Inter-process communication (IPC)

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Chapter 2 of Tanenbaum's book

Chapter 4 and 5 of OSTEP book

In this lecture, we cover

- Pipes
  - Uni-directional (if used cleanly)
  - ‘ps -aux | more’
- Signals
  - Event notification from one process to another
- Shared Memory
  - Common piece of read/write memory.
  - Needs synchronization for access

Other forms of IPC

- Parent-child
  - Command-line arguments,
  - wait(…), waitpid(…)
  - exit(…)

- Reading/modifying common files
  - Servers commonly use 'pid' file to determine other active servers.

- Semaphores
  - Locking and event signaling mechanism between processes

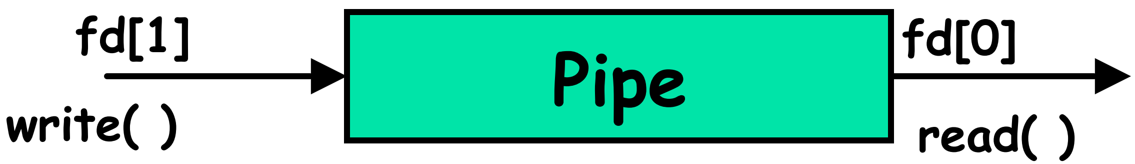
- Sockets
  - Bi-directional
  - Not just across the network, but also between processes.

Pipes

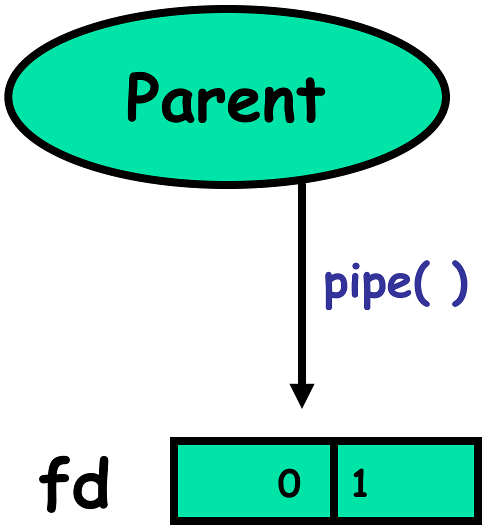
Pipe Abstraction

- Write to one end, read from another

- pipe( )



Parent-child communication using pipe



Here's an example.
https://oscourse.github.io/examples/pipe1.c

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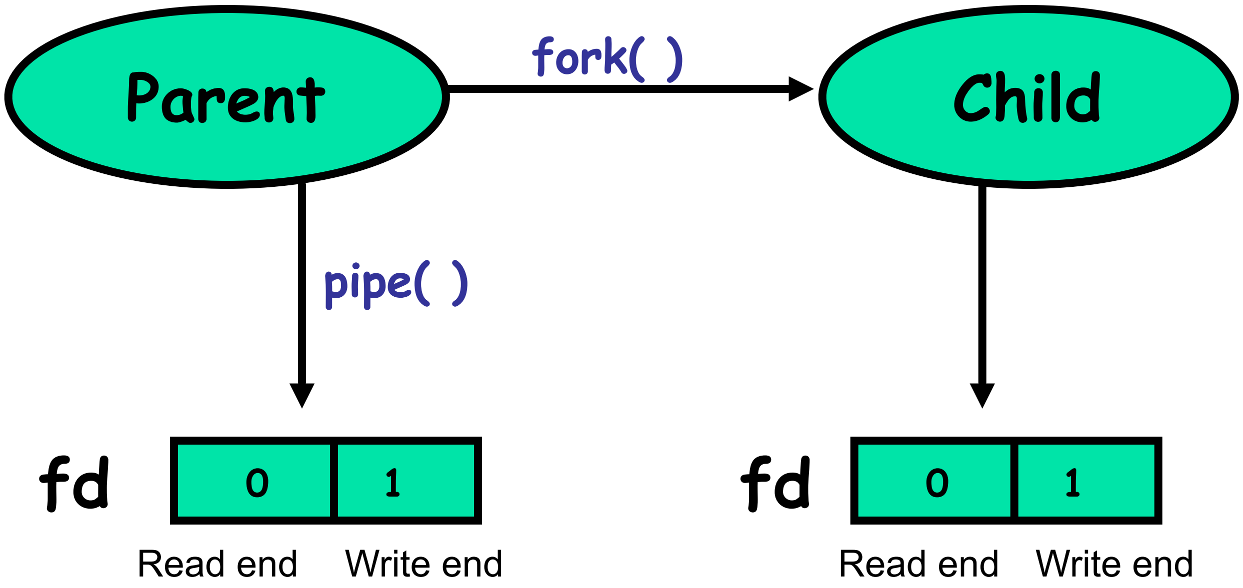

