CS 11 C track: lecture 6

- Last week: pointer arithmetic
- This week:
  - The `gdb` program
  - `struct`
  - `typedef`
  - linked lists

`gdb` for debugging (1)

- `gdb`: the <u>G</u>nu <u>D</u>e<u>B</u>ugger
- http://www.cs.caltech.edu/courses/cs11/material/c/mike/misc/gdb.html
- Use when program core dumps
- or when want to walk through execution of program line-by-line

`gdb` for debugging (2)

- Before using **`gdb`**:
  - Must compile C code with additional flag: **`-g`**
  - This puts all the source code into the binary executable
- Then can execute as: **`gdb myprogram`**
- Brings up an interpreted environment

`gdb` for debugging (3)

`gdb> run`

- Program runs...
- If all is well, program exits successfully, returning you to prompt
- If there is (*e.g.*) a core dump, `gdb` will tell you and abort the program

`gdb` for debugging (4)

- If your program needs command-line arguments, *e.g.* `myprogram 1 2 3`, then you should do this in `gdb`:

```
gdb> run 1 2 3
```

- This will run `myprogram` with the command-line arguments `1`, `2`, and `3`

`gdb` – basic commands (1)

- Stack backtrace ("`where`")
  - Your program core dumps
  - Where was the last line in the program that was executed before the core dump?
  - That's what the `where` command tells you

gdb – basic commands (2)

```
gdb> where
```

last call

last call in your code

```
#0 0x4006cb26 in free () from /lib/libc.so.6
#1 0x4006ca0d in free () from /lib/libc.so.6
#2 0x8048951 in board_updater (array=0x8049bd0,
   ncells=2) at 1dCA2.c:148
#3 0x80486be in main (argc=3, argv=0xbffff7b4) at
   1dCA2.c:44
#4 0x40035a52 in __libc_start_main () from /lib/
   libc.so.6
```

stack backtrace

`gdb` – basic commands (3)

- Look for topmost location in stack backtrace that corresponds to your code
- Watch out for
  - freeing memory you didn't allocate
  - accessing arrays beyond their maximum elements
  - dereferencing pointers that don't point to part of a `malloc()`ed block

gdb – basic commands (4)

- `break`, `continue`, `next`, `step` commands
- `break` causes execution to stop on a given line

  `gdb> break foo.c: 100` (setting a breakpoint)
- `continue` resumes execution from that point
- `next` executes the next line, then stops
- `step` executes the next statement
  - goes into functions if necessary (`next` doesn't)

gdb – basic commands (5)

- `print` and `display` commands
- `print` prints the value of any program expression

```
gdb> print i
$1 = 100
```

- `display` prints a particular value every time execution stops

```
gdb> display i
```

gdb – printing arrays (1)

- `print` will print arrays as well

```
int arr[] = { 1, 2, 3 };


gdb> print arr
$1 = {1, 2, 3}
```

- N.B. the `$1` is just a name for the result

```
print $1
$2 = {1, 2, 3}
```

gdb – printing arrays (2)

- `print` has problems with dynamically-allocated arrays

```
int *arr;
arr = (int *)malloc(3 * sizeof(int));
arr[0] = 1; arr[1] = 2; arr[2] = 3;


gdb> print arr
$1 = (int *) 0x8094610
```

- Not very useful...

gdb – printing arrays (3)

- Can print this array by using `@` (gdb special syntax)

```
int *arr;
arr = (int *)malloc(3 * sizeof(int));
arr[0] = 1; arr[1] = 2; arr[2] = 3;


gdb> print *arr@3
$2 = {1, 2, 3}
```

`gdb` – abbreviations

- Common `gdb` commands have abbreviations

`p` (same as `print`)

`c` (same as `continue`)

`n` (same as `next`)

`s` (same as `step`)

- More convenient to use when interactively debugging

structs (1)

- Way to package primitive data objects into an aggregate data object
- `struct` declaration:

```
struct point {
    int x;
    int y;
    double dist; /* from origin */
};  /* MUST have semicolon! */
```

structs (2)

- `struct` declaration usually done outside of function, like a function prototype
- Create/initialize `struct` like this:

```
struct point p;
p.x = 0;    /* "dot syntax" */
p.y = 0;
p.dist = sqrt(p.x*p.x + p.y*p.y);
```

structs (3)

- Using a `struct`:

```
void foo(void) {
    struct point p;
    p.x = 10; p.y = -3;
    p.dist = sqrt(p.x*p.x + p.y*p.y);
    /* do stuff with p */
}
```

structs (4)

- Using `malloc()` with structs:

```
struct point *make_point(void) {
    struct point *p;
    p = (struct point *)
      malloc(sizeof(struct point));
    return p;
}  /* free struct elsewhere */
```

structs (5)

- Using pointers to structs :

```
void init_point(struct point *p) {
    (*p).x = (*p).y = 0;
    (*p).dist = 0.0;
    /* syntactic sugar: */
    p->x = p->y = 0;
    p->dist = 0.0;
}
```

structs (6)

- structs can contain arrays or other structs
- Usually use pointers to structs instead of just plain structs

```
struct foo {
    int x;
    struct point p1;   /* Unusual */
    struct point *p2;  /* Typical */
};
```

structs (7)

- structs can be "recursive":

```
struct node {
    int value;
    struct node *next;
};
```

- but can't have `struct node next` inside declaration (why?)

`typedef` (1)

- Typing `struct point` all the time is tedious
- Use a `typedef` (type alias):

original type new name

```
typedef struct point Point;
typedef int Length;
```

- Original type comes first
- New name is at the end

`typedef` (2)

- Type component of `typedef` can also be a struct

```
typedef struct {  /* no name for struct */
    int x;
    int y;
    double dist;
} Point;
Point p1, p2;  /* no "struct" */
```

- N.B. This is an *anonymous* struct

typedef (3)

- Recursively defined structs:

```
typedef struct _node {
    int value;
    struct _node *next;
} node;
```

typedef (4)

- Read this as:

```
typedef
    struct _node {
        int value;
        struct _node *next;
    }
node;
```

Linked lists

- `node` is the linked list struct!
- Set `next` pointer to next node in list
- If `next` is `NULL`, then at end of list
- Linked lists are just chains of `node`s

Creating a linked list (1)

```
node *list, *n, *prev;
```

Linked list (diagram)

`list`

`n`

`prev`

Creating a linked list (2)

```
n = (node *)malloc(sizeof(node));
list = n;  /* list points to first node */
n->value = 10;
prev = n;  /* pointer to previous node */
```

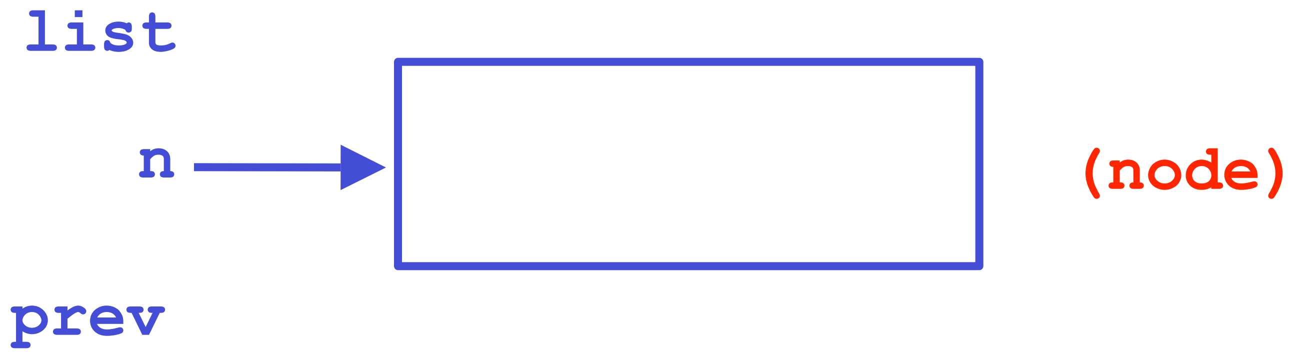
Linked list (diagram)

`list`

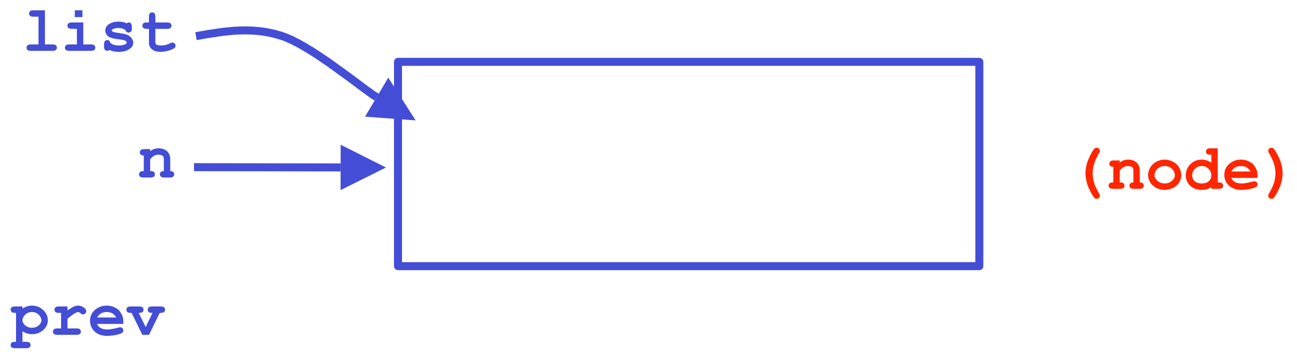
`n`

`prev`

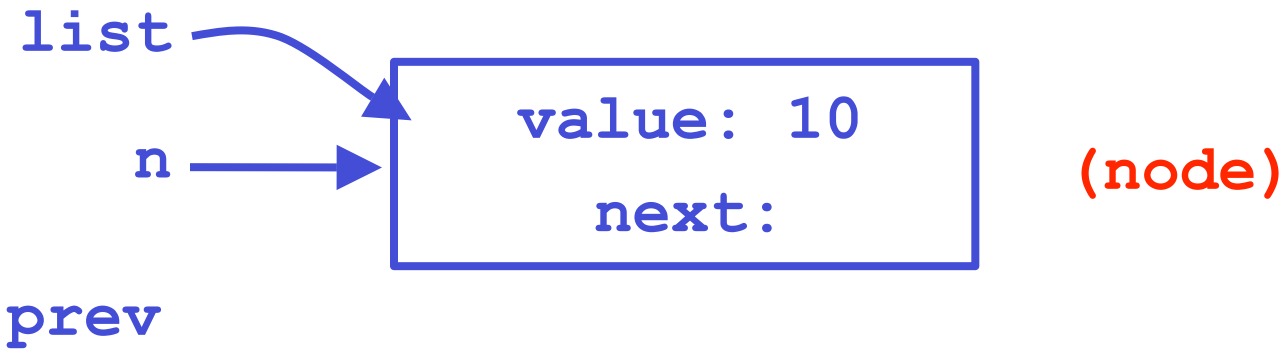
Linked list (diagram)



