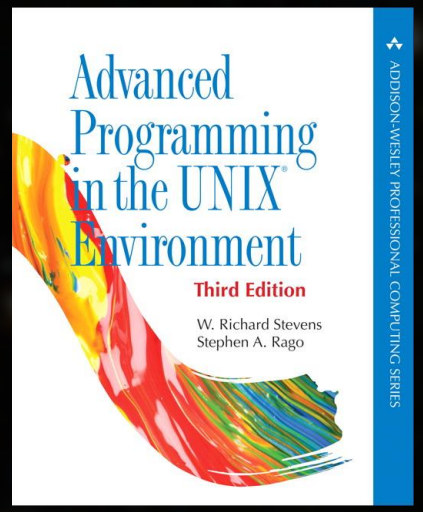
The Prestige (2006), Christopher Nolan

Lab09 and Lec09 → Nov. 24



Chapter 15: Inter-Process Communication

Multiprocessing

aka multiprogramming

Single Processor ~~Multiprocessor~~

Inter-Process Communication (IPC)

Parent ↔ Child

Any Process ↔ Any Other Process

Single Processor ~~Multiprocessor~~

Signals

Software Shocks: Urgent Communications

I'll send you a signal, if you don't do anything about it, I'll kill you!

IPC

Normal Communication

Can you do this for me? Yes, here is it. Anything else?

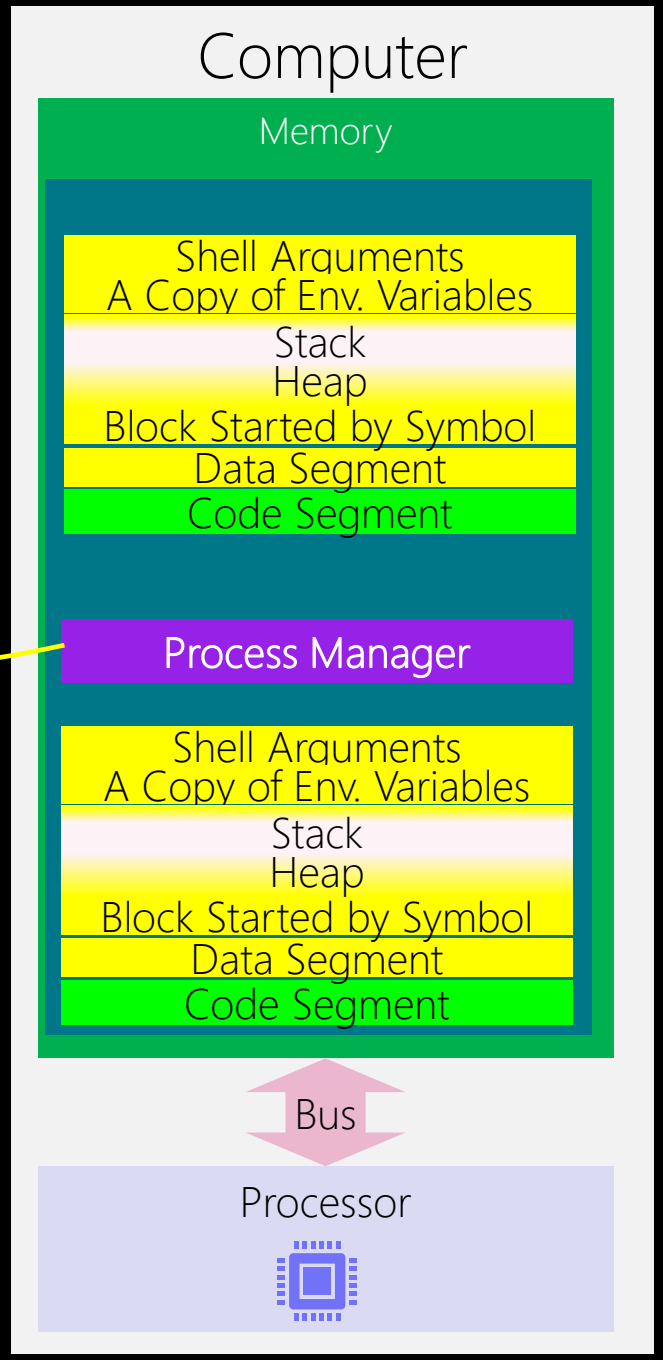
```
int child_pid = fork();
if(child_pid == -1){
        perror("impossible to have a child!");
        exit(1);
}
if(child_pid >= 0){//(child_pid != -1)
        if(child_pid > 0)
                printf("I am the parent, pid=%d\n", getpid());
        else{//(child_pid == 0)
                printf("I am the child, pid=%d\n", getpid());
                printf("My parent's pid=%d\n", getppid());
                //Assign child's tasks here
                exit(0);
        }
}
//Assign parent tasks here
```

Child's Tasks

Parent's Tasks

Wait for the child

```
 exit(0);
```



Child

Parent

Any change by the child is in the child copy

Any change by the parent is in the parent copy

Parent ← Child

Passing the Results of Tasks

Passing Information

But the memory space of child is totally distinct from each other!