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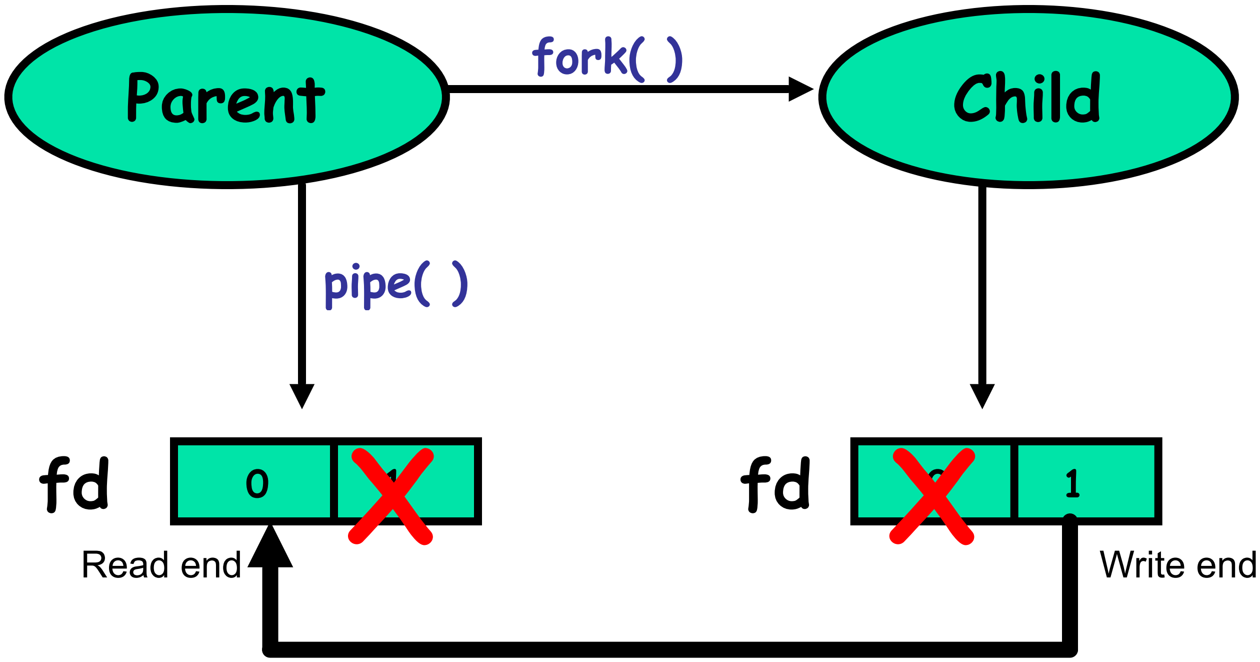

Here's an example.