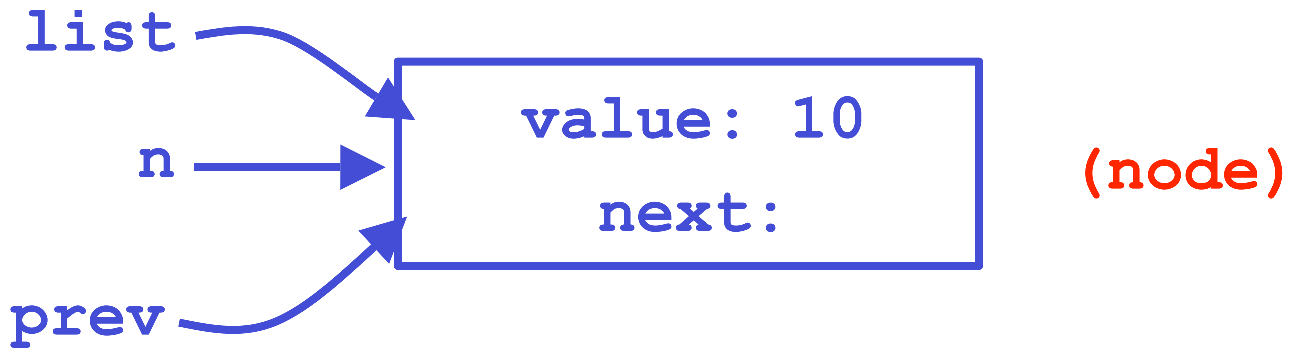
Linked list (diagram)



Linked list (diagram)



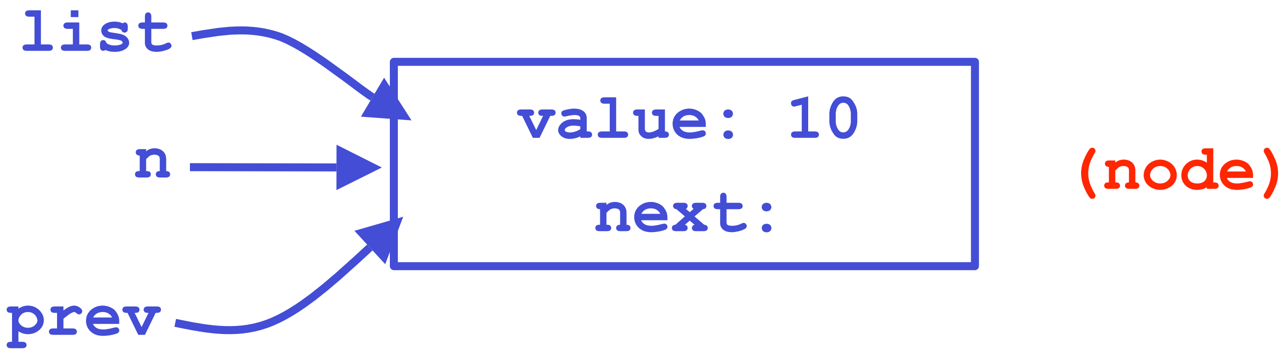
Linked list (diagram)



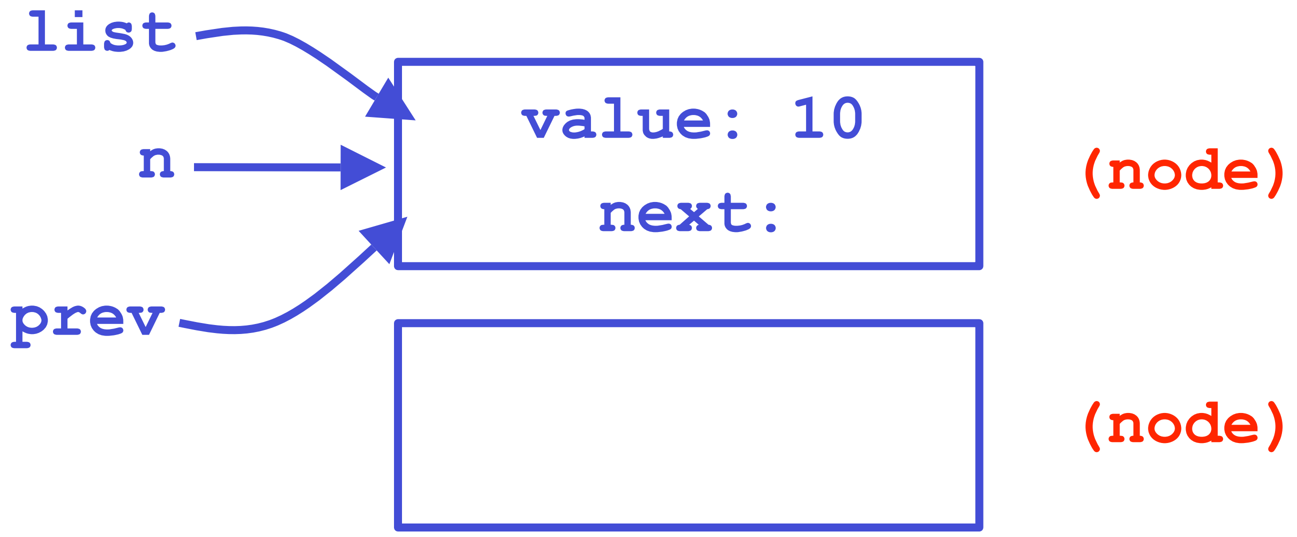
Creating a linked list (3)

```
n = (node *)malloc(sizeof(node));
prev->next = n; /* connect nodes */
prev = n;
n->value = 20;
/* ... continued on next slide ... */
```

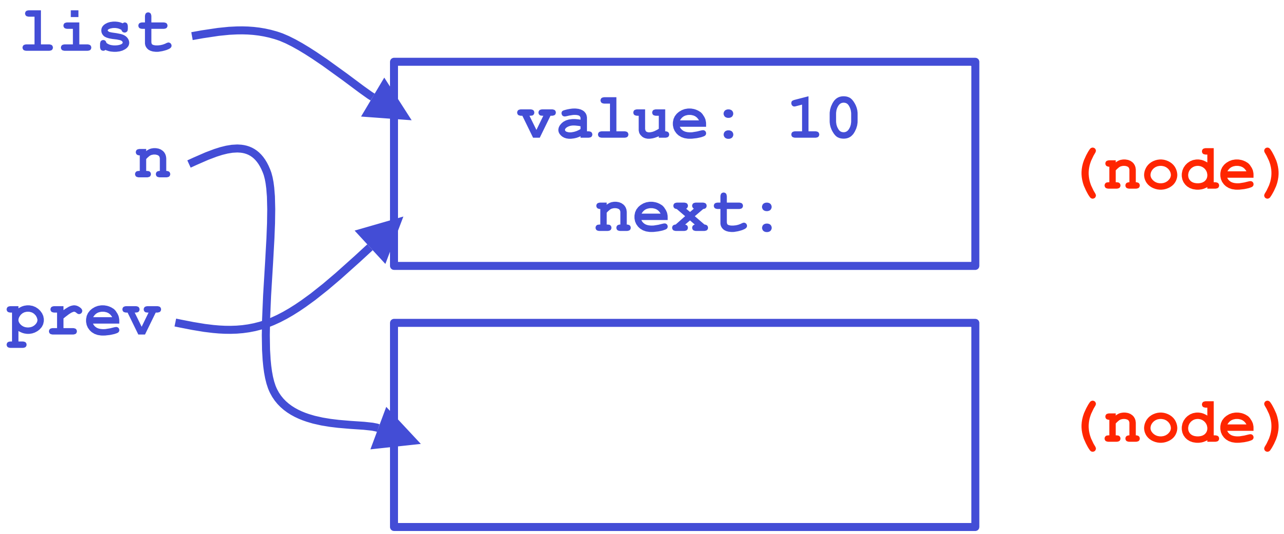
Linked list (diagram)



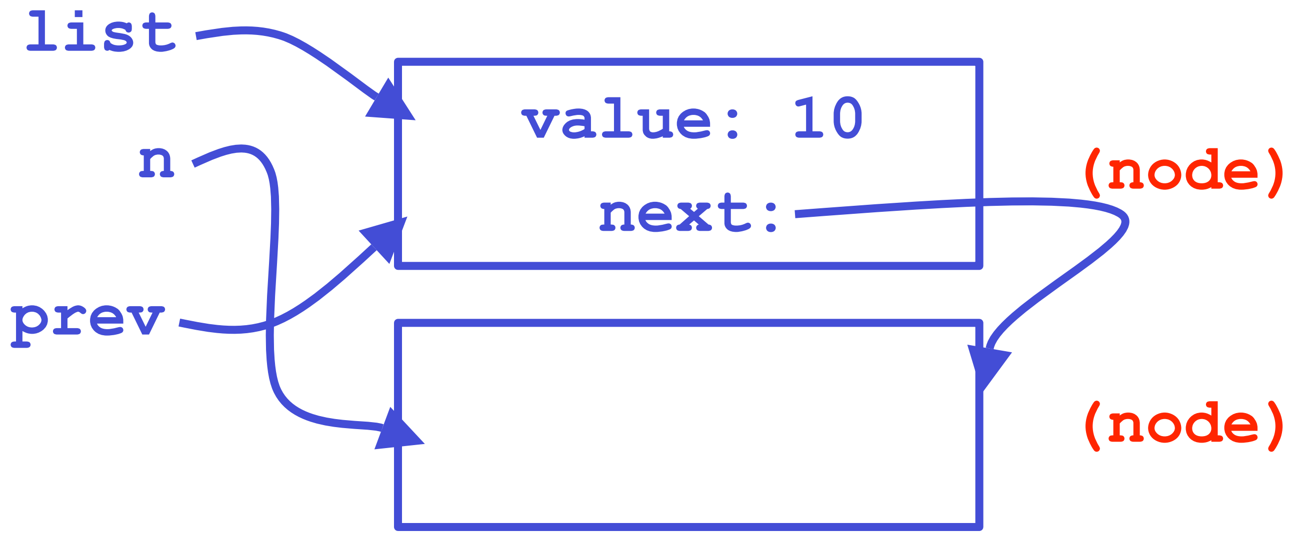
Linked list (diagram)