Parent ← Child

Passing the Results of Tasks

Passing Information

A) Share a Single File/Device (Lab09)
B) Share Part of Memory

Parent

Parent: (fd) → Child

13

```
int child_pid = fork();
if(child_pid == -1){
        perror("impossible to have a child!");
        exit(1);
}
if(child_pid >= 0){//(child_pid != -1)
        if(child_pid > 0)
                printf("I am the parent, pid=%d\n", getpid());
        else{//(child_pid == 0)
                printf("I am the child, pid=%d\n", getpid());
                printf("My parent is pid=%d\n", getppid());
        }
}
```

```
//Assign parent tasks here
int *child_exit;
wait(child_exit);
```

Parent ← fd

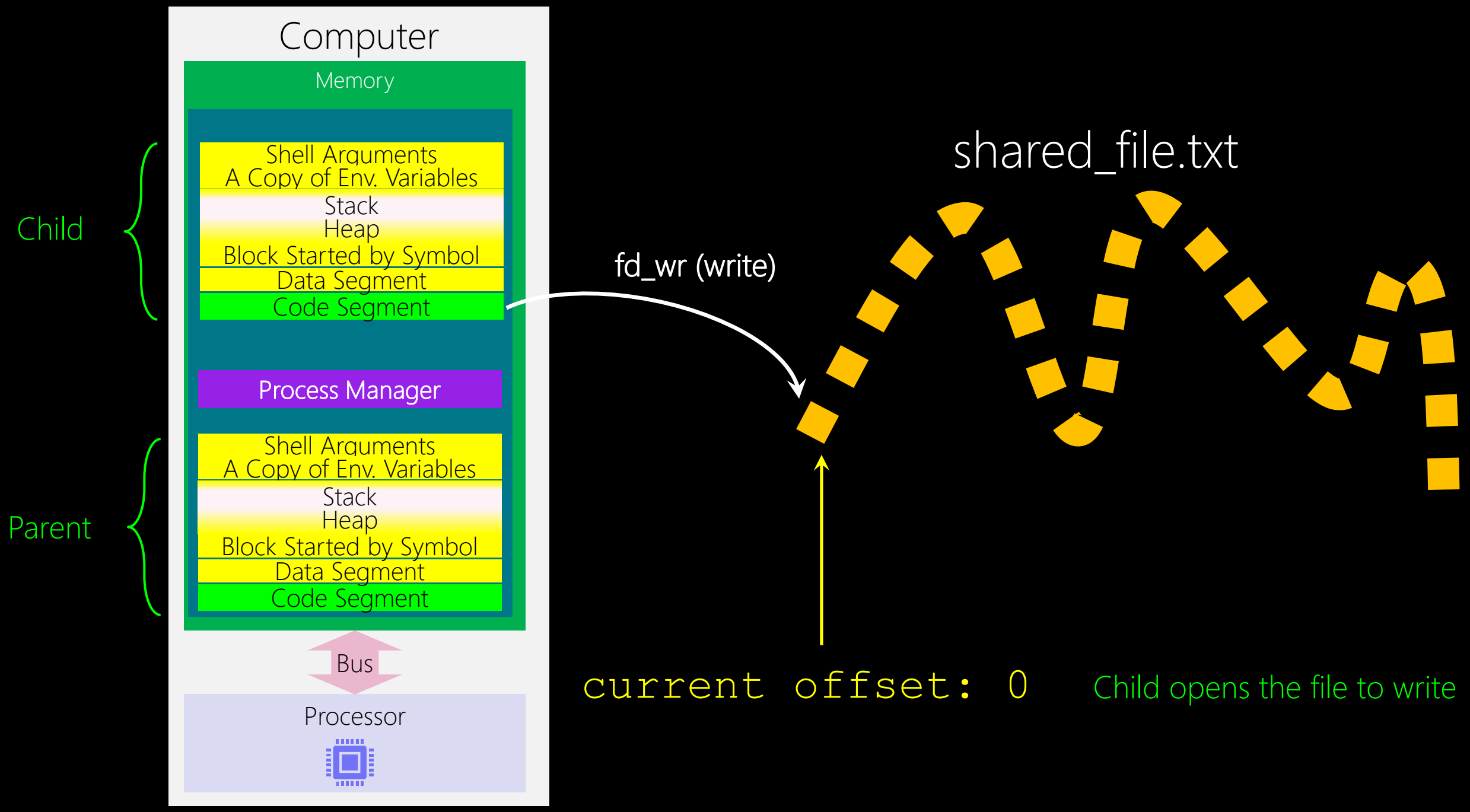
Child

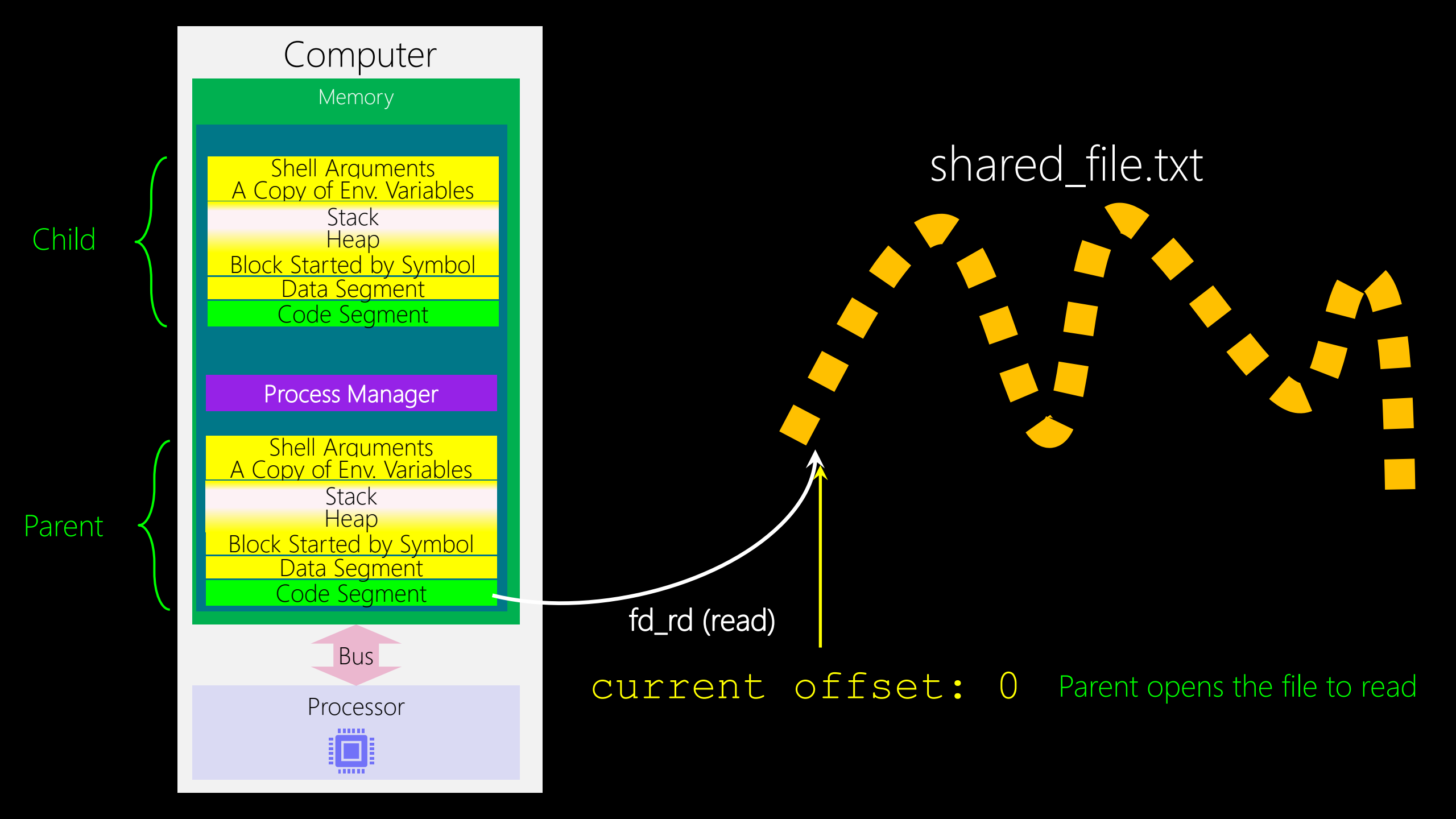
Parent: (fd) → Child

0

```
int child_pid = fork();
if(child_pid == -1){
        perror("impossible to have a child!");
        exit(1);
}
if(child_pid >= 0){//(child_pid != -1)
        if(child_pid > 0)
                printf("I am the parent, pid=%d\n", getpid());
        else{//(child_pid == 0)
                printf("I am the child, pid=%d\n", getpid());
                printf("My parent is pid=%d\n", getppid());
                exit(0);
        }
}
```

Child → fd


Computer
Memory
Child
Shell Arguments
A Copy of Env. Variables
Stack
Heap
Block Started by Symbol
Data Segment
Code Segment
Process Manager
Parent
Shell Arguments
A Copy of Env. Variables
Stack
Heap
Block Started by Symbol
Data Segment
Code Segment
Bus
Processor
fd_wr (write)
shared_file.txt
current offset: 0
Child opens the file to write


Computer
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Data Segment
Code Segment
Process Manager
Parent
Shell Arguments
A Copy of Env. Variables
Stack
Heap
Block Started by Symbol
Data Segment
Code Segment
Bus
Processor
shared_file.txt
fd_rd (read)
current offset: 0
Parent opens the file to read

Example I

$$Y = X^2 + 5$$