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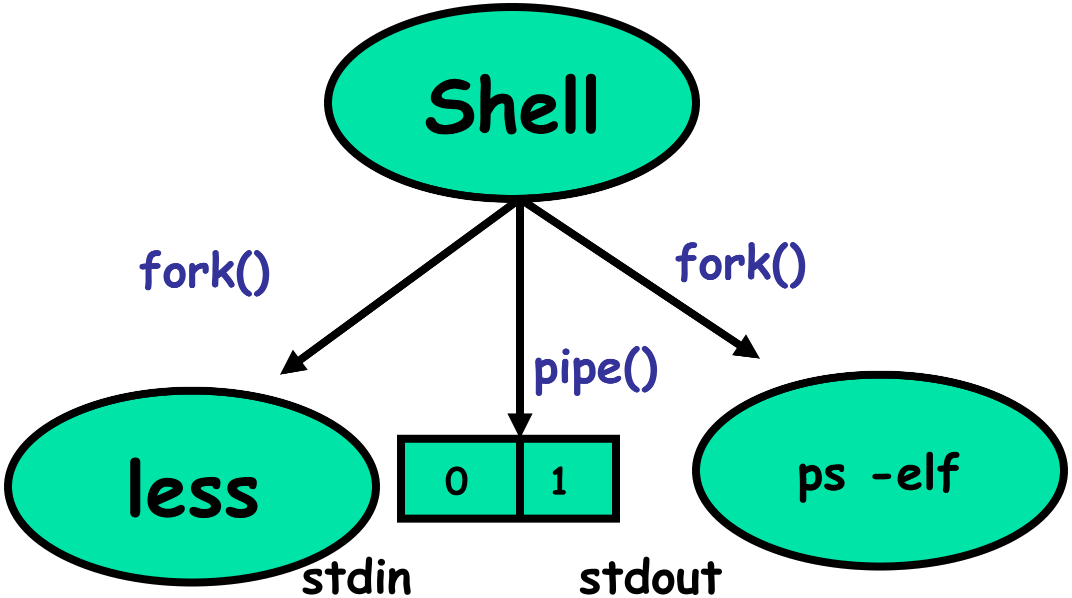
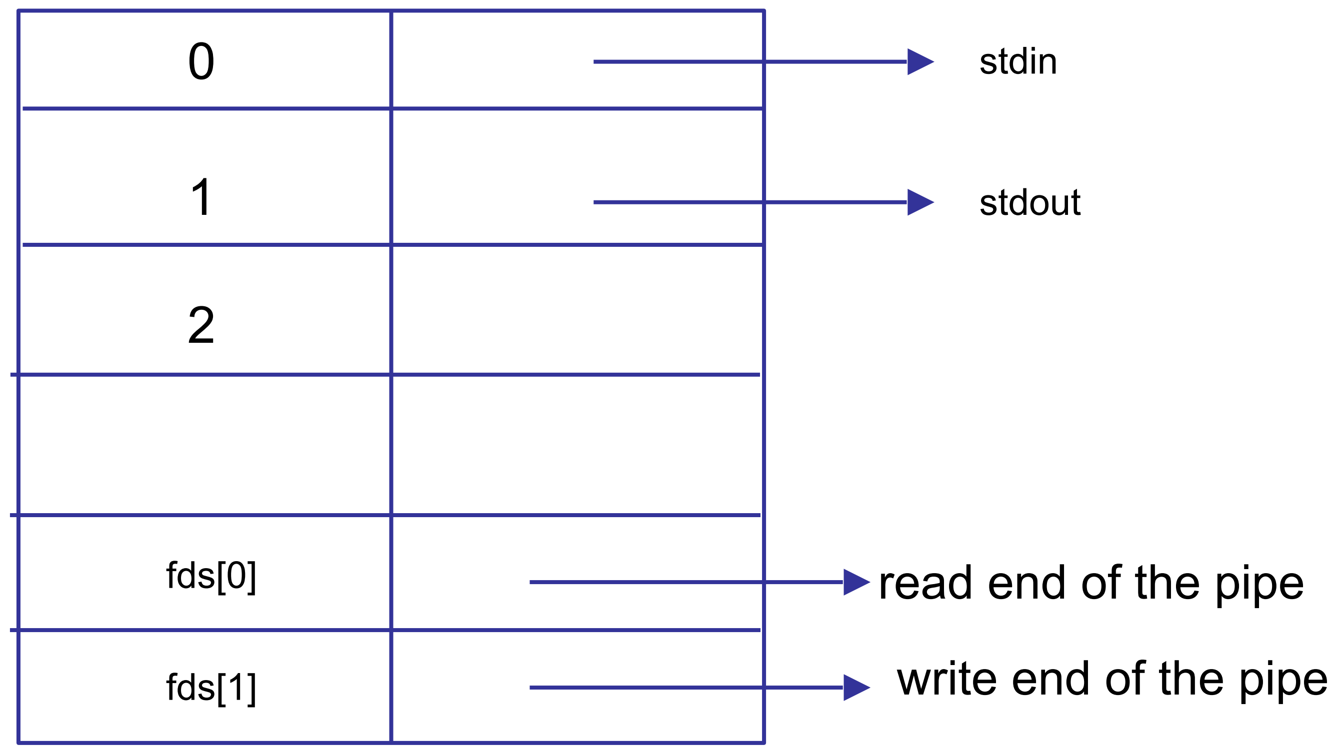
Filters in shell command-line
ps -elf | less



Here's an example.
https://oscourse.github.io/examples/pipe2.c

Understanding fds: File-Descriptor Table

- Each process has a file-descriptor table
- One entry for each open file
- "File" = regular files, stdin, stdout, pipes, I/O devices etc.