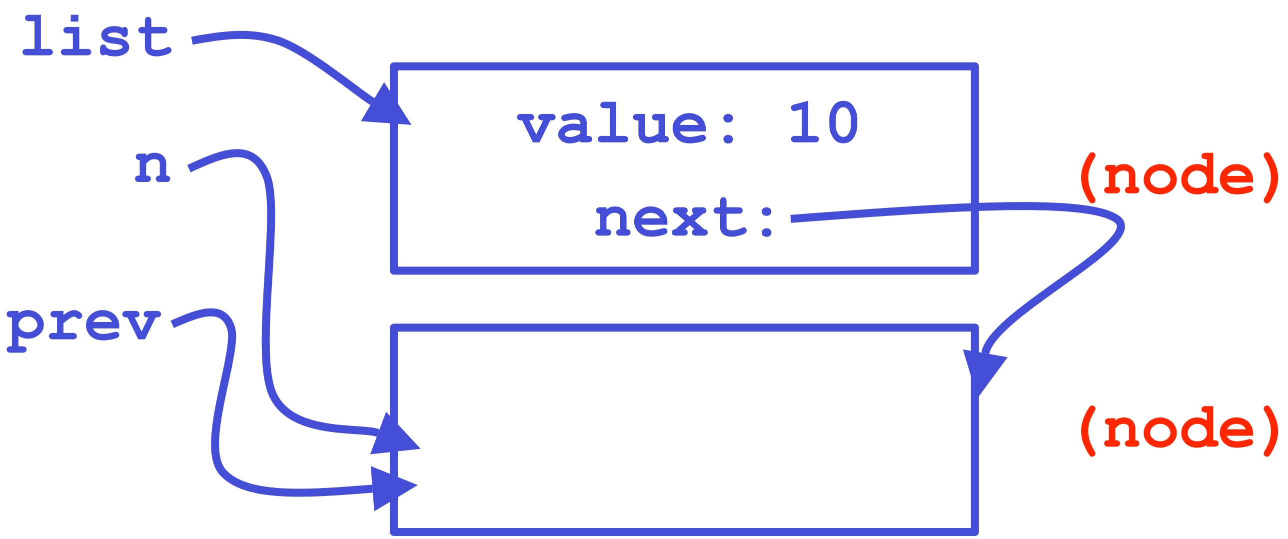
Linked list (diagram)



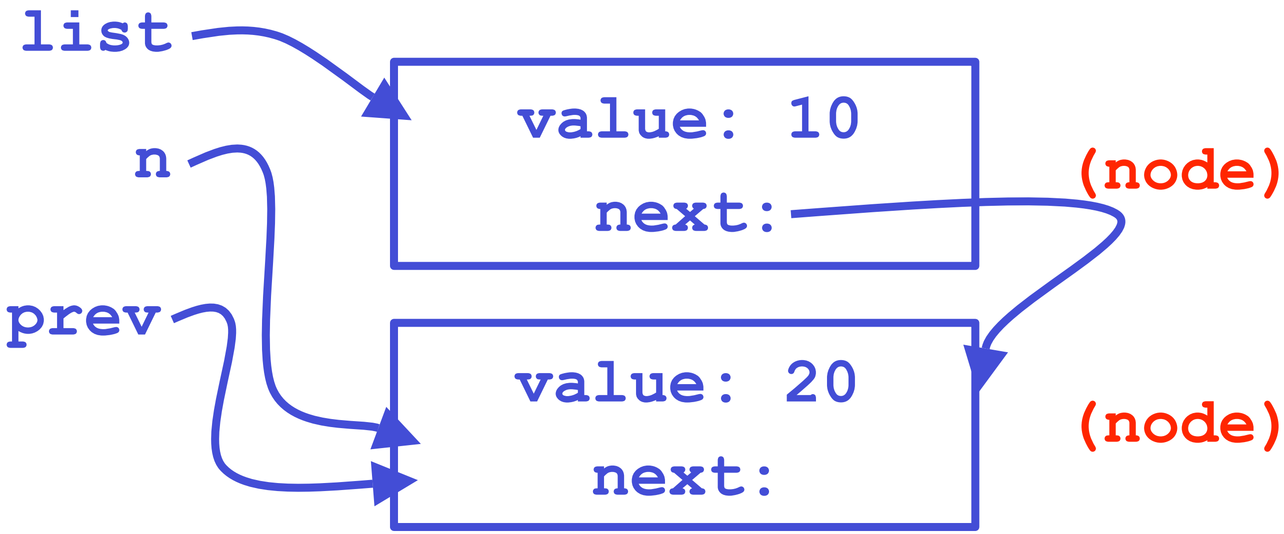
Linked list (diagram)



Linked list (diagram)



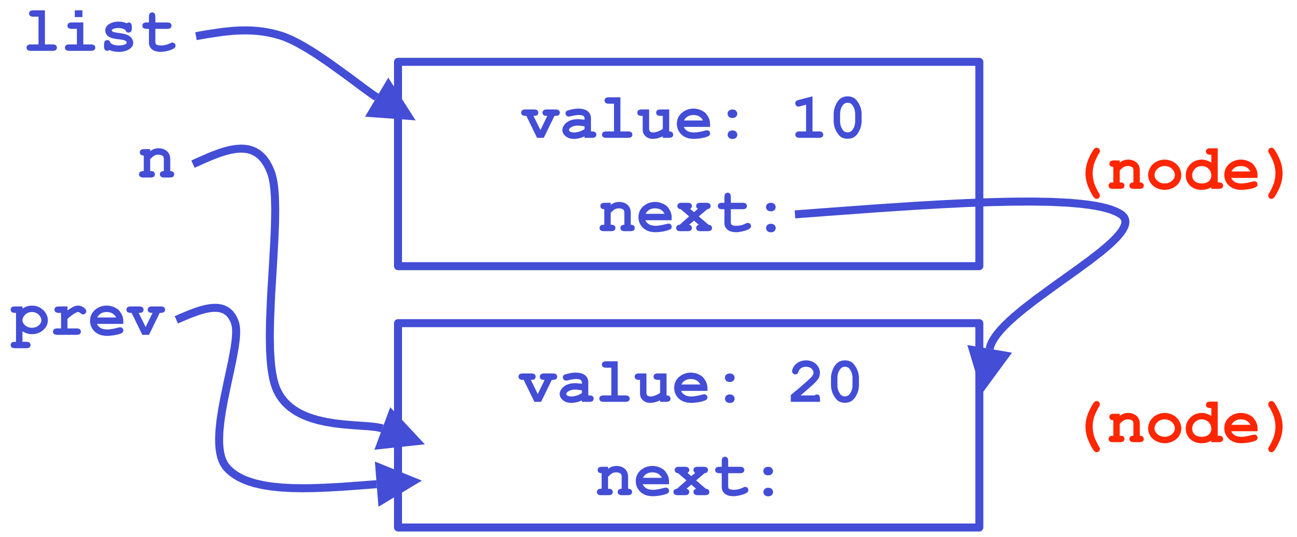
Linked list (diagram)



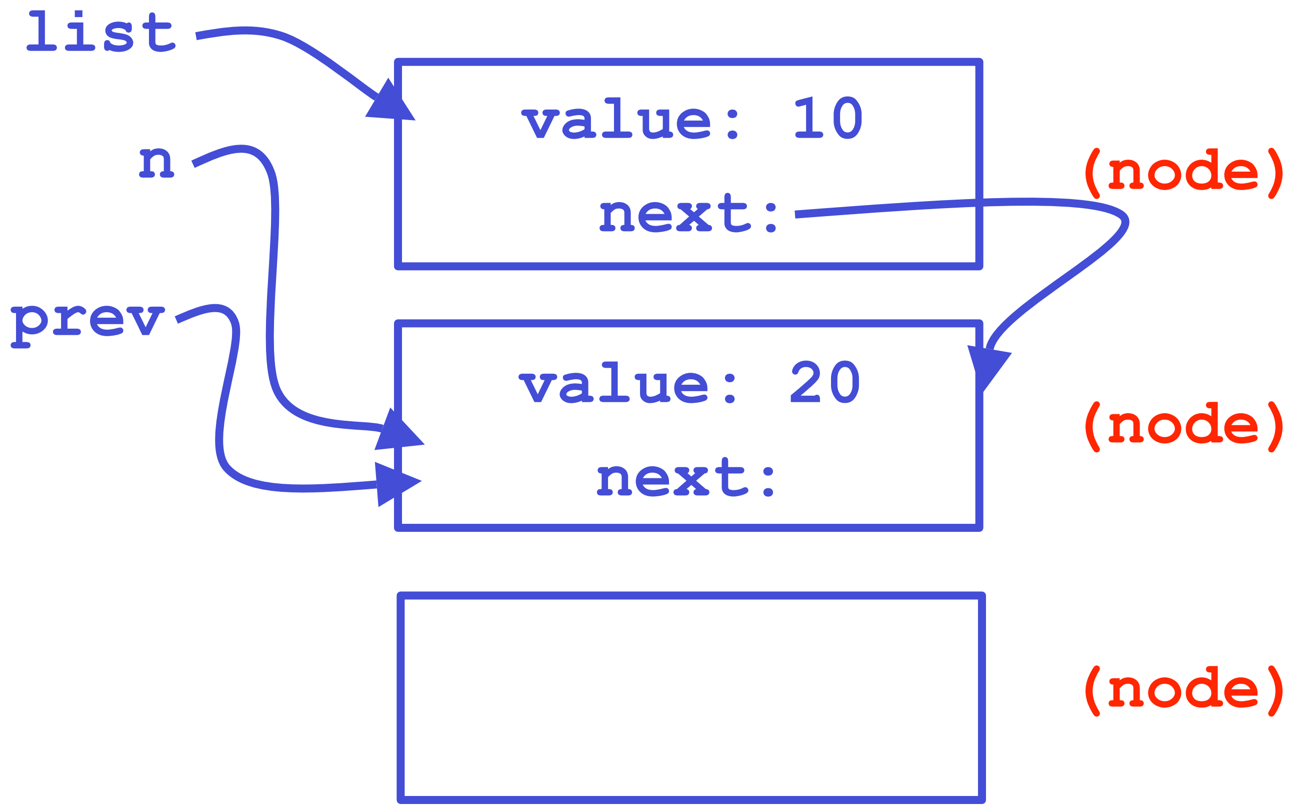
Creating a linked list (4)

```
/* Continued... */
n = (node *) malloc(sizeof(node));
prev->next = n;
prev = n;
n->value = 30;
n->next = NULL;  /* End of list marker. */
```

