Recitation

By yzhuang, sseshadr

Agenda

- Debugging practices
  - GDB
  - Valgrind
  - Strace
- Errors and Wrappers
  - System call return values and wrappers
  - Uninitialization
  - `malloc()` related bugs
- System IO

Debugging Practices

General Debugging

- printfs are a good start, but won't solve everything
- Remember printfs CHANGE your code
  - And how it's compiled
  - And how it runs
    - Especially for races
- A lot of the debugging tools should be used with the –g compiler flag

GDB

- From bomblab / buflab
- You WILL need it for malloc
- Demo?

Valgrind

- Memory related issues
- Lots of options
- `man valgrind`
- `valgrind --leak-check=full ./a.out`
- Demo?

strace

- From the man page
  - "In the simplest case strace runs the specified command until it exits. **It intercepts and records the system calls which are called by a process and the signals which are received by a process.** The name of each system call, its arguments and its return value are printed on standard error or to the file specified with the -o option."
- Cool for debugging!

Errors and Wrappers

System Call Error Handling

- Always handle errors for every system call
  - #include <errno.h>
  - Failed system calls almost always return -1
  - Global integer error number: errno
  - Getting error description: strerror(errno)
- We deduct style points for not handling system call errors

Wrappers

- If a system call is frequently used, create a wrapper for it. For example:

```
pid_t Fork(void){
    pid_t pid;
    if ( (pid = fork() ) < 0 ){ //error handling }
    return pid;
}
```

- Proclab: always handle errors
  - You can choose whether to use wrappers

malloc

- #include <stdlib.h>
- void *malloc(size_t *size*);
- Allocates *size* bytes of memory
- A pointer is returned
- Returned memory **uninitialized!!**

```
p=(struct cacheline*) malloc( sizeof(cacheline) );
P->valid = ????
```

  - Cachelab: using uninitialized valid bit (very bad)!

calloc

- With malloc
  - Either initialize
  - Or use calloc
- void * calloc (size_t num, size_t size);
  - Allocate num * size bytes of memory
  - Initialized to 0
- Caveat: what if num * size causes an overflow? Check before calling calloc.

free

- Free memory allocated by malloc/calloc
- Common mistakes:
  - Freeing memory already freed
  - Freeing memory not allocated
  - Writing to memory already freed
  - Index-out-of-bound accesses of allocated array
  - Not freeing allocated memory

I/O

System I/O Basics

- Four basic operations:
  - `open`
  - `close`
  - `read`
  - `write`
- What’s a file descriptor?
  - Returned by `open`.
  - `int fd = open(“/path/to/file”, O_RDONLY);`
    - fd is some positive value or -1 to denote error

System I/O Basics

- **Every** process starts with 3 open file descriptors
  - 0 - STDIN
  - 1 - STDOUT
  - 2 - STDERR
- Can I `close` these file descriptors?
  - Yes!
  - But you shouldn't… this next example is just for illustrative purposes

Sample Code

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int main(int argc, char ** argv){

   int fd = atoi(argv[1]);
   argc = argc; /* Keep GCC Happy */

   fprintf(stdout, "STDOUT:close(%d) = %d\n",fd,close(fd));
   fprintf(stderr, "ERROR:close(%d) = %d\n",fd,close(fd));

   return 1;

}
```

What are the outputs when run with `./a.out 0` , `./a.out 1` , and `./a.out 2` ?

Sample Code

```c
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int main(int argc, char ** argv){

    int fd = atoi(argv[1]);
    argc = argc; /* Keep GCC Happy */

    fprintf(stdout, "STDOUT:close(%d) = %d\n",fd,close(fd));
    fprintf(stderr, "STDERR:close(%d) = %d\n",fd,close(fd));

    return 1;

}
```

```
>> ./a.out 0
STDOUT:close(0) = 0
STDERR:close(0) = -1
```

Why -1 on the second time??