Handling long chain of filters — Recursive approach

- create a pipe
- fork a child
- redirect stdin and/or stdout as necessary
- fork another child for next level of recursion with a shorter command
- exec the command for the current level

Pipe provides a byte-stream abstraction

- You can read and write at arbitrary byte boundaries.
  - E.g. Byte lengths sequence written
    - 10, 10, 10, 10
  - byte lengths sequence read
    - 5, 15, 15, 5

- As opposed to **message abstraction,** which provides explicit message boundaries.
  - E.g. network packets

Being careful with read()/write()

- read(fds[0], buf, 6);
  - Doesn't mean read will return with 6 bytes of data!
  - It could be less. Why?

- Some reasons
  - read() could reach end of input stream (EOF).
  - Other endpoint may abruptly close the connection
  - read() could return on a signal.

- So you MUST incorporate error handling with every I/O call (actually with any system call)

Error handling…

- You must
  - First check the return value of every read(…)/write(…) system call.
  - Then either…
  - Wait to read/write more data OR
  - Handle any error conditions

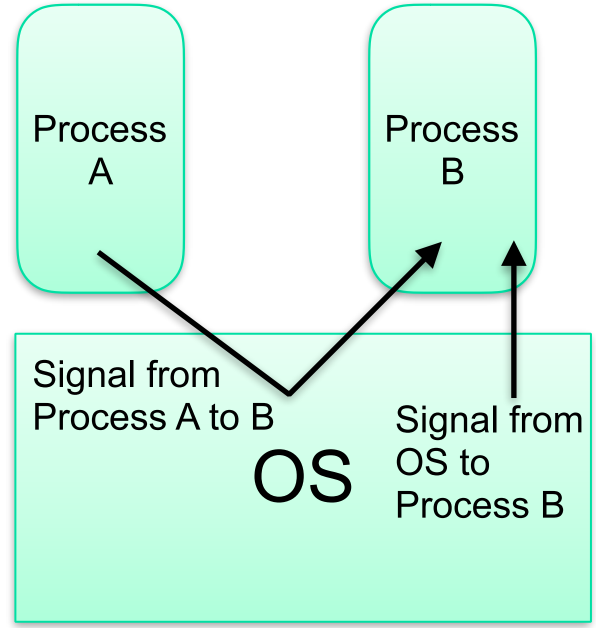
More convinient to write a wrapper function

```
/* Write "n" bytes to a descriptor. */
ssize_t  writen(int fd, const void *vptr, size_t n)
{
        size_t          nleft;
        size_t         nwritten;
        const char      *ptr;

        ptr = vptr;
        nleft = n;
        while (nleft > 0) {
              if ((nwritten = write(fd, ptr, nleft))<=0){
                    if (errno == EINTR)
                       nwritten = 0;  /* call write() again*/
                    else return(-1);  /* error */
              }
              nleft -= nwritten;
              ptr   += nwritten;
        }
        return(n);

}
```