1) Parent to Child: please do the X to the power of 2
2) Parent: I do the addition with 5

```
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";
```

1) Parent define the filename to be shared by the child

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";

        int X = atoi(argv[1]);
```

2) Parent receives the number by the user in the argv[1]

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";

        int X = atoi(argv[1]);

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
```

3) Parent create the child

Child's Tasks

```c
        }
}
int child_exit;
wait(&child_exit);//wait for the child to X^2
```

4) Waits for the child to finish

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";

        int X = atoi(argv[1]);

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
```

Child's Tasks

```c
        }
    }
    int child_exit;
    wait(&child_exit);//wait for the child to X^2
```

```c
int fd = open(filename_2_share, O_RDONLY);
printf("parent opens the file with fd: %d\n", fd);
int Y[1];
int byte_read = read(fd, Y, sizeof(Y));
printf("parent read %d bytes\n", byte_read);
close(fd);
```

5) When child is done, parent, opens the file and reads the child's result

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";

        int X = atoi(argv[1]);

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
```

Child's Tasks

```c
        }
    }
    int child_exit;
    wait(&child_exit);//wait for the child to X^2

    int fd = open(filename_2_share, O_RDONLY);
    printf("parent opens the file with fd: %d\n", fd);
    int Y[1];
    int byte_read = read(fd, Y, sizeof(Y));
    printf("parent read %d bytes\n", byte_read);
    close(fd);

    int result = Y[0] + 5;
    printf("here is the result: %d\n", result);
    exit(0);
}
```

6) Parent, adds child's result with 5 and prints out the final result

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";

        int X = atoi(argv[1]);