```
>> ./a.out 1
STDERR:close(1) = -1
```

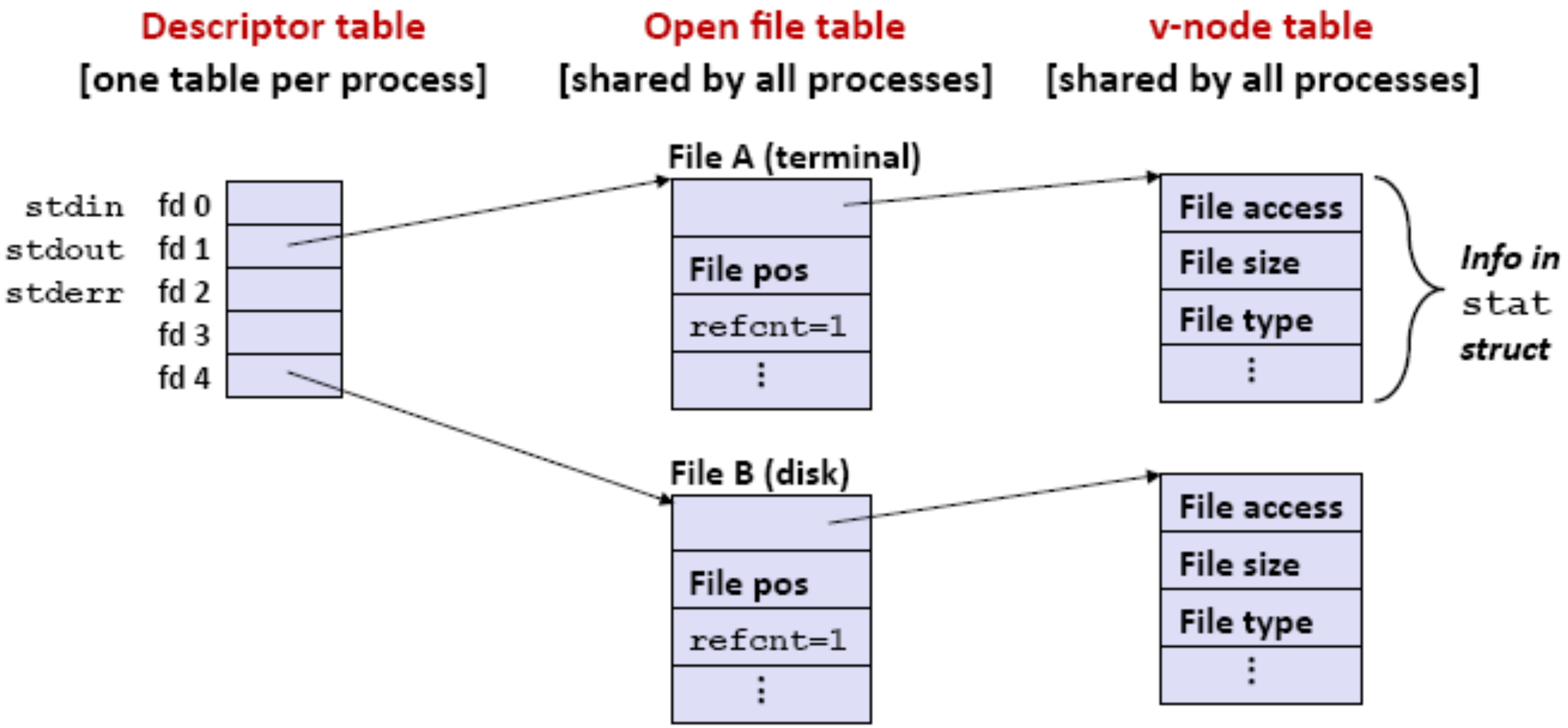
Why no STDOUT output? And why -1 for close return value?