Signals

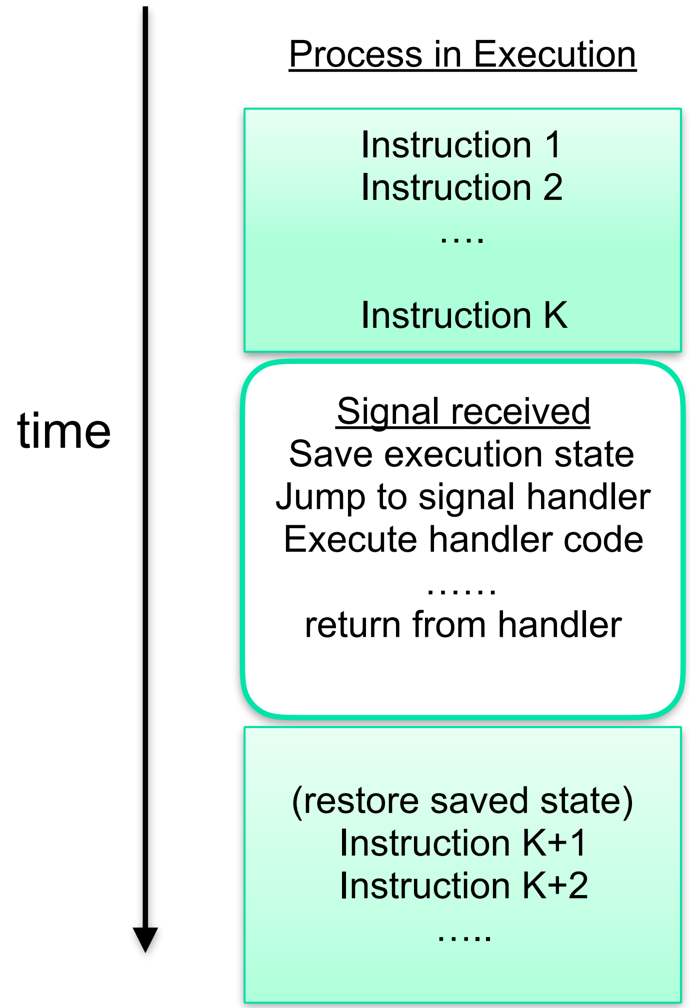
Signals Overview

- Signal is a notification to a process that an event has occurred.
  - Could come from another process or from the OS
- Type of event determined by type of signal
- Try listing all signal types using
  - % kill –l
- Some interesting signals
  - SIGCHLD, SIGKILL, SIGSTOP



Handling Signals

- Signals can be caught – i.e. an action (or handler) can be associated with them
  - SIGKILL and SIGSTOP cannot be caught.
- Actions can be customized using
  - sigaction(…)
  - which associates a signal handler with the signal.
- Default action for most signals is to terminate the process
  - Except SIGCHLD and SIGURG are ignored by default.
- Unwanted signals can be ignored
  - Except SIGKILL or SIGSTOP
- Here's an example.
  - https://oscourse.github.io/examples/signals_ex.c



More on SIGCHLD

- Sent to parent when a child process terminates or stops.
- If act.sa_handler is SIG_IGN
  - SIGCHLD will be ignored (default behavior)
- If act.sa_flags is SA_NOCLDSTOP
  - SIGCHLD won't be generated when children stop
- act.sa_flags is SA_NOCLDWAIT
  - children of the calling process will not be transformed into zombies when they terminate.
- These need to be set in sigaction() before parent calls fork()

Handling child's exit without blocking on wait()

- Parent could install a signal handler for SIGCHLD

- Call **wait(...)/waitpid(...)** inside the signal handler

```
void handle_sigchld(int signo) {
          pid_t pid;
          int stat;

          pid = wait(&stat); //returns without
  blocking

          printf("child %d terminated\n", pid);
}
```