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
```

```c
printf("I am the child, pid=%d\n", getpid());

int Y[1];
Y[0] = X * X;
```

```c
        }
        int child_exit;
        wait(&child_exit);//wait for the child to X^2

        int fd = open(filename_2_share, O_RDONLY);
        printf("parent opens the file with fd: %d\n", fd);
        int Y[1];
        int byte_read = read(fd, Y, sizeof(Y));
        printf("parent read %d bytes\n", byte_read);
        close(fd);

        int result = Y[0] + 5;
        printf("here is the result: %d\n", result);
        exit(0);
}
```

1) Child, brings the input (X) to the power of 2

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";

        int X = atoi(argv[1]);

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
```

```c
printf("I am the child, pid=%d\n", getpid());

int Y[1];
Y[0] = X * X;
int fd = open(filename_2_share, O_WRONLY | O_CREAT, S_IRUSR | S_IWUSR);
printf("child opens the file with fd: %d\n", fd);
```

```c
        }
        int child_exit;
        wait(&child_exit);//wait for the child to X^2

        int fd = open(filename_2_share, O_RDONLY);
        printf("parent opens the file with fd: %d\n", fd);
        int Y[1];
        int byte_read = read(fd, Y, sizeof(Y));
        printf("parent read %d bytes\n", byte_read);
        close(fd);

        int result = Y[0] + 5;
        printf("here is the result: %d\n", result);
        exit(0);
}
```

2) Child, opens the file to write the result

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";

        int X = atoi(argv[1]);

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
```

```c
printf("I am the child, pid=%d\n", getpid());

int Y[1];
Y[0] = X * X;
int fd = open(filename_2_share, O_WRONLY | O_CREAT, S_IRUSR | S_IWUSR);
printf("child opens the file with fd: %d\n", fd);
int byte_write = write(fd, Y, sizeof(Y));
printf("child write %d bytes.\n", byte_write);
close(fd);
```

```c
        }
        int child_exit;
        wait(&child_exit);//wait for the child to X^2

        int fd = open(filename_2_share, O_RDONLY);
        printf("parent opens the file with fd: %d\n", fd);
        int Y[1];
        int byte_read = read(fd, Y, sizeof(Y));
        printf("parent read %d bytes\n", byte_read);
        close(fd);

        int result = Y[0] + 5;
        printf("here is the result: %d\n", result);
        exit(0);
}
```

3) Child, writes the result to the file

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        char filename_2_share[] = "child_results.txt";

        int X = atoi(argv[1]);

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
```

```c
printf("I am the child, pid=%d\n", getpid());

int Y[1];
Y[0] = X * X;
int fd = open(filename_2_share, O_WRONLY | O_CREAT, S_IRUSR | S_IWUSR);
printf("child opens the file with fd: %d\n", fd);
int byte_write = write(fd, Y, sizeof(Y));
printf("child write %d bytes.\n", byte_write);
close(fd);

printf("I brough the number to the power 2 and wrote the result: %d.\n", Y[0]);
exit(0);
```

```c
        }
        int child_exit;
        wait(&child_exit);//wait for the child to X^2

        int fd = open(filename_2_share, O_RDONLY);
        printf("parent opens the file with fd: %d\n", fd);
        int Y[1];
        int byte_read = read(fd, Y, sizeof(Y));
        printf("parent read %d bytes\n", byte_read);
        close(fd);

        int result = Y[0] + 5;
        printf("here is the result: %d\n", result);
        exit(0);
}
```

4) Child is done. Exit successfully.

```
hfani@alpha:~$ cc parent_child_file.c -o parent_child_file
hfani@alpha:~$ ./parent_child_file 4
I am a lonely process, pid=27601
I am the parent, pid=27601
I am the child, pid=27602
child opens the file with fd: 3
child write 4 bytes.
I brough the number to the power 2 and wrote the result: 16.
parent opens the file with fd: 3
parent read 4 bytes
here is the result: 21
```