```
>> ./a.out 2
STDOUT:close(2) = 0
```

Why no STDERR output? And why 0 for close return value this time?

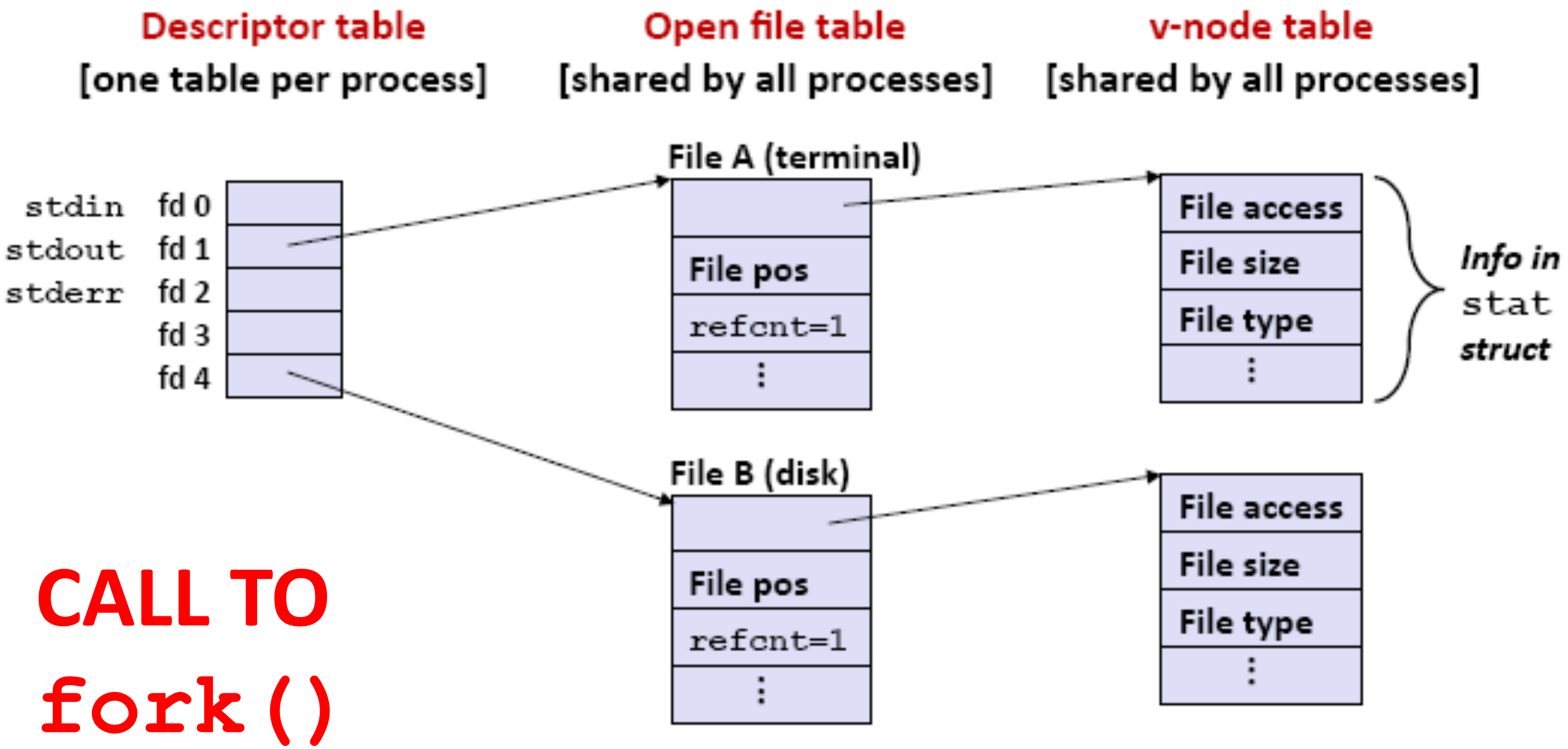
Some Real Stuff

From Lecture:



Some Real Stuff

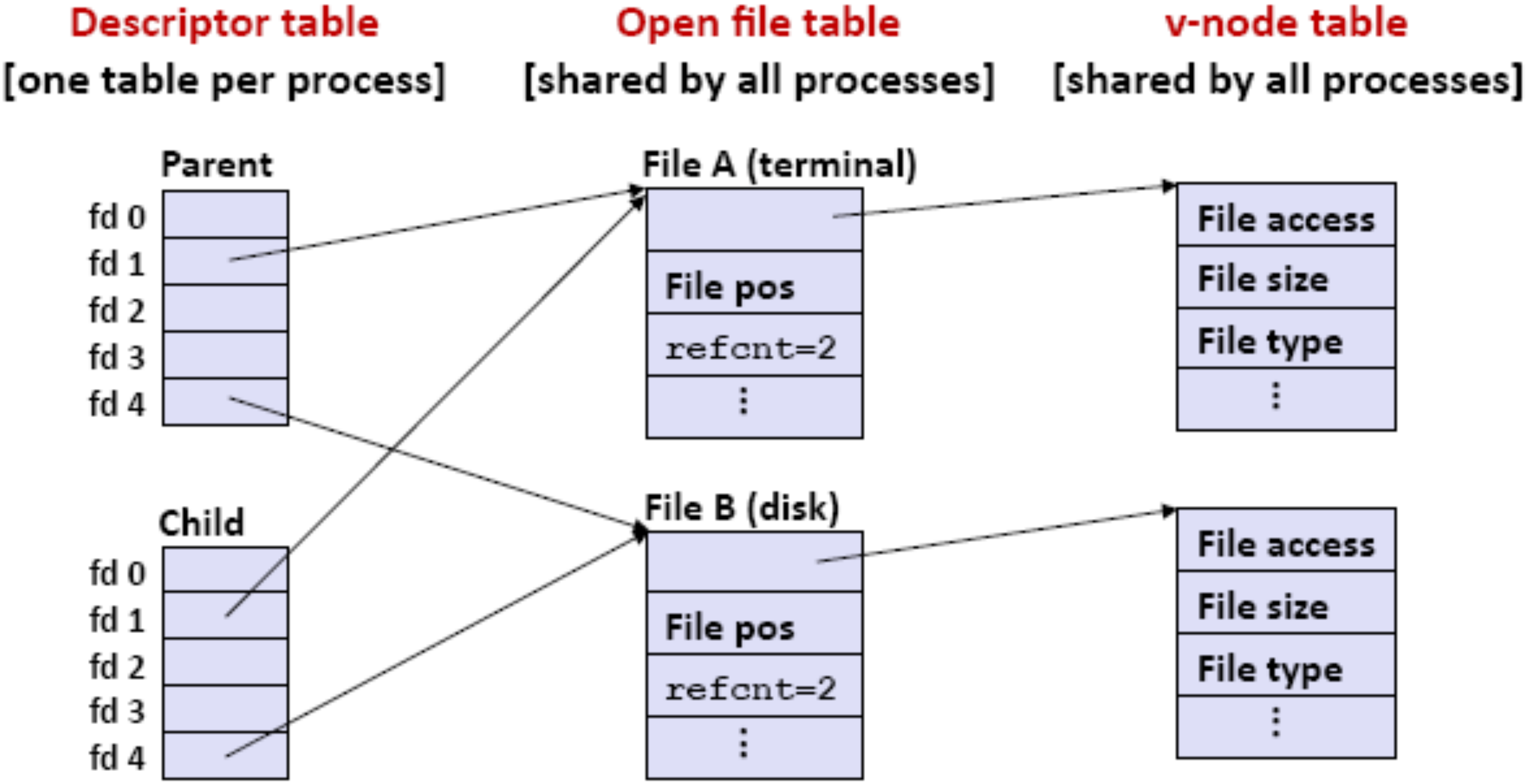
