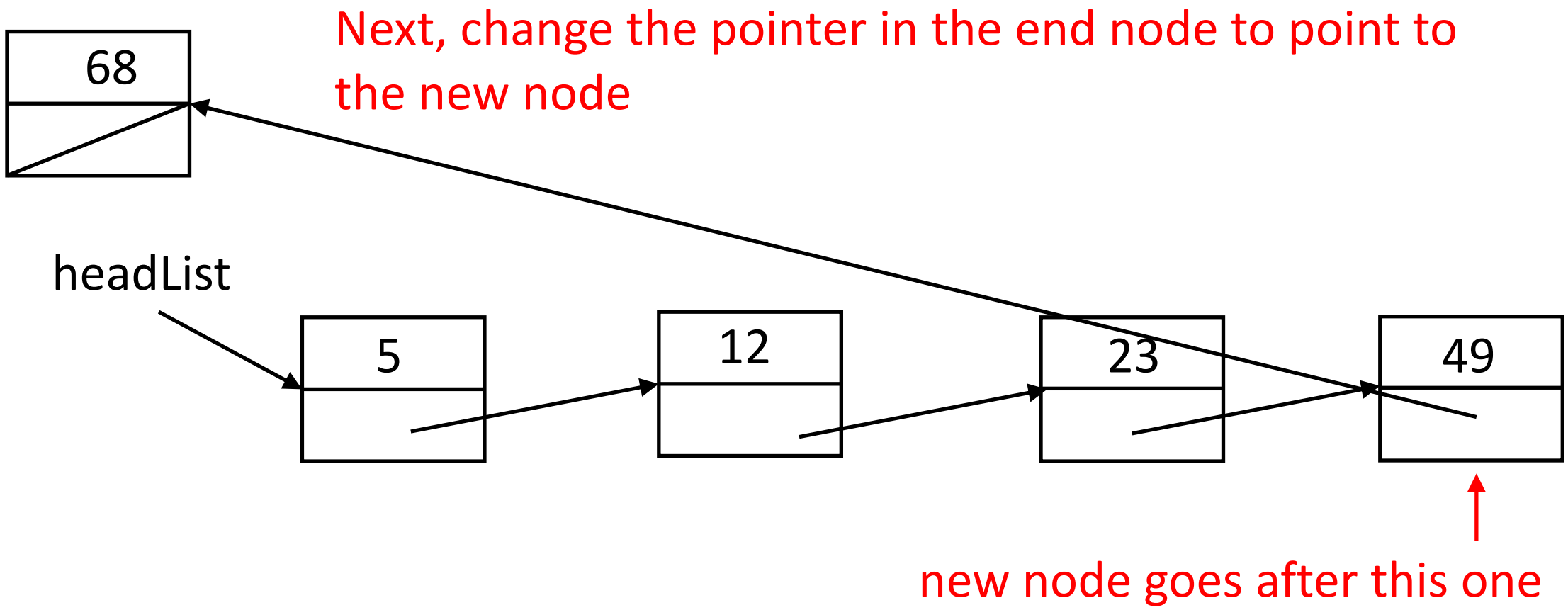
- Finally, make the node p points to point to new

```
p->next = new;
```

Insertion: At the End of the List



Insertion: At the End of the List



Code for This

- new is a pointer to the new node, headList points to the head of the list, and p is a pointer to node
- First, find the node at the end

```
for(p = headList;
     p != NULL && p->next != NULL;
          p = p->next)
     /* do nothing */;
```

- Next, change the pointer in what p points to to point to new

```
p->next = new;
```

- This may be an excess, but make sure new's pointer field is NULL

```
new->next = NULL;
```

Multiple Arrays

- Need to store several data of different types about something
- Example: sort planets by their diameters
- Use 2 arrays
  - char *names[9]
  - int diameters[9]
- When sorting, need to keep both arrays aligned
  - So when swapping 2 elements of array diameter, the corresponding elements of array names must also be swapped
- Alternate approach: use structures!

Same with Structures

- Instead of 2 arrays, combine into one structure for each element, and use an array of structures

```
struct celestial {
    char *name;    /* pointer to name of planet */
    int diameter; /* diameter of planet in km */
} planets[9];
```

- This allocates space for 9 planets
- When you swap elements, you only need to swap one, not two, as in the parallel arrays case

gdb

- A dynamic debugger
- To run it, compile your program with the `-g` option
  - This adds in debugging information *gdb* uses
  - You can use *gdb* without it but it simplifies the use greatly
- Then load it into *gdb* by:

```
gdb executable
```

- Note you use the executable file and *not* the source code file
  - You can also load the executable once *gdb* starts

Inside the *gdb* Shell

- Once started, you get a prompt "(gdb)"
- If you forgot to name the executable in the command line:

```
(gdb) file executable
```

- One other handy feature

```
(gdb) help
```

- You will get a list of commands you can ask for help on
- Then type

```
(gdb) help command
```

Executing the program

- Type:

(gdb) run arg_1 . . . arg_n

- This runs the program with command line arguments arg_1 through arg_n
  - If there are no command line arguments, just type ``run''
- If there are no problems, the program runs to completion
- If the program stop with a message like this, there's a problem

```
Program received signal SIGSEGV, Segmentation fault.
0x00005555555551b5 in nfact (n=<error reading variable: Cannot access
memory at address 0x7fffff7fefec>) at nfact2.c:12
```

Stopping the Program Before It Ends

- A *breakpoint* causes the execution to stop at that point
- Here's an example:

```
(gdb) break 15
Breakpoint 1 at 0x5555555551b8: file nfact2.c, line 15.
```

- This causes execution to stop when it reaches line 15
  - If you have multiple source files, name the file before the number:

```
(gdb) break nfact2.c:15
```

- It shows some useful information

```
Breakpoint 1, nfact (n=15) at nfact2.c:15
15 x = nfact(n+1);
```

Conditional Breakpoints

- Causes a breakpoint to stop execution when a condition is met
- Here's an example:

```
(gdb) break 15 if n >= 20
Breakpoint 1 at 0x5555555551b8: file nfact2.c, line 15.
```

- This causes execution to stop when it reaches line 15 *and* n is 20 or more
  - If you have multiple source files, name the file before the number:

```
(gdb) break nfact2.c:15 15 if n >= 20
```

What Can You Do When Stopped?

- You can continue the execution from the breakpoint:

```
(gdb) continue
```

- You can execute one statement at a time to step through the program
  - If it encounters a function, it goes into that function and executes one statement at a time

```
(gdb) step
```

  - n (next) is like s but treats the function as part of the statement and does not go into it

```
(gdb) next
```

Printing Values

- You can print the value of an expression

```
(gdb) print expression
```

- If you prefer hexadecimal

```
(gdb) print/x expression
```

Watchpoints

- Like breakpoints, but keyed to variables

```
(gdb) watch x
```

- Whenever x changes values, the program stops and *gdb* prints old and new values of x

Other Useful Commands

- backtrace
- where
  - These show the stack, that is, the functions that have been called and not yet returned
- delete 2
  - Delete breakpoint 2 (or watchpoint 2)
- info breakpoints
  - List the breakpoints (and watchpoints)
- info frame
  - Show the *current* frame