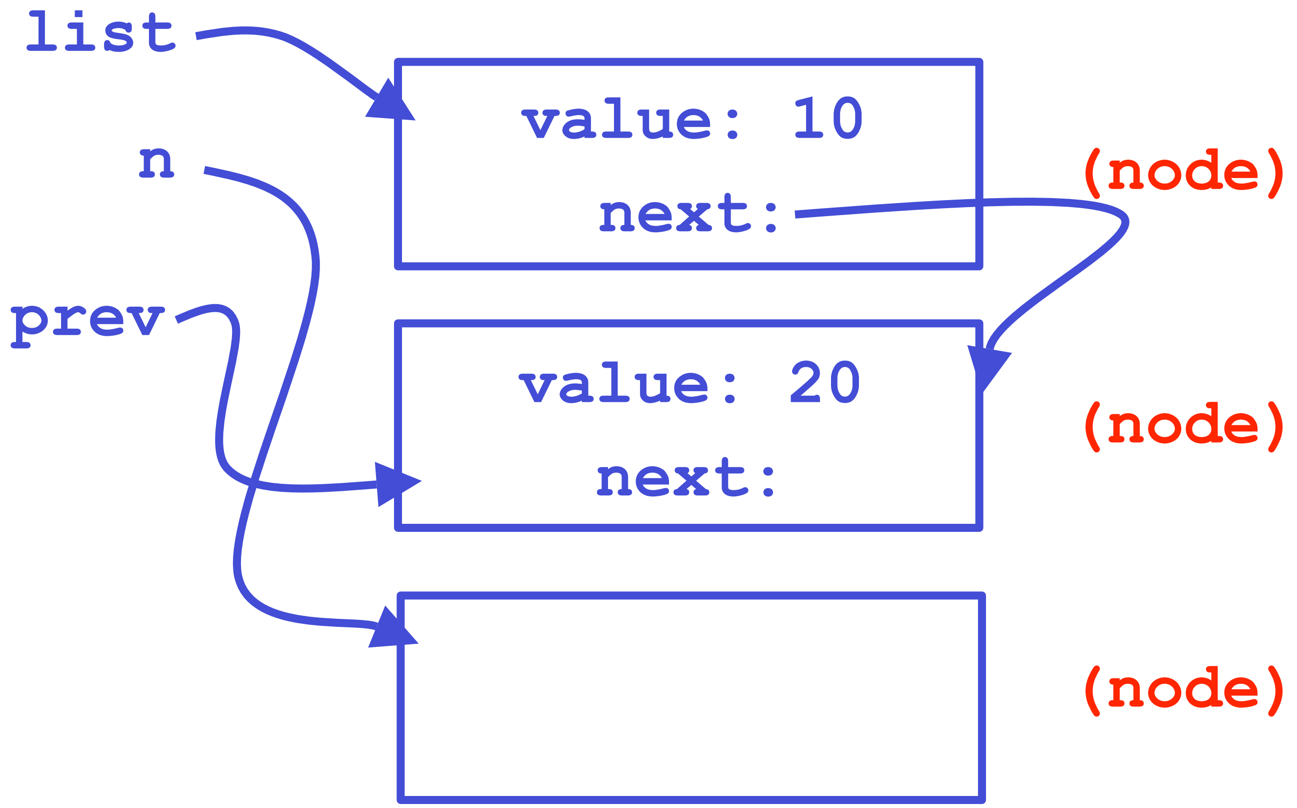
Linked list (diagram)



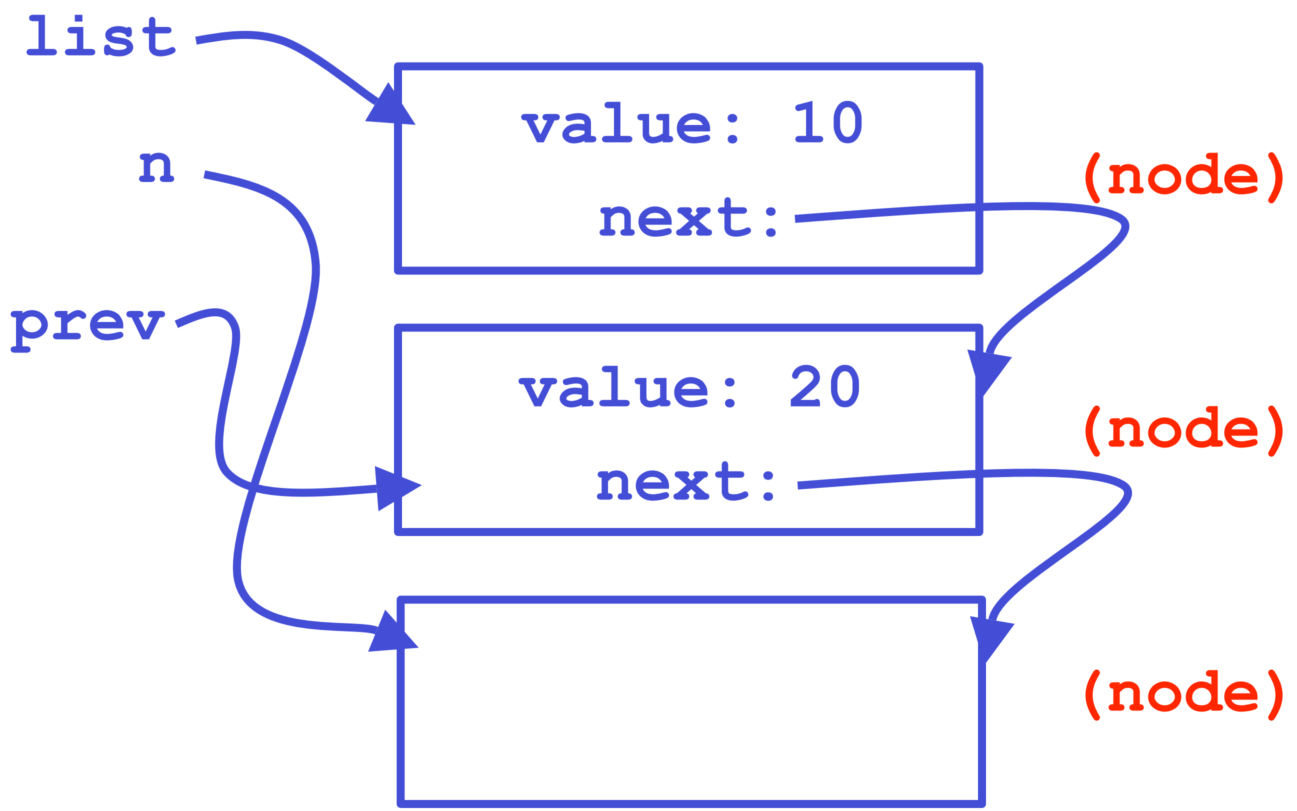
Linked list (diagram)



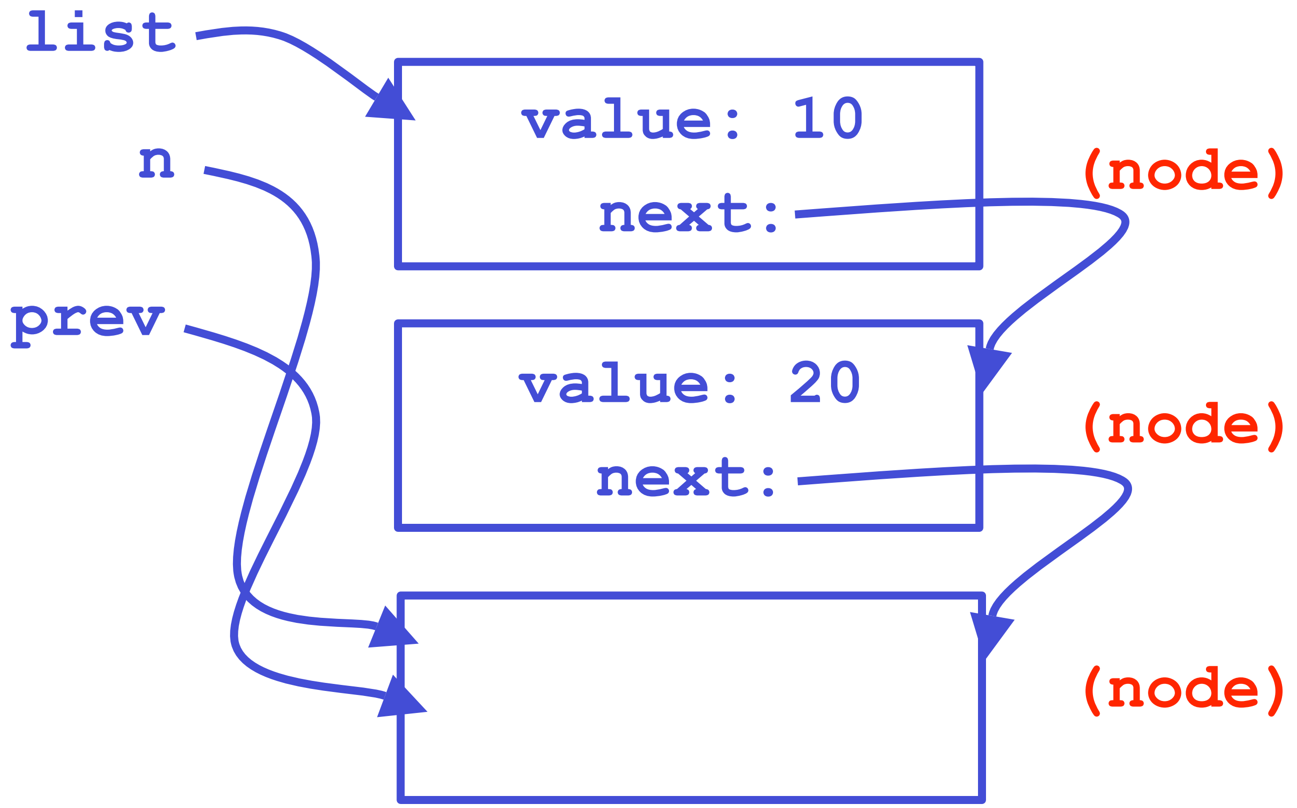
Linked list (diagram)



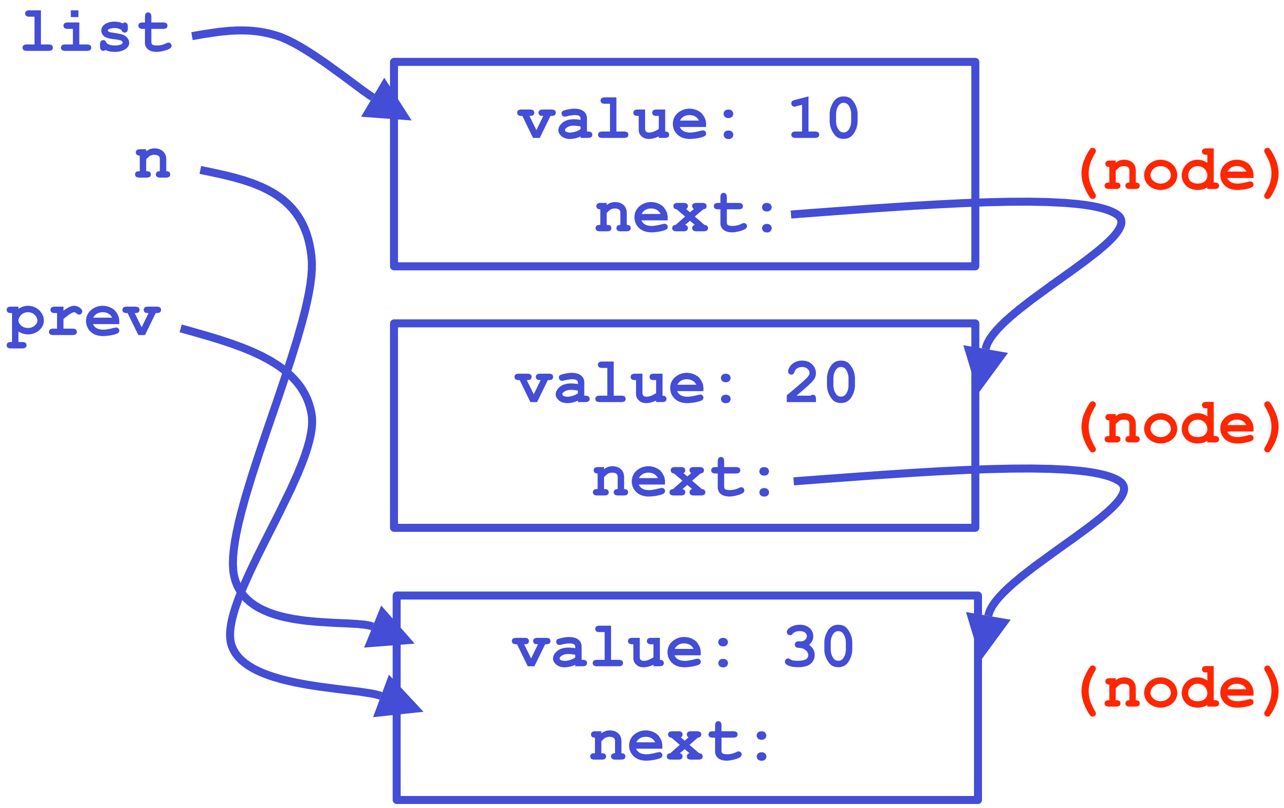
Linked list (diagram)