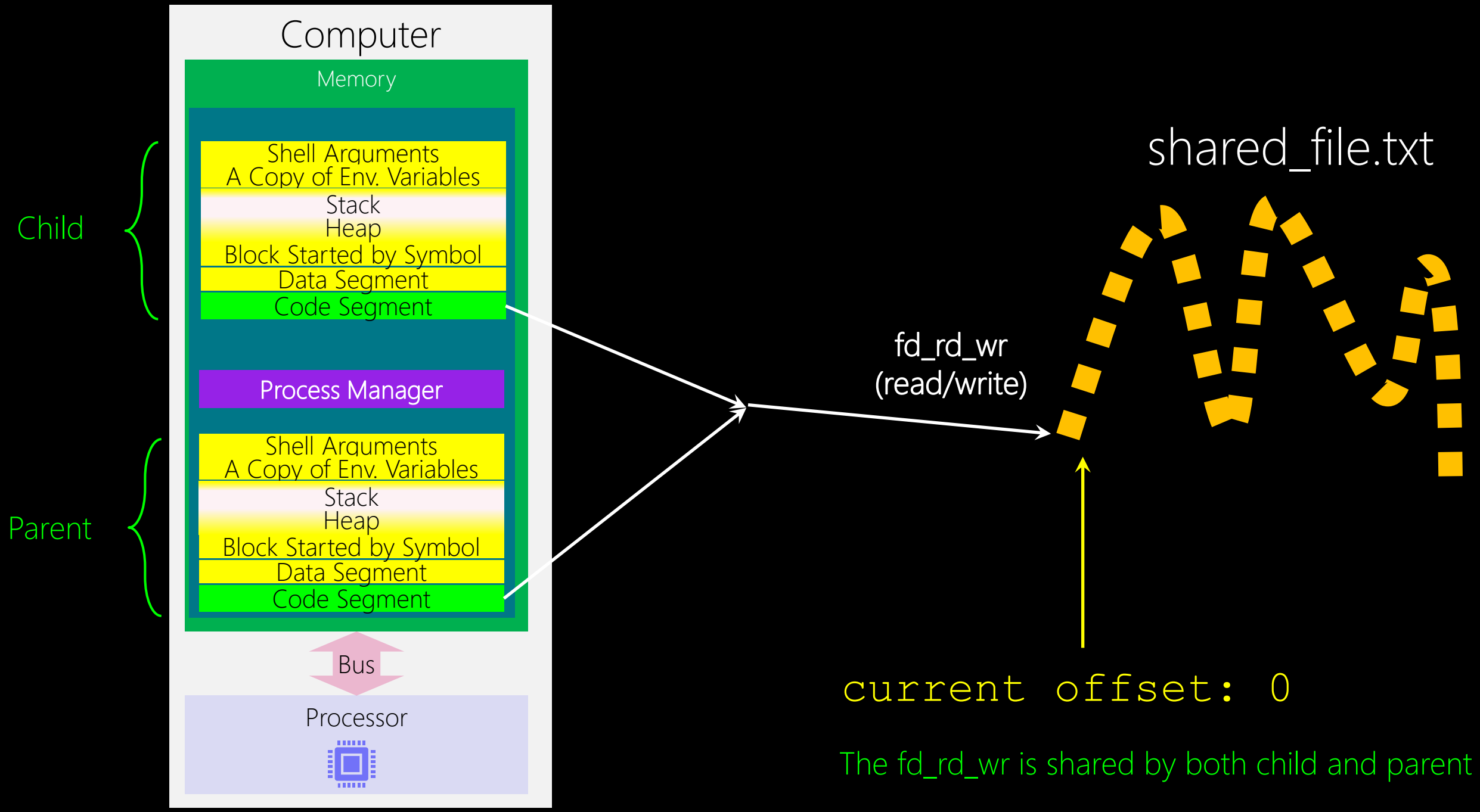
```
hfani@alpha:~$ vi child_results.txt
hfani@alpha:~$ hexdump child_results.txt
```

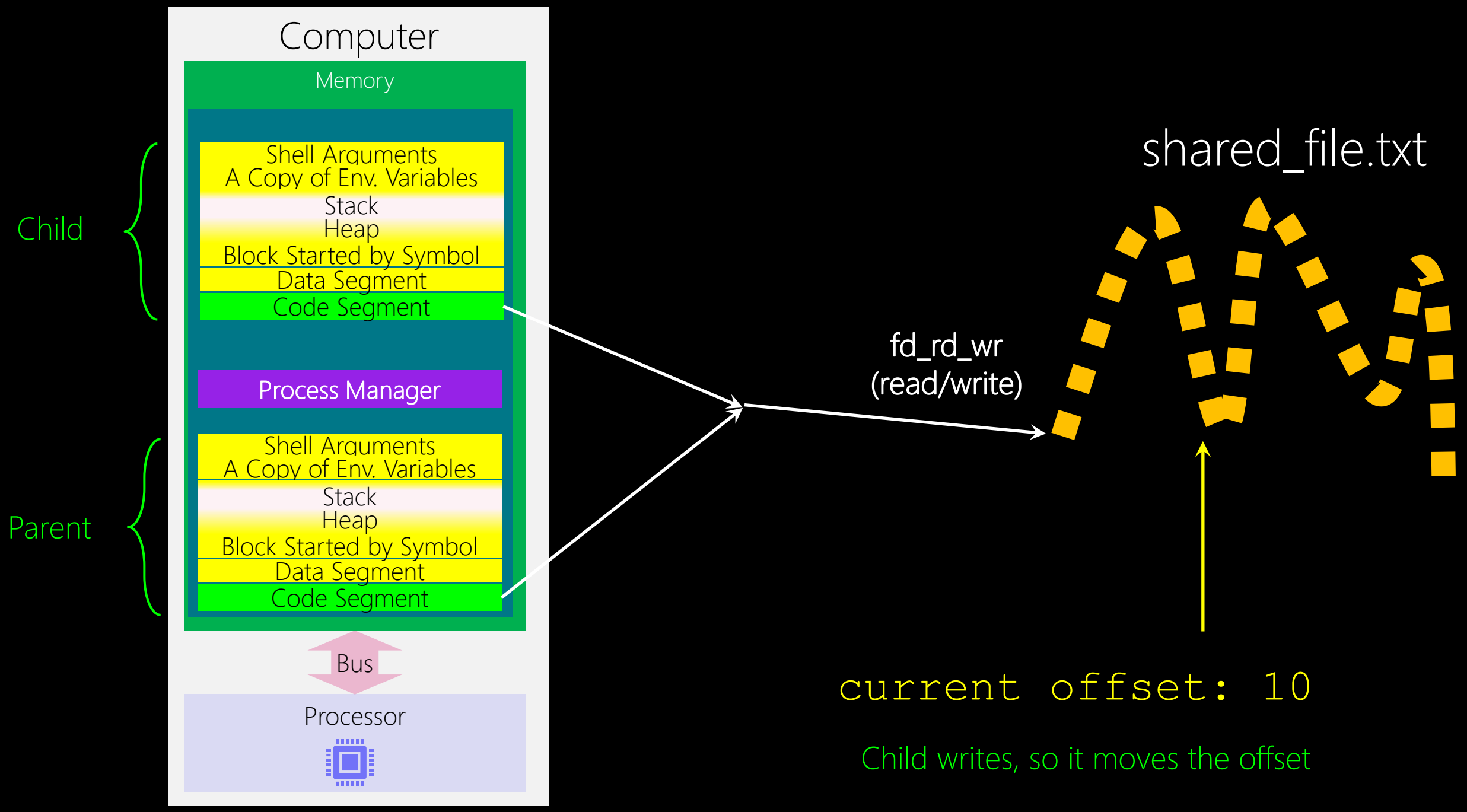
Which one is the correct command to see what child has written?