From Lecture:



CALL TO
`fork()`

Some Real Stuff

From Lecture:

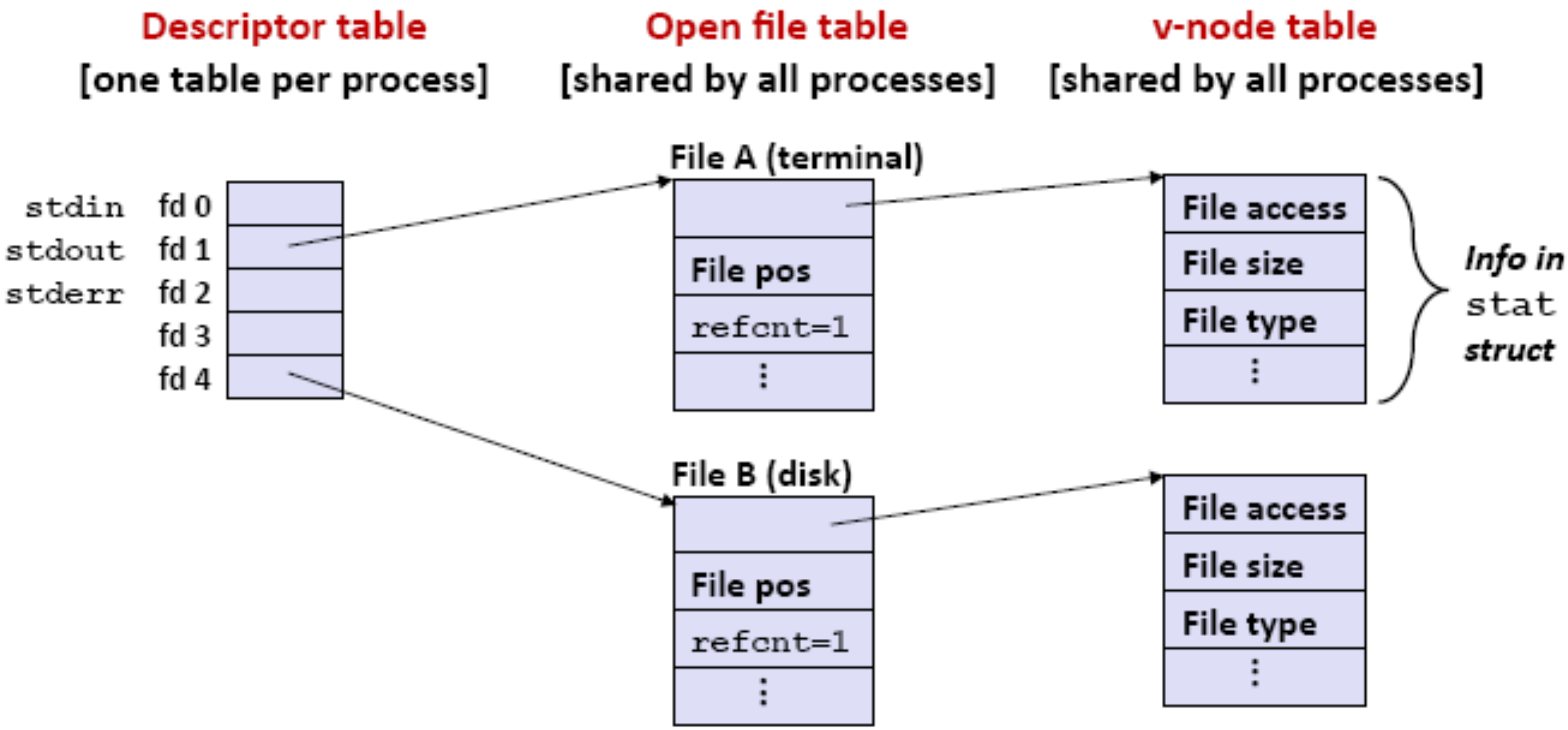


Dup

- What is file redirection?
  - Redirection vs. Pipes
    - Redirection has one “input” of a file, pipes can be between tasks