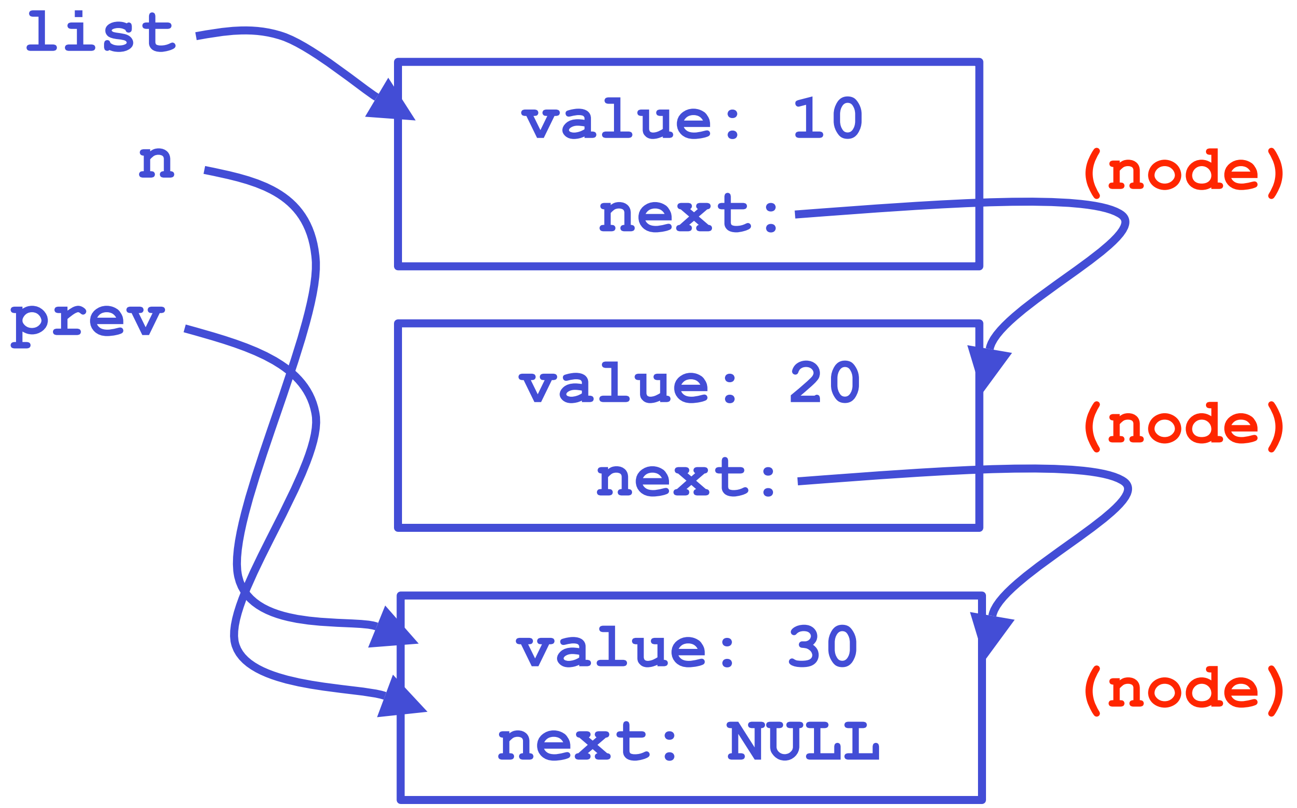
Linked list (diagram)



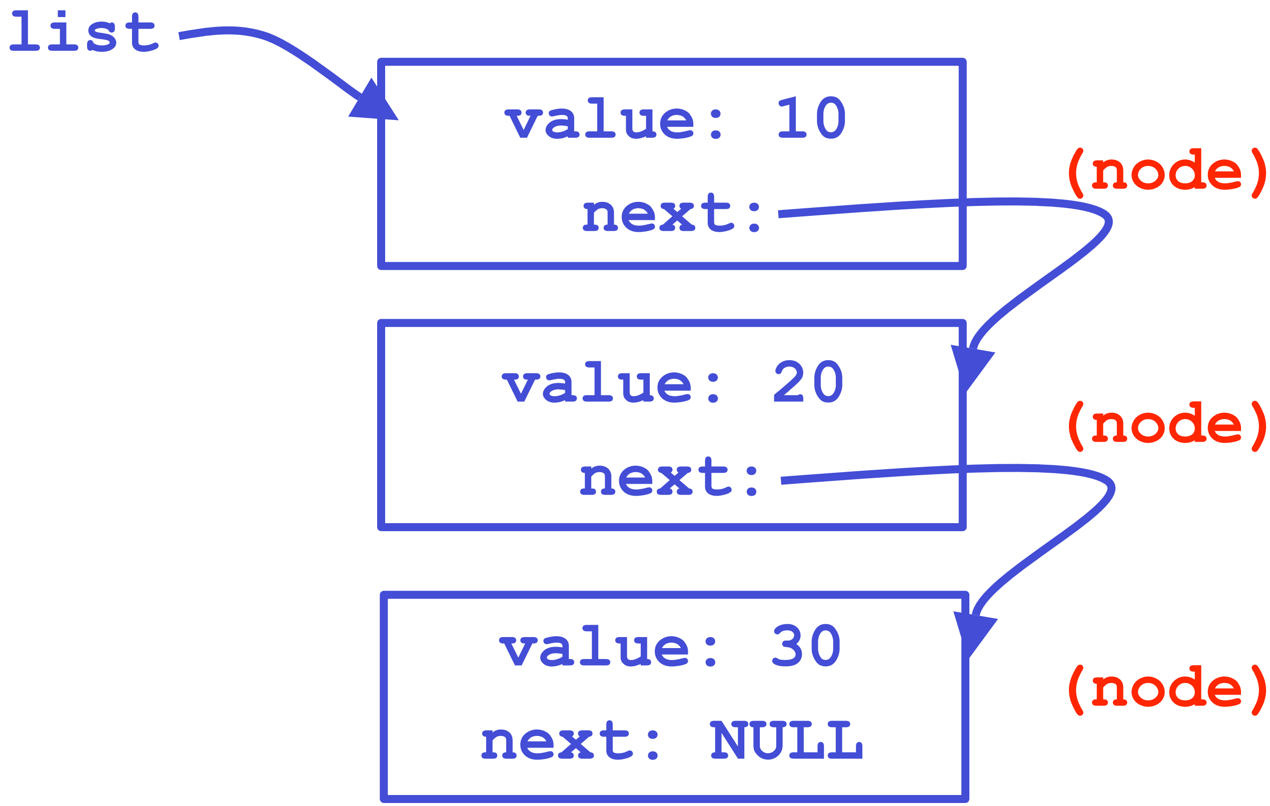
Linked list (diagram)



Linked list (diagram)



Linked list (final diagram)



Creating a linked list (5)

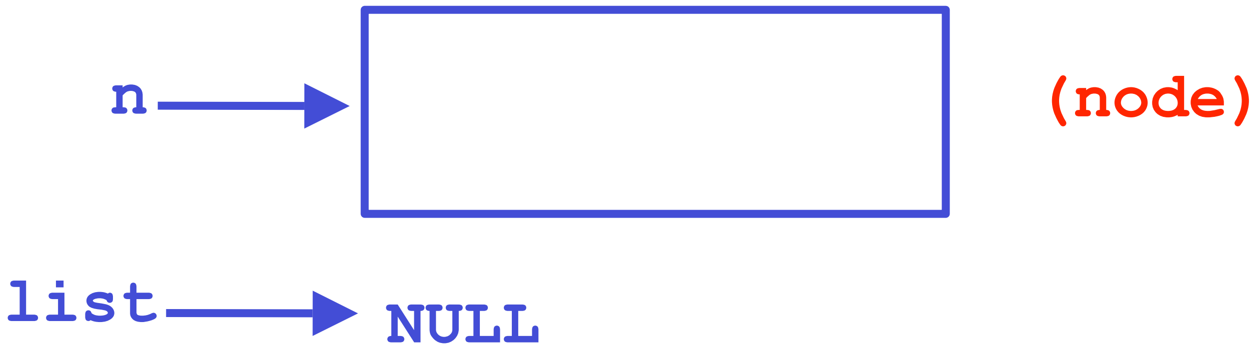
- Can also create linked lists from the end back to the front
- Actually easier to do it that way when possible
  - example: lab 6 command-line arguments
- End-of-list is represented as NULL pointer
- add nodes to previous list (or to NULL)

Creating a linked list (6)

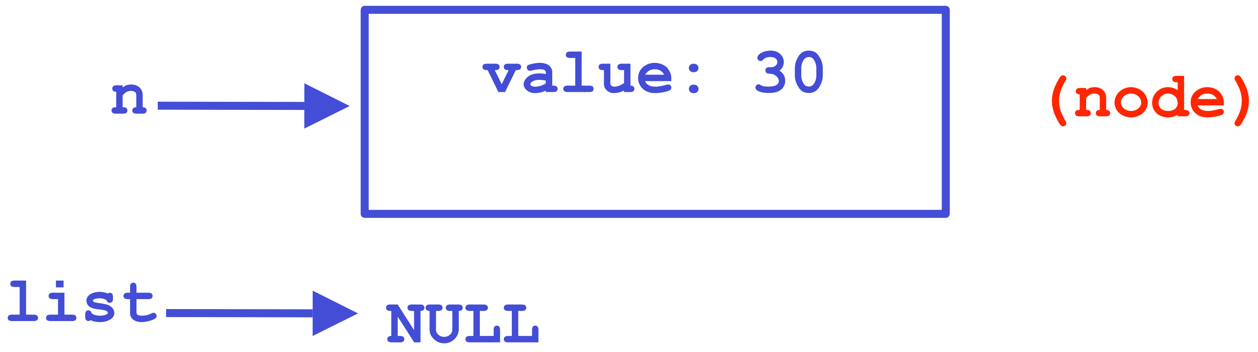
```
list = NULL;     /* Empty list. */
n = (node *) malloc(sizeof(node));
n->value = 30;
n->next = list;
list = n;      /* now 1-node list */
```