Example II

Parent opens the file for the Read/Write

Just pass the fd for writing to the child


Computer
Memory
Child
Shell Arguments
A Copy of Env. Variables
Stack
Heap
Block Started by Symbol
Data Segment
Code Segment
Process Manager
Parent
Shell Arguments
A Copy of Env. Variables
Stack
Heap
Block Started by Symbol
Data Segment
Code Segment
Bus
Processor
fd_rd_wr
(read/write)
shared_file.txt
current offset: 0
The fd_rd_wr is shared by both child and parent


Computer
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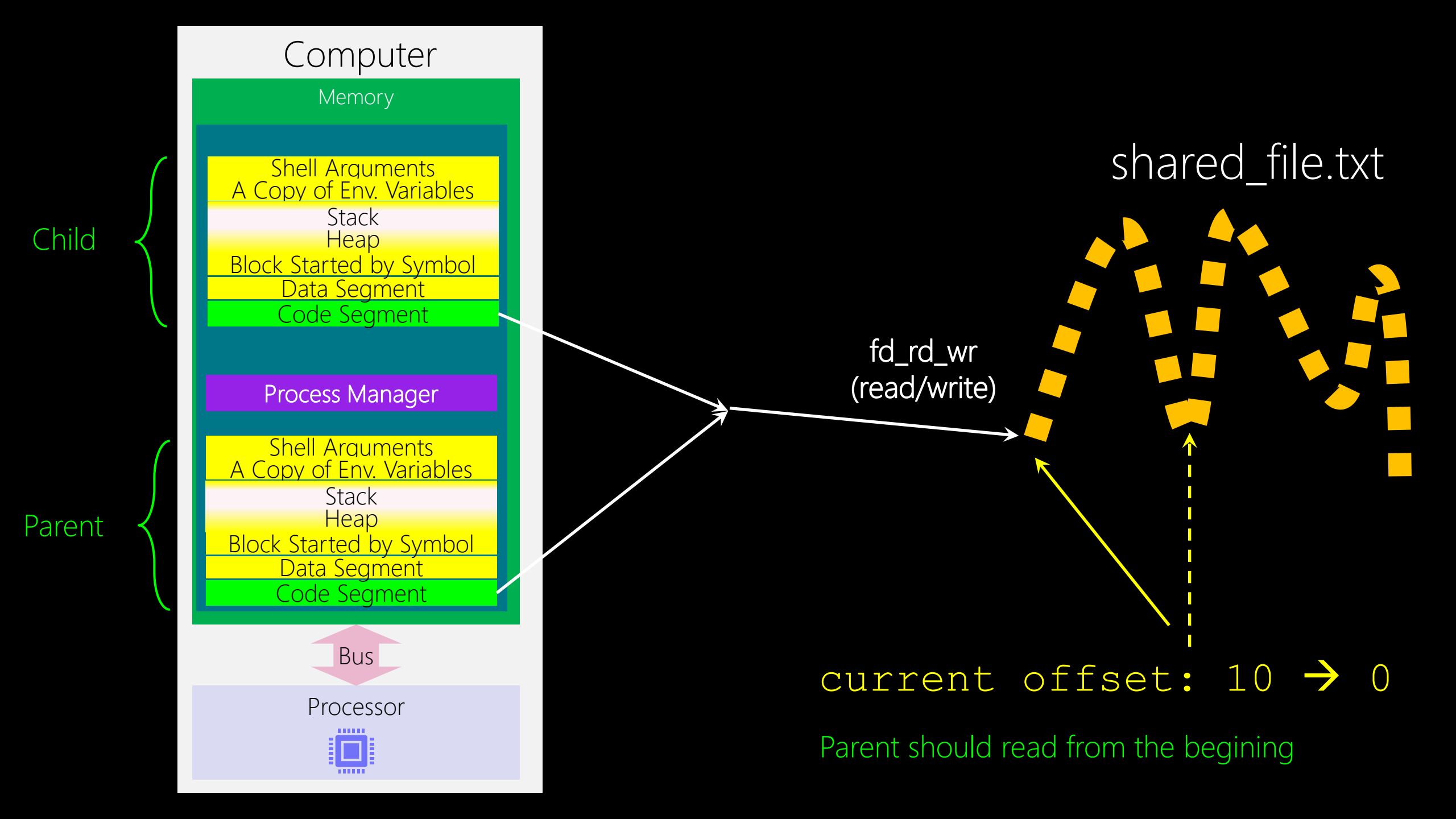
Data Segment
Code Segment
Process Manager
Parent
Shell Arguments
A Copy of Env. Variables
Stack
Heap
Block Started by Symbol
Data Segment
Code Segment
Bus
Processor
fd_rd_wr
(read/write)
shared_file.txt
current offset: 10
Child writes, so it moves the offset