    - Ex: `cat < filename`
    - Ex: `find . | cat`
  - What is `dup2`?
    - It switches which file a file descriptor is pointing to!
  - What is `dup`?
    - It initializes another file descriptor to point to an already existing file!

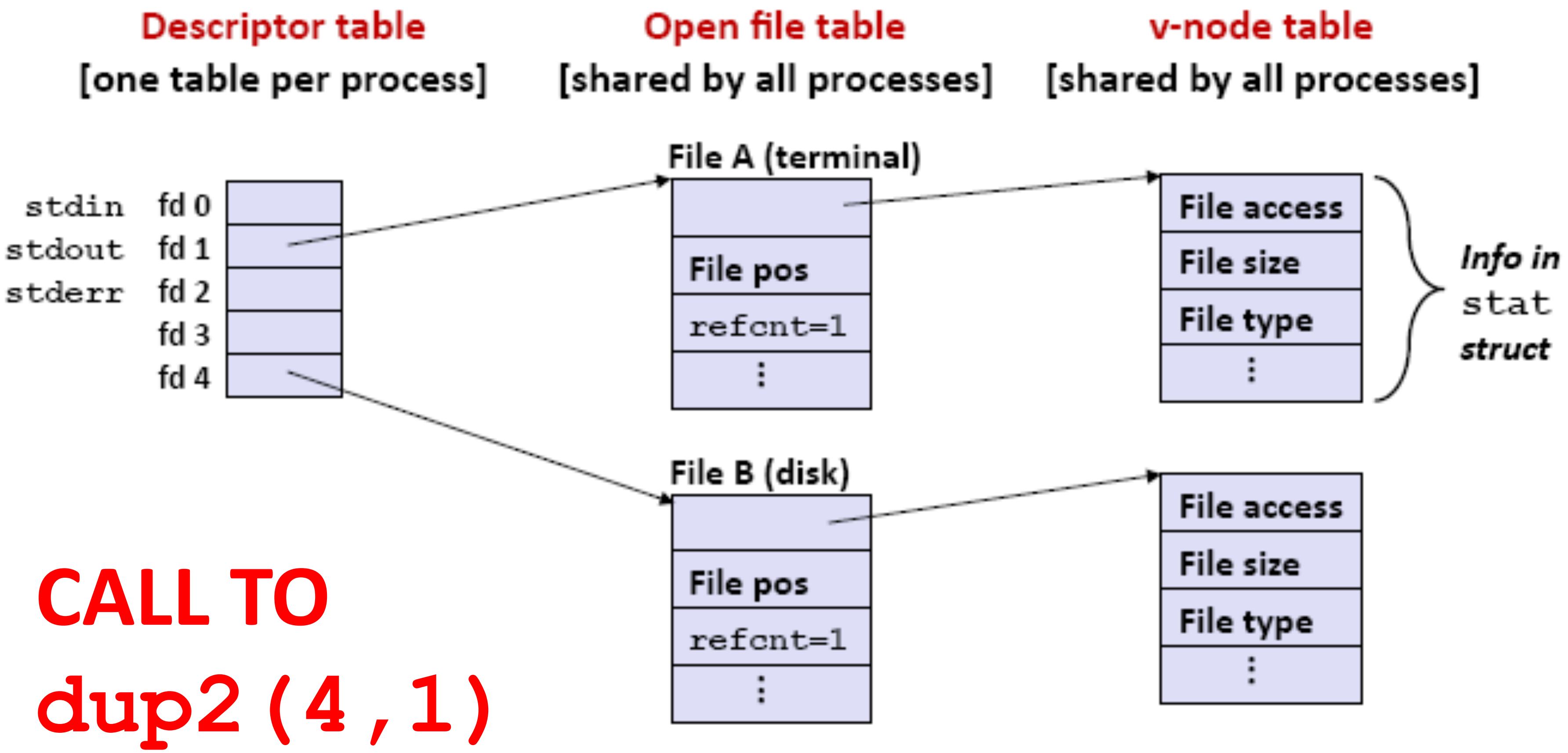
Some Real Stuff

From Lecture:



Some Real Stuff

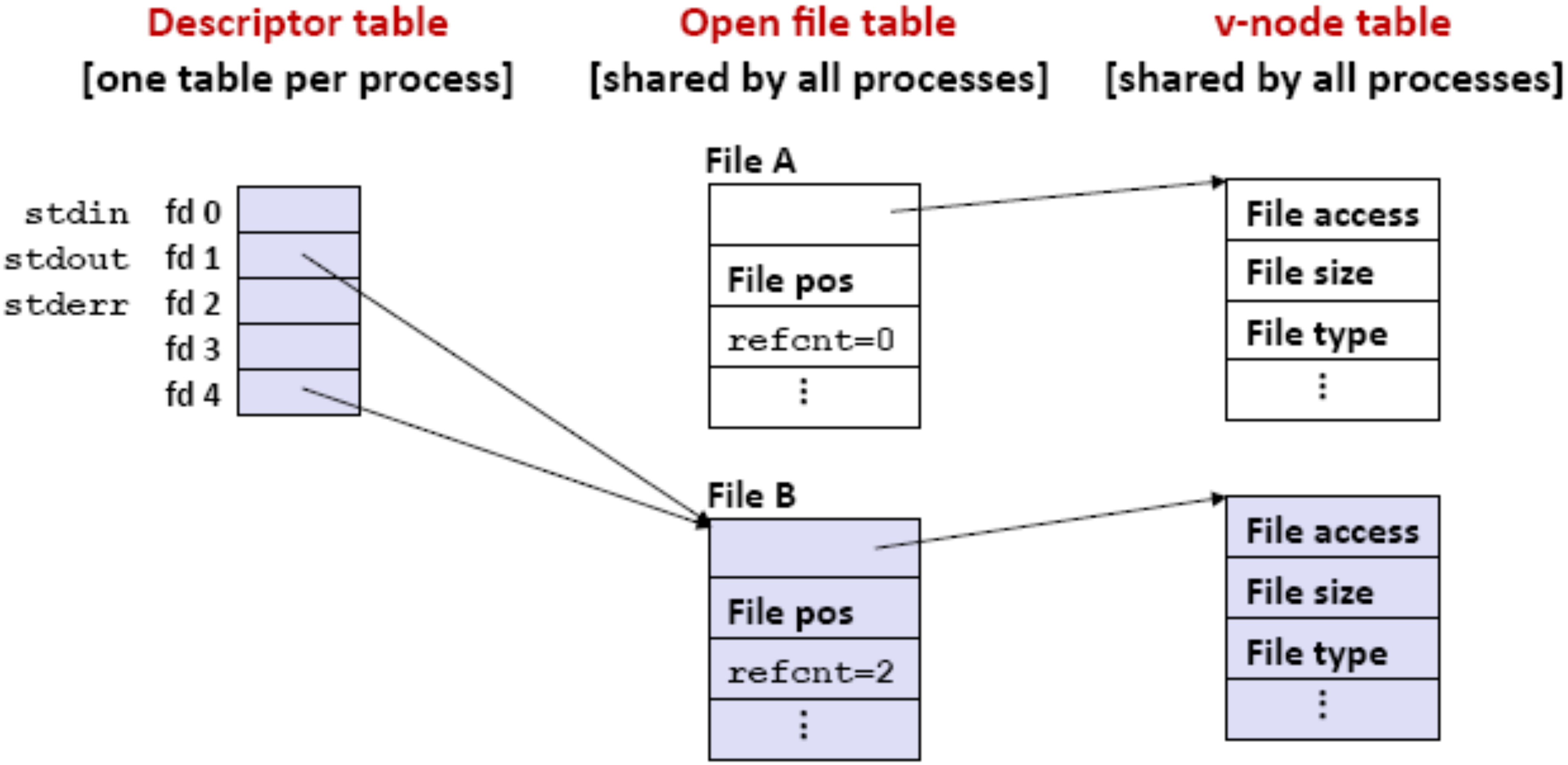
From Lecture:



CALL TO
`dup2(4,1)`

Dup

From Lecture



Dup

- So what is `dup`, and what is `dup2`?