Linked list (diagram)

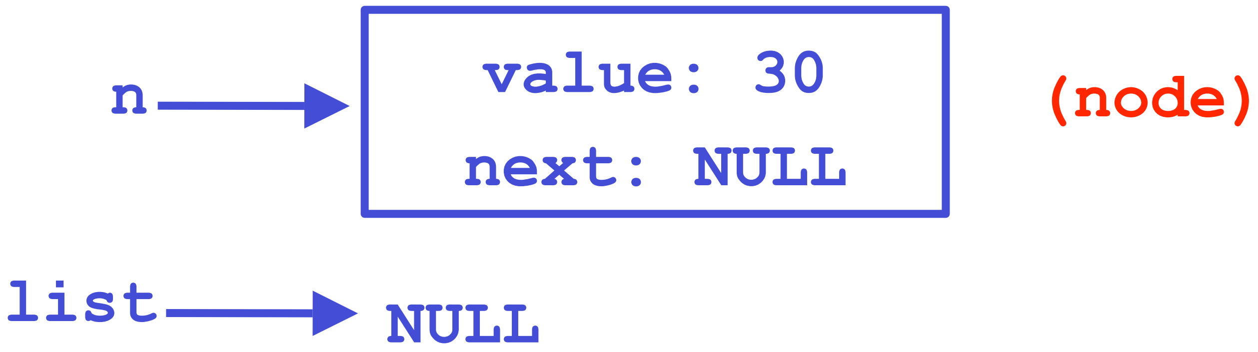
Linked list (diagram)



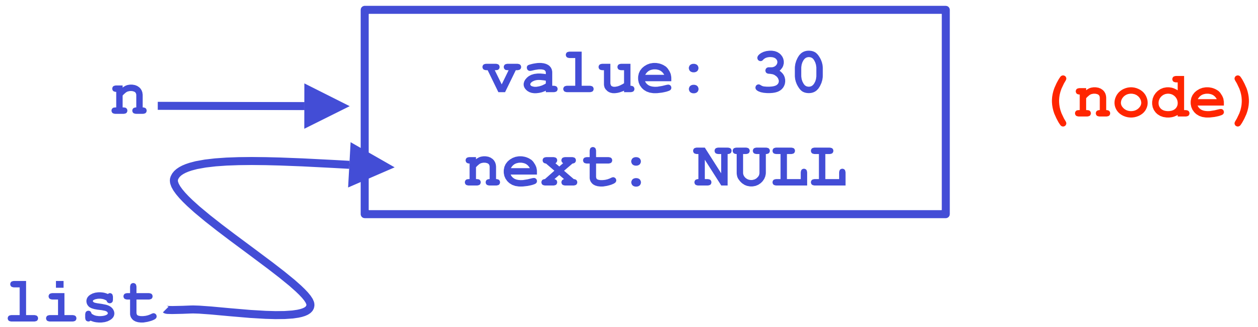
Linked list (diagram)



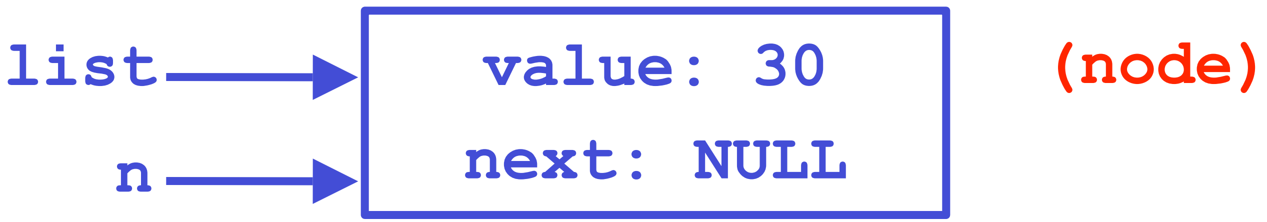
Linked list (diagram)



Linked list (diagram)



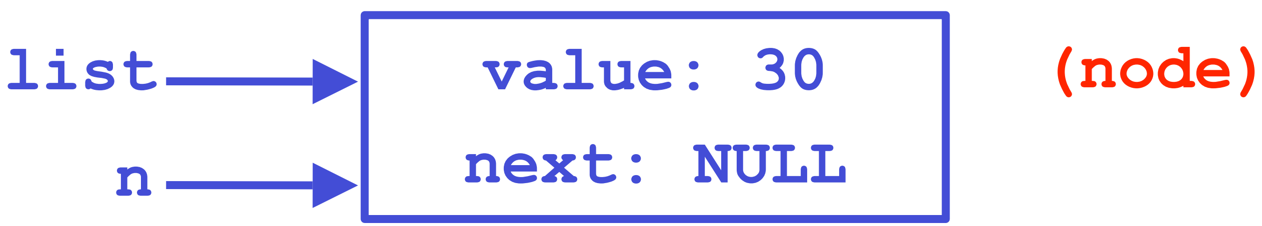
Linked list (diagram)



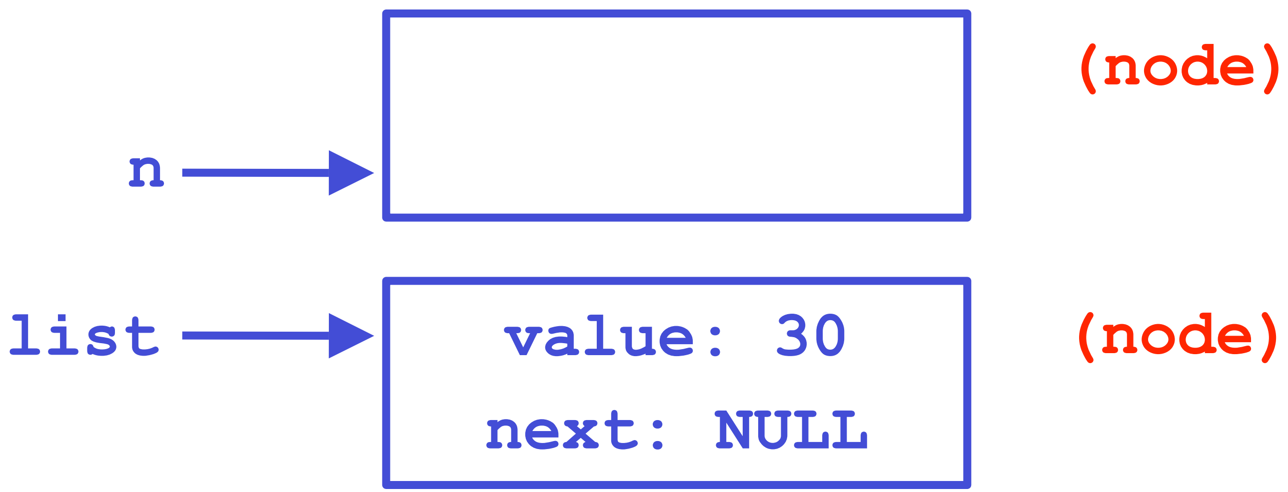
Creating a linked list (7)

```
n = (node *) malloc(sizeof(node));
n->value = 20;
n->next = list;
list = n;      /* now 2-node list */
```

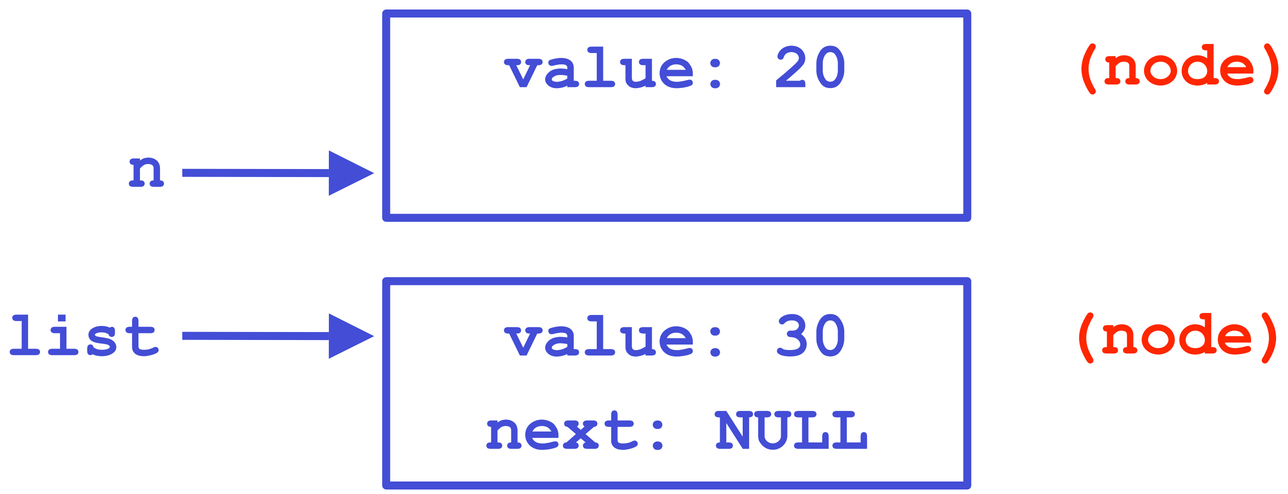
Linked list (diagram)



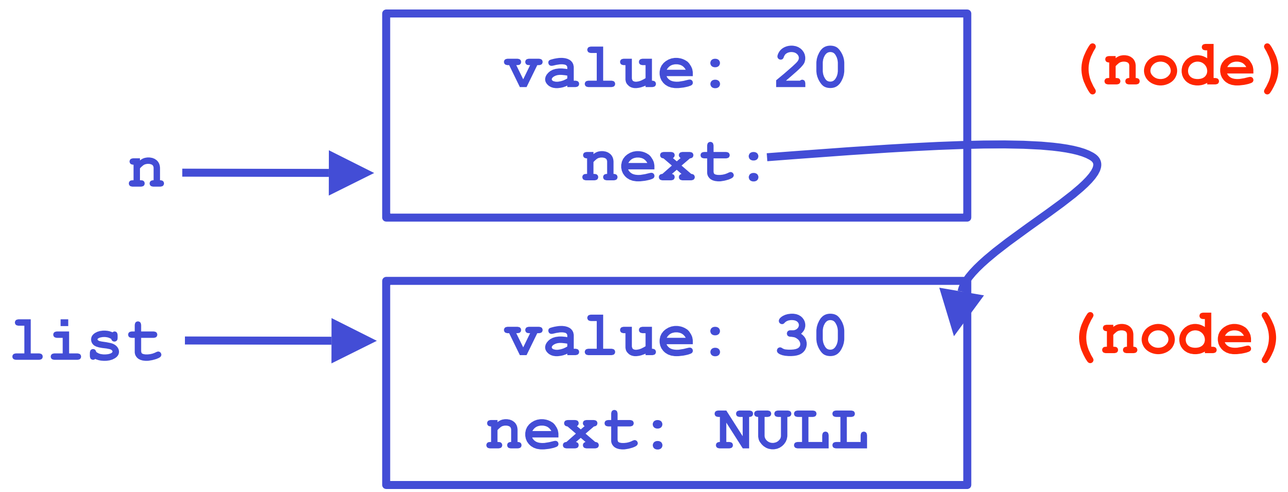
Linked list (diagram)