Computer
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Child
Shell Arguments
A Copy of Env. Variables
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Heap
Block Started by Symbol
Data Segment
Code Segment
Process Manager
Parent
Shell Arguments
A Copy of Env. Variables
Stack
Heap
Block Started by Symbol
Data Segment
Code Segment
Bus
Processor
fd_rd_wr
(read/write)
shared_file.txt
current offset: 10 → 0
Parent should read from the begining

```
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        int fd = open("child_results_fd.txt", O_RDWR | O_CREAT, S_IRUSR | S_IWUSR);
        printf("parent opens the file for R/W with fd: %d\n", fd);
        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        int Y[1];
                        Y[0] = X * X;
                        int byte_write = write(fd, Y, sizeof(Y));
                        printf("child write %d bytes.\n", byte_write);
                        exit(0);
                }
        }
        int child_exit;
        wait(&child_exit);//wait for the child to X^2
        int Y[1];
        lseek(fd, 0, SEEK_SET);
        int byte_read = read(fd, Y, sizeof(Y));
        printf("parent read %d bytes\n", byte_read);
        exit(0);
}
```

```c
int main(int argc, char *argv[]){
        printf("I am a lonely process, pid=%d\n", getpid());
        int fd = open("child_results_fd.txt", O_RDWR | O_CREAT, S_IRUSR | S_IWUSR);
        printf("parent opens the file for R/W with fd: %d\n", fd);

        int X = atoi(argv[1]);

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("I am the child, pid=%d\n", getpid());

                        int Y[1];
                        Y[0] = X * X;
                        int byte_write = write(fd, Y, sizeof(Y));
                        printf("child write %d bytes.\n", byte_write);

                        printf("I brough the number to the power 2 and wrote the result: %d.\n", Y[0]);
                        exit(0);
                }
        }
        int child_exit;
        wait(&child_exit);//wait for the child to X^2

        int Y[1];
        lseek(fd, 0, SEEK_SET);
        int byte_read = read(fd, Y, sizeof(Y));
        printf("parent read %d bytes\n", byte_read);
        close(fd);

        int result = Y[0] + 5;
        printf("here is the result: %d\n", result);
        exit(0);
}
```

Question:
When child exits, shouldn't kernel close all open file descriptors?!
Then, the parent is using a closed file descriptor! This program fails, does not it?

Continuous Communication → Conversation

In previous examples, there exist a single communication.

Example III

$Y = X^2 + 5$ for any X by user until X=-1

1) Child: I do X to the power of 2
2) Parent: I do the addition with 5
3) Parent & Child: We do this forever (until the user put -1)

Example III: Solution A

```
void main(void){
        while(1){
                Example II's Code with some minor change
        }
}
```

```
hfani@charlie:~$ vi parent_child_conv_a.c
int main(int argc, char *argv[]){
        while(1){
        int fd = open("child_results_conv.txt", O_RDWR | O_CREAT, S_IRUSR | S_IWUSR);
        printf("parent opens the file for R/W with fd: %d\n", fd);
        //int X = atoi(argv[1]);
        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("I am the child, pid=%d and given the fd %d\n", getpid(), fd);

                        int Y[1] = {-1};
                        int X;
                        printf("enter a positive number:\n");
                        scanf("%d", &X);
                        if(X == -1){
                                printf("child: the user wants to end the program.\n");
                                write(fd, Y, sizeof(Y));
                                exit(0);
                        }
                        Y[0] = X * X;
                        int byte_write = write(fd, Y, sizeof(Y));
                        printf("child write %d bytes.\n", byte_write);

                        printf("I brought the number to the power 2 and wrote the result: %d.\n", Y[0]);
                        exit(0);
                }
        }
        int child_exit;
        wait(&child_exit);//wait for the child to X^2

        int Y[1];
        lseek(fd, 0, SEEK_SET);
        int byte_read = read(fd, Y, sizeof(Y));
        printf("parent read %d bytes\n", byte_read);
        close(fd);

        if(Y[0] == -1){
                printf("child exits on user -1. I exit too.\n");
                exit(0);
        }

        int result = Y[0] + 5;
        printf("here is the result: %d\n", result);
}
//exit(0);
```

1) Child: Ask the user for a positive number
2) Child: If it's -1, write it down to the file and exit
3) Child: Otherwise, do the task

1) Parent: Read the value written by the child
2) Parent: If it's -1, exit
3) Parent: Otherwise, do the task

Example III: ~~Solution A~~

Very Bad Solution, Indeed Wrong!

Why?

```
void main(void){
        while(1){
                Example II's Code with some minor change
        }
}
```

```
hfani@charlie:~$ ./parent_child_conv
parent opens the file for R/W with fd: 3
I am the parent, pid=739728
I am the child, pid=739729 and given the fd 3
enter a positive number:
2
child write 4 bytes.
I brought the number to the power 2 and wrote the result: 4.
parent read 4 bytes
here is the result: 9
parent opens the file for R/W with fd: 3
I am the parent, pid=739728
I am the child, pid=739760 and given the fd 3
enter a positive number:
4
child write 4 bytes.
I brought the number to the power 2 and wrote the result: 16.
parent read 4 bytes
here is the result: 21
parent opens the file for R/W with fd: 3
I am the parent, pid=739728
I am the child, pid=739971 and given the fd 3
enter a positive number:
41
child write 4 bytes.
I brought the number to the power 2 and wrote the result: 1681.
parent read 4 bytes
here is the result: 1686
parent opens the file for R/W with fd: 3
I am the parent, pid=739728
I am the child, pid=740147 and given the fd 3
enter a positive number:
-1
child: the user wants to end the program.
parent read 4 bytes
child exits on user -1. I exit too.
```

The parent is the same, but each time we give birth to a new child!