  -
    ```
    int fd1 = open(…);
    int fd2 = dup(fd1);
    ```

  -
    ```
    int fd1 = open(…);
    int fd2; dup2(fd1, fd2);
    ```
- Are these the same??
  - NO!
  - The first is OK, the second uses an uninitialized variable! Remember, it's not
    `dup2(fd1, &fd2);`

File writing example

- Questions
  - What are all of the possible contents of the file after running this code??
  - What is wrong with the style of this code?
  - How would you close these file descriptors?

```c
#include <stdio.h>
#include <unistd.h>

int main()
{
  int fd1, fd2, fd3, parent = 0;
  char *fname = "filename";

  fd1 = open(fname, O_CREAT|O_TRUNC|O_RDWR, S_IRUSR|S_IWUSR);
  write(fd1, "A", 1);

  fd3 = open(fname, O_APPEND|O_WRONLY, 0);
  write(fd3, "BBB", 3);

  if((parent = fork()))
    fd2 = dup(fd1);
  else
    fd2 = fd3;

  write(fd2, "C", 1);
  write(fd3, "D", 1);

  if(parent) waitpid(-1, NULL, 0);

  return 0;
}
```

File writing example

- Answers
  - Possible outputs:
    - ACBBDCD
    - ACBBCDD
  - What is wrong with the style of this code?
    - Didn’t check error codes, didn’t close anything, no comments.
  - How would you close these file descriptors?
    - fd2 sometimes needs `close()`’d, sometimes doesn’t!
    - So: don’t do both `fd2 = fd3`; and `fd2 = dup(f1);`

Practice!!

- Tons of practice available in past exam #2’s
- Very likely to be an I/O question on the next test!