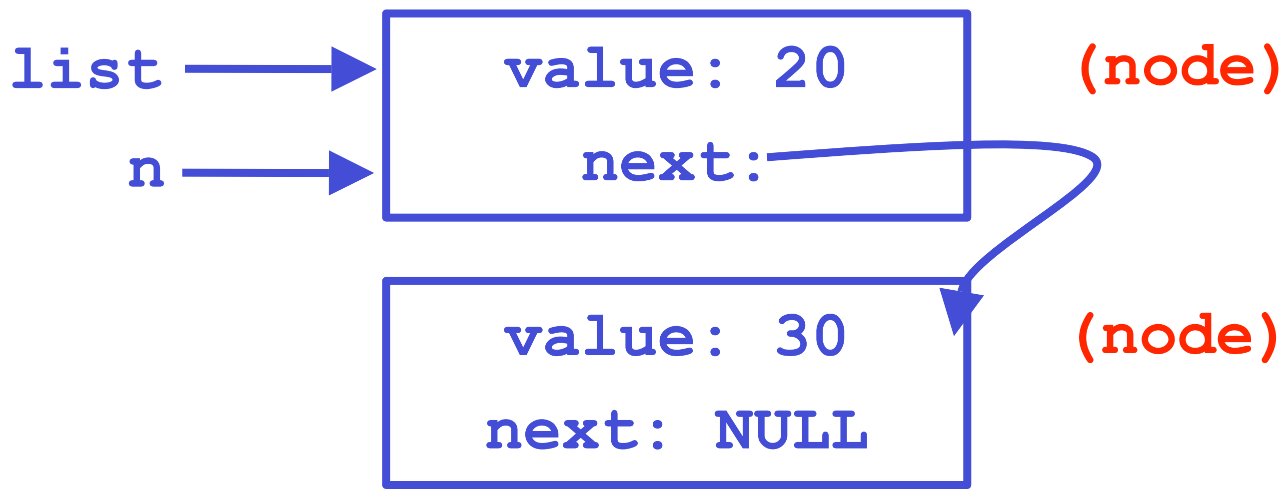
Linked list (diagram)



Linked list (diagram)



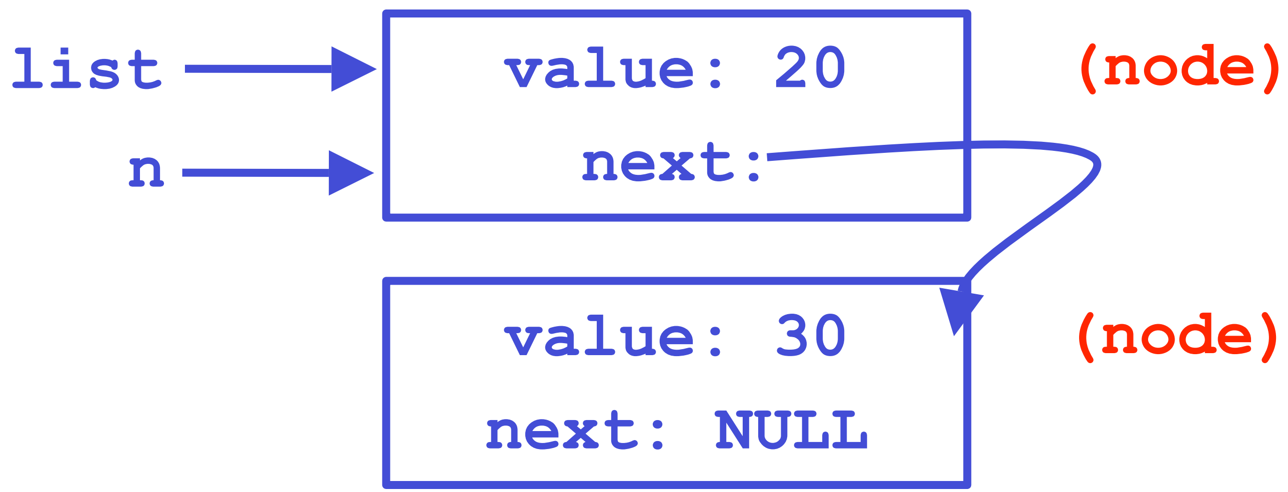
Linked list (diagram)



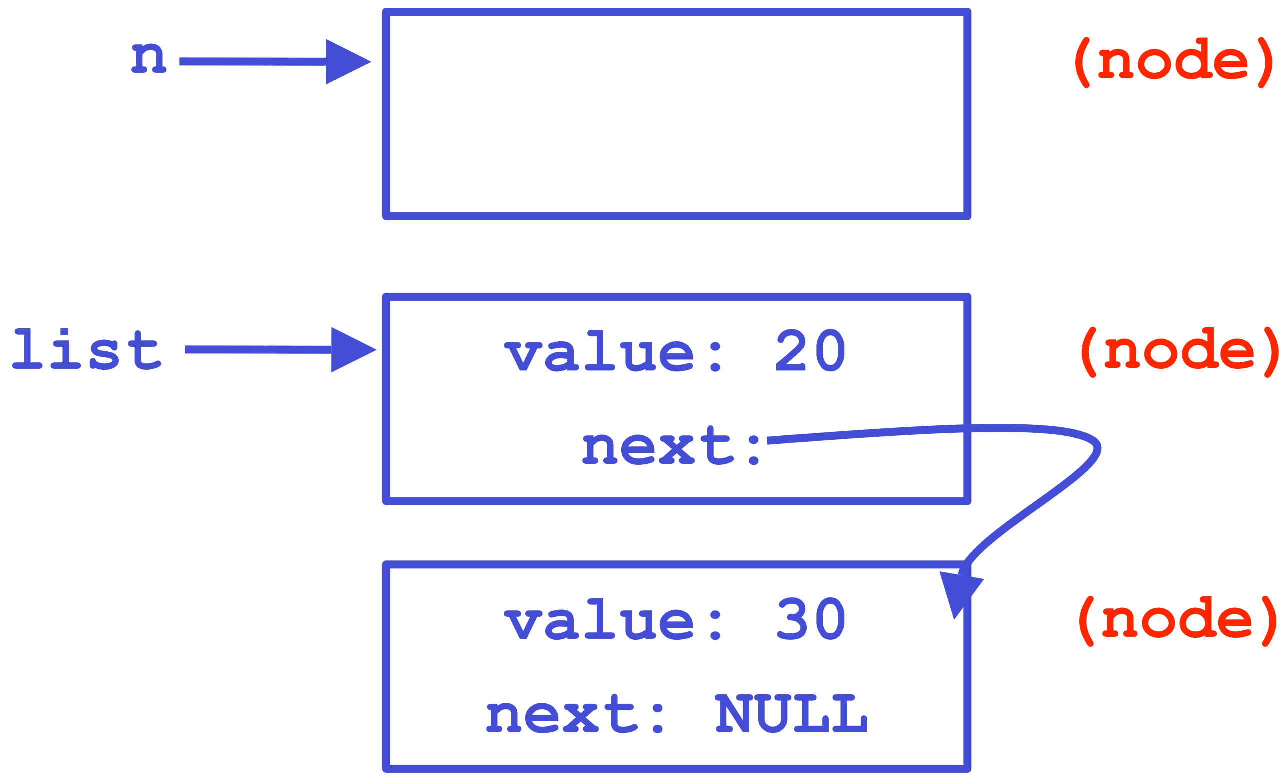
Creating a linked list (8)

```
n = (node *) malloc(sizeof(node));
n->value = 10;
n->next = list;
list = n;      /* now 3-node list */
```

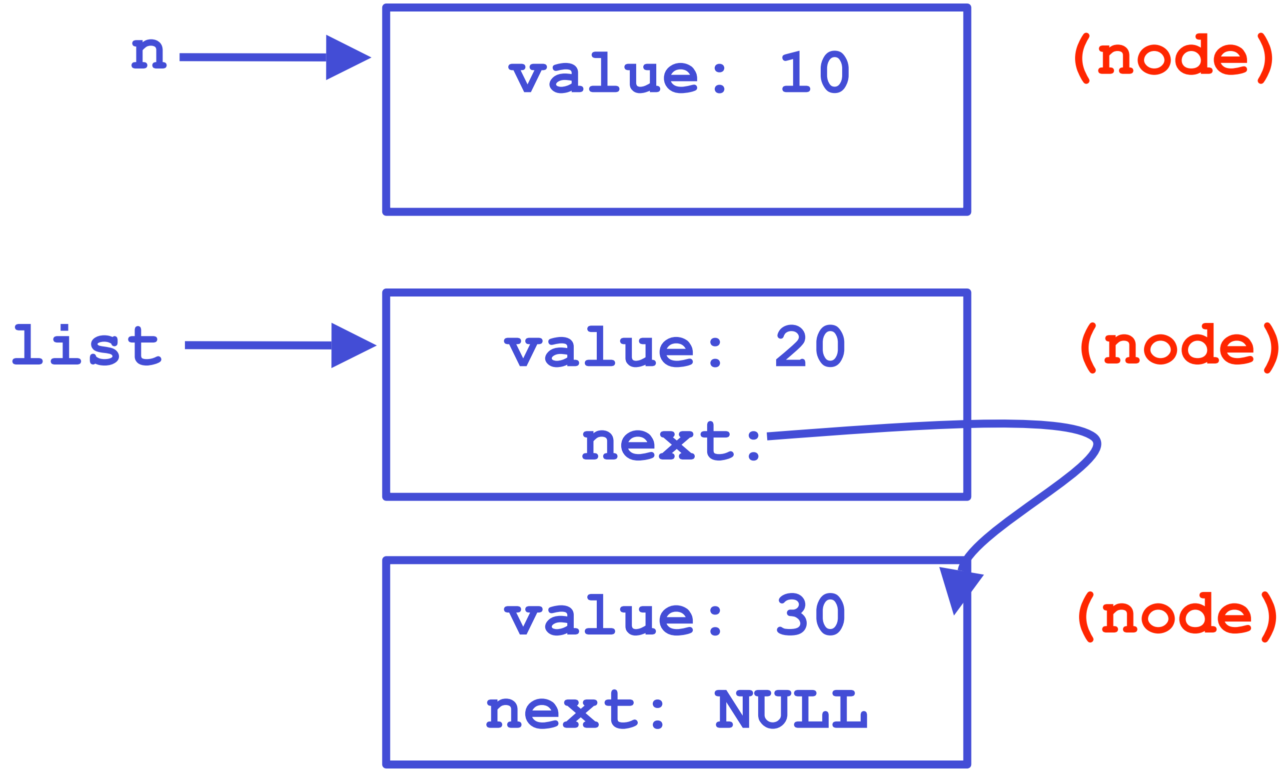
Linked list (diagram)