- Here's an example.
  - https://oscourse.github.io/examples/sigchld.c

More information…

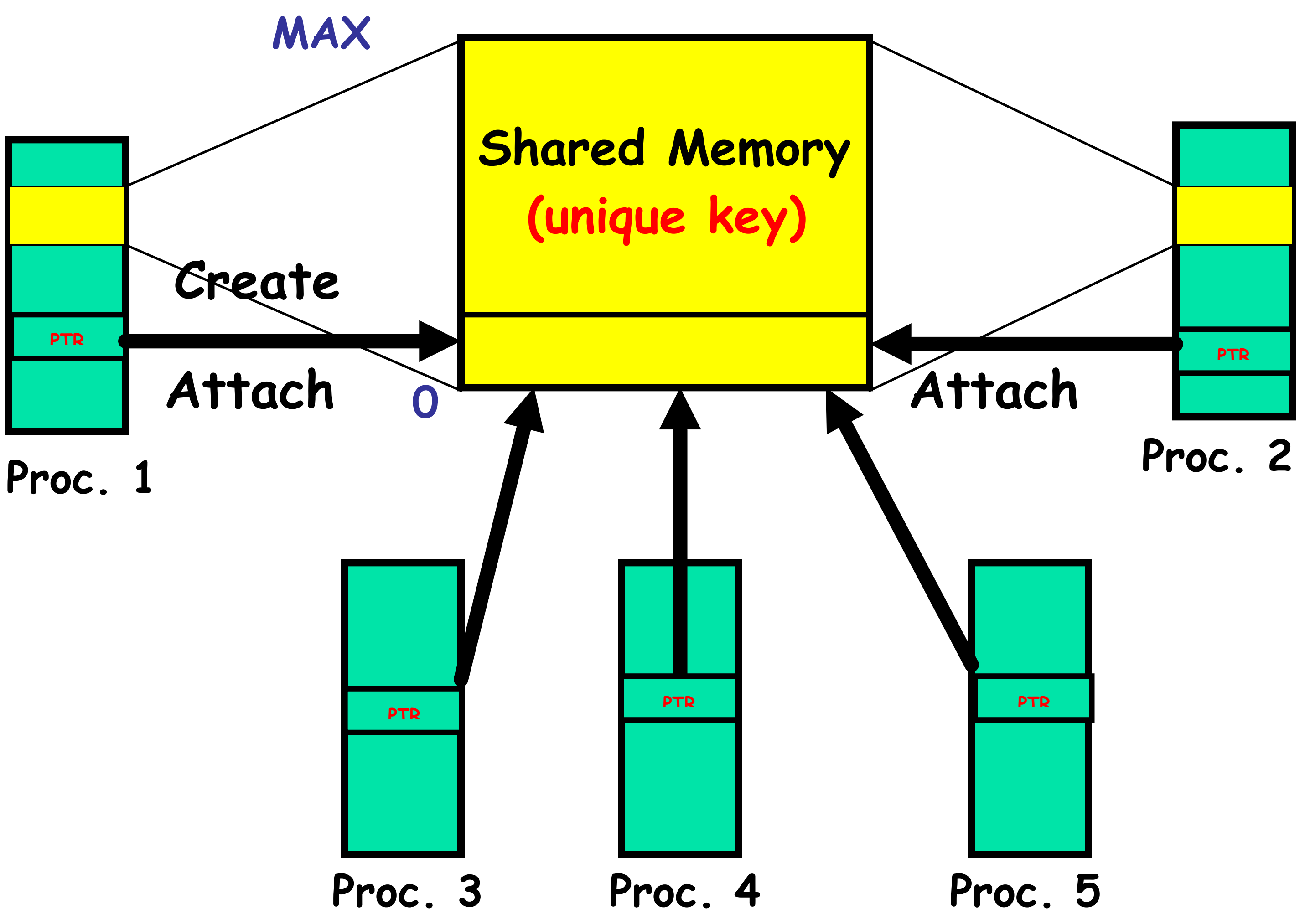
- Check ‘man sigaction(…)’
- Understand what happens when signal is delivered in the middle of a system call?
  - Different OSes have different behavior.
- Google for keywords “Unix Signals”
  - Tons of useful links

Shared Memory, Semaphores

- Man pages : shmget, shmat, shmdt, shmctl, semget, semop, semctl

Shared Memory

Common chunk of read/write memory among processes



Creating Shared Memory

```
int shmget(key_t key, size_t size, int shmflg);
```

```
Example:
 key_t key;
 int shmid;

 key = ftok("<somefile>", 'A');

 shmid = shmget(key, 1024, 0644 | IPC_CREAT);
```

Here's an example.

https://oscourse.github.io/examples/shm_create.c

Attach and Detach Shared Memory

```
void *shmat(int shmid, void *shmaddr, int shmflg);
int shmdt(void *shmaddr);
```

Example:

```
    key_t key;
    int shmid;
    char *data;
    key = ftok("<somefile>", 'A');
    shmid = shmget(key, 1024, 0644);
    data = shmat(shmid, (void *)0, 0);
    // read or write something to data here.
    shmdt(data);
```

Here's an example.

https://oscourse.github.io/examples/shm_attach.c

Deleting Shared Memory

```
int shmctl(int shmid, int cmd, struct shmid_ds *buf);
```

```
shmctl(shmid, IPC_RMID, NULL);
```

Example:

https://oscourse.github.io/examples/shm_delete.c

Command-line IPC control

- ipcs
  - Lists all IPC objects owned by the user
- ipcrm
  - Removes specific IPC object

References

- Unix man pages
- “Advanced Programming in Unix Environment” by Richard Stevens
  - http://www.kohala.com/start/apue.html