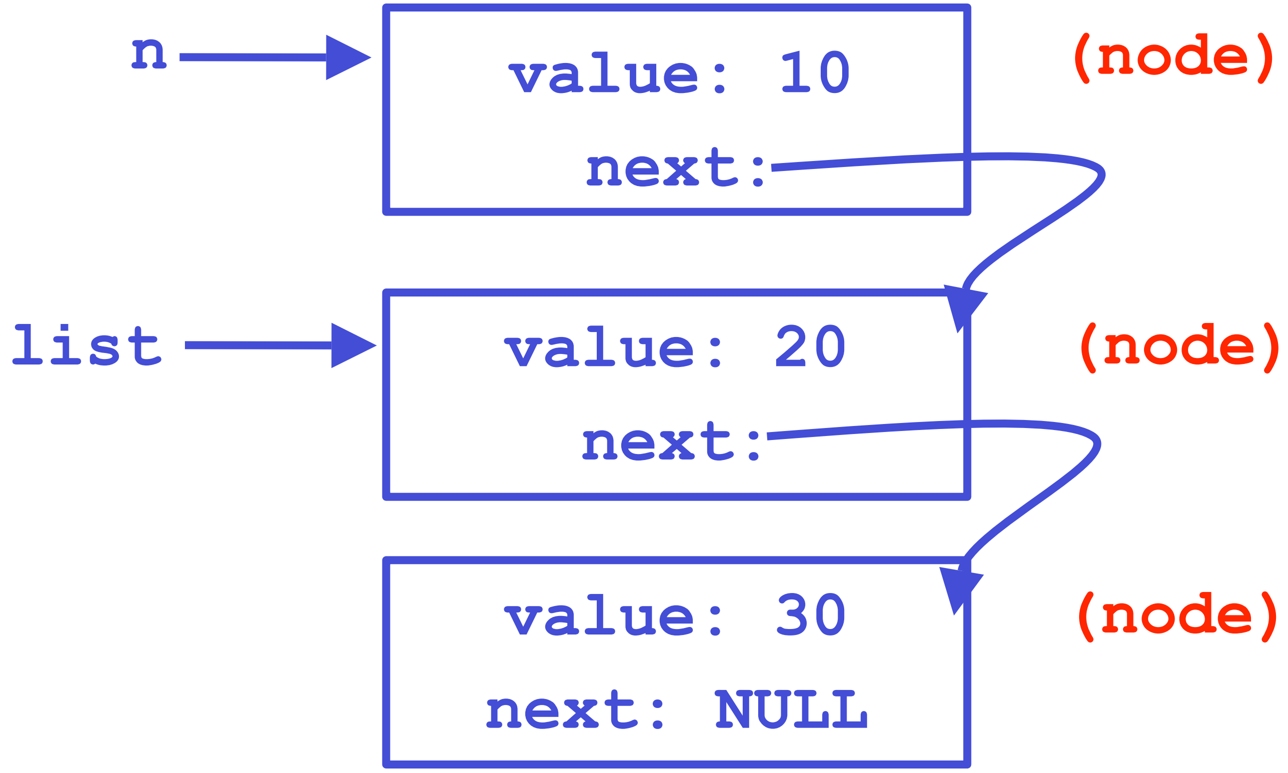
Linked list (diagram)



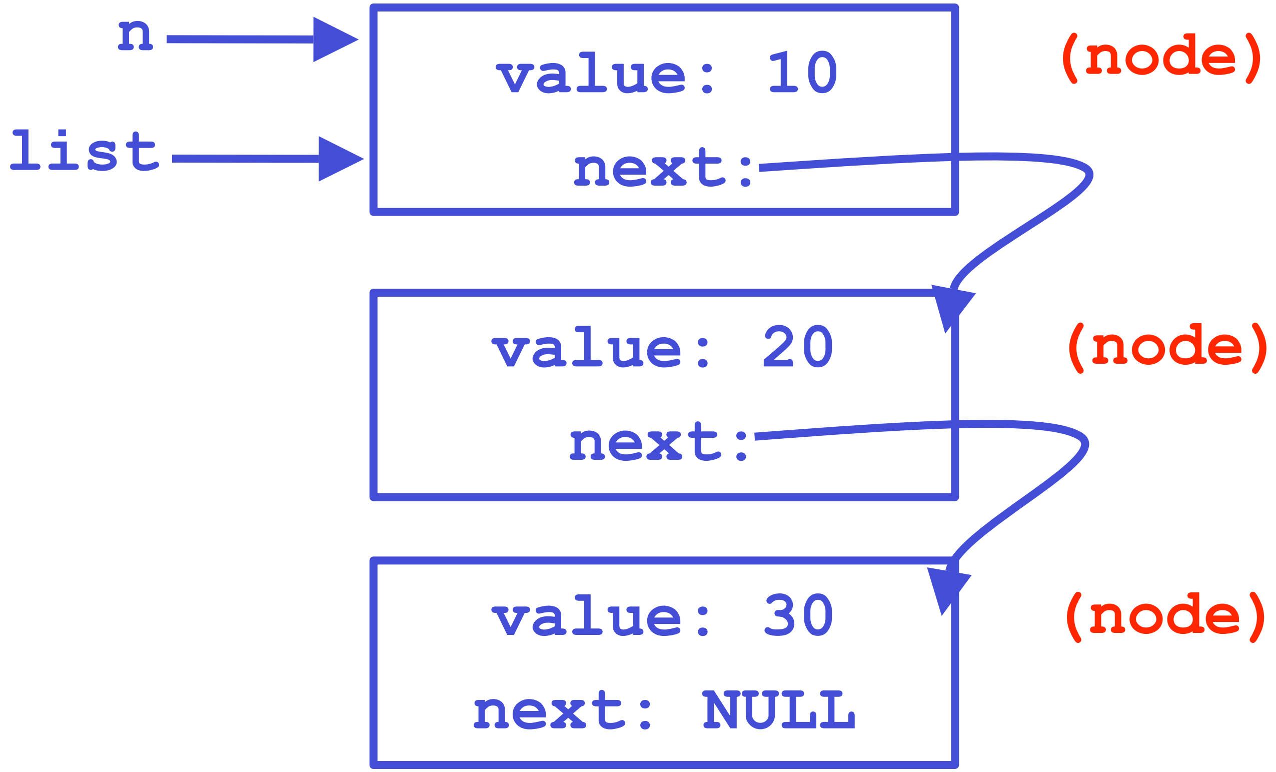
Linked list (diagram)



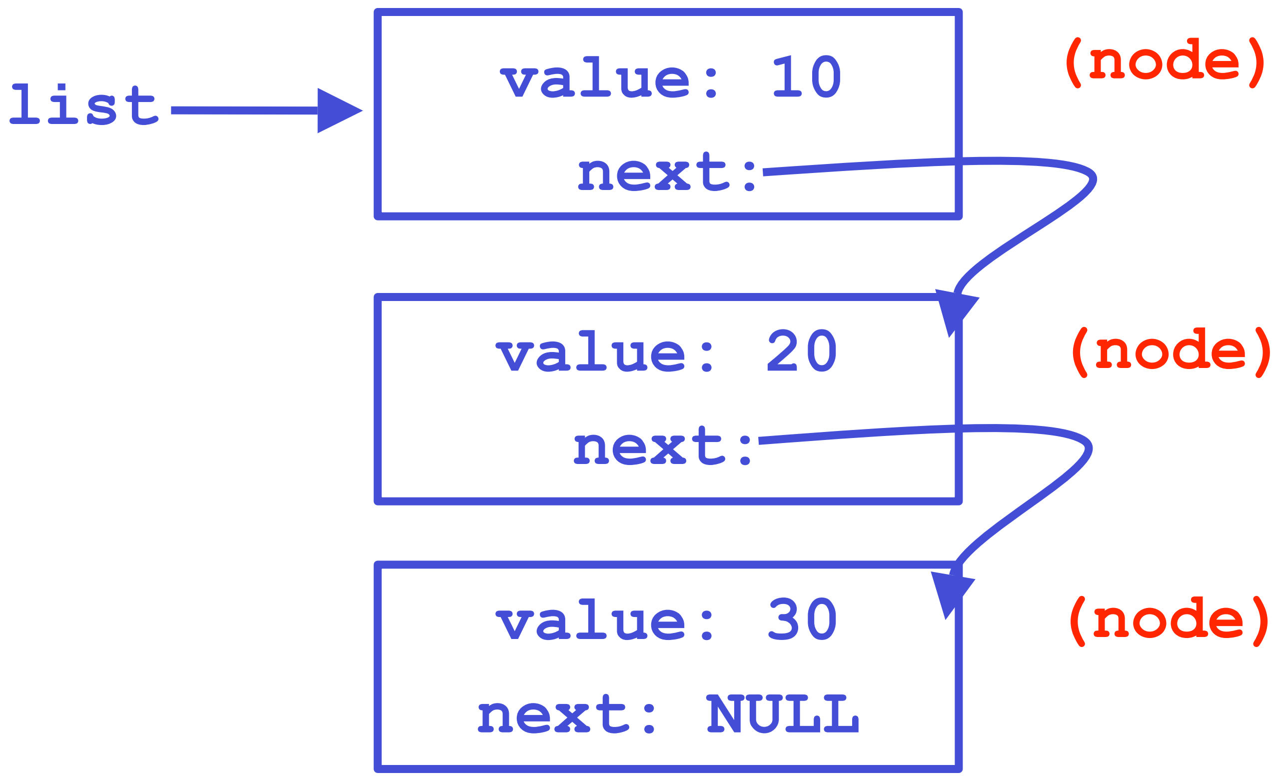
Linked list (diagram)



Linked list (diagram)



Linked list (final diagram)



Checking `malloc()`

- Previous code simplified to fit on slide
- Actually should check every `malloc` call for failure

```
n = (node *)malloc(sizeof(node));
if (n == NULL)
{
    fprintf(stderr,
        "Error: out of memory.\n");
    exit(1);
}
```

Iterating through a linked list

- Standard idiom for going through linked lists:

```
node *n;
/* Set all node values to zero. */
for (n = list; n != NULL; n = n->next) {
    n->value = 0;
}
```

- You should be able to figure out how this works

Lab 6

- This week's lab:
  - New sorting algorithm: "quicksort"
  - More efficient than ME sort, bubblesort
  - Use on linked lists, not arrays
  - Memory management will be a challenge!

Next time

- Hash tables
- More "fun" with pointers ;-)