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Example III: Solution B

Parent

Child

Parent

Child

There is nothing for me yet. I sleep.

Parent

There is nothing for me yet. I sleep.

Child

I'm waiting for the user …

Parent

There is nothing for me yet. I sleep.

Child

I'm waiting for the user …

User entered X

Parent

There is nothing for me yet. I sleep.

Child

I'm waiting for the user ...

User entered X

Write X * X

Parent

There is nothing for me yet. I sleep.

Child

I'm waiting for the user ...

User entered X

Write X * X

Wake up ma! There is sth for you.

Parent

There is nothing for me yet. I sleep.

Child

I'm waiting for the user ...

User entered X

Write X * X

Wake up ma! There is sth for you.

It's my turn to sleep.

Parent

There is nothing for me yet. I sleep.

Ok, Read X*X

Child

I'm waiting for the user ...

User entered X

Write X * X

Wake up ma! There is sth for you.

It's my turn to sleep.

Parent	Child
There is nothing for me yet. I sleep.	I'm waiting for the user …
	User entered X
	Write X * X
Ok, Read X*X	Wake up ma! There is sth for you.
X*X + 5	It's my turn to sleep.

Parent

There is nothing for me yet. I sleep.

Ok, Read X*X

X*X + 5

Print out the final result

Child

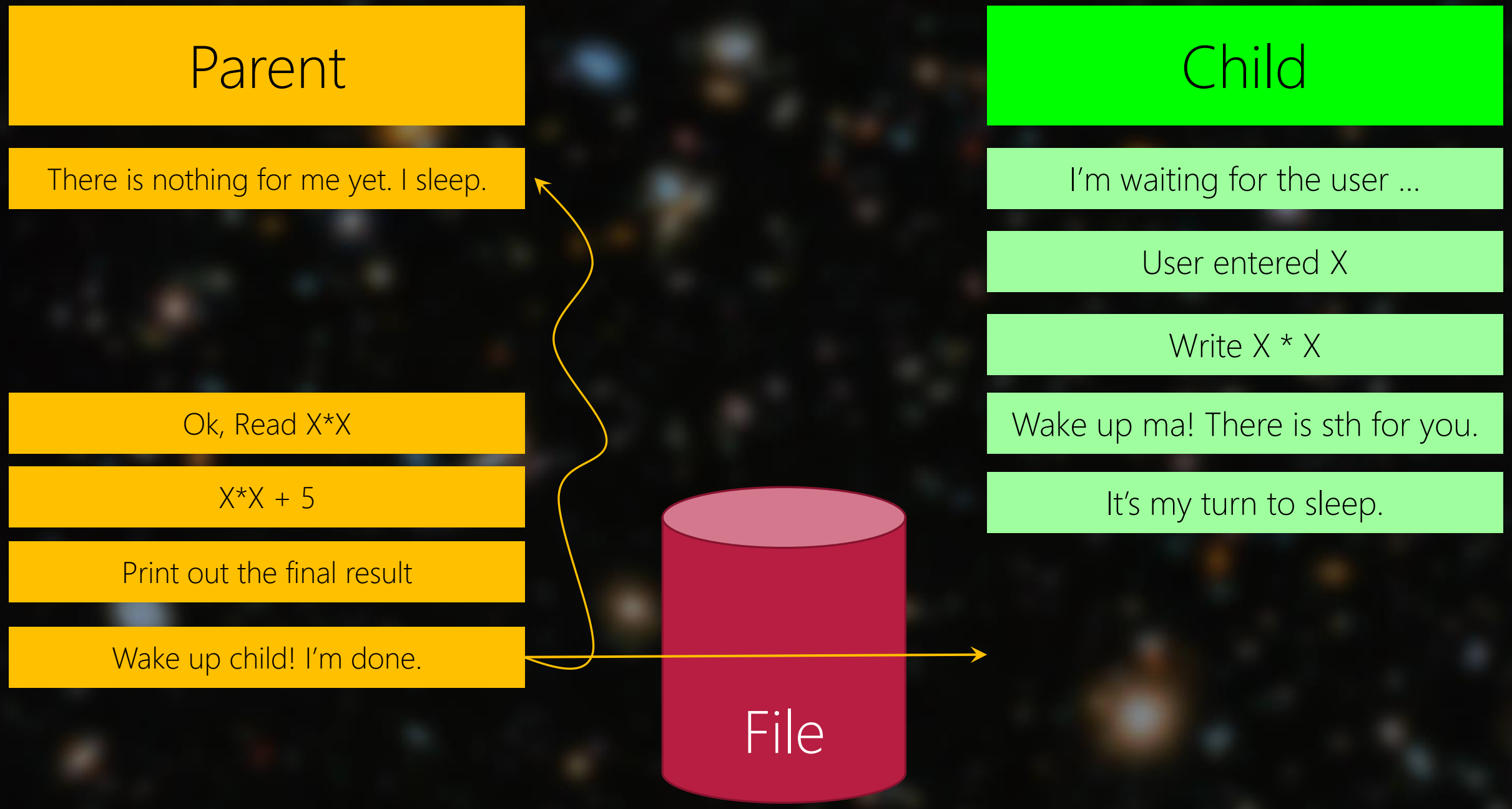
I'm waiting for the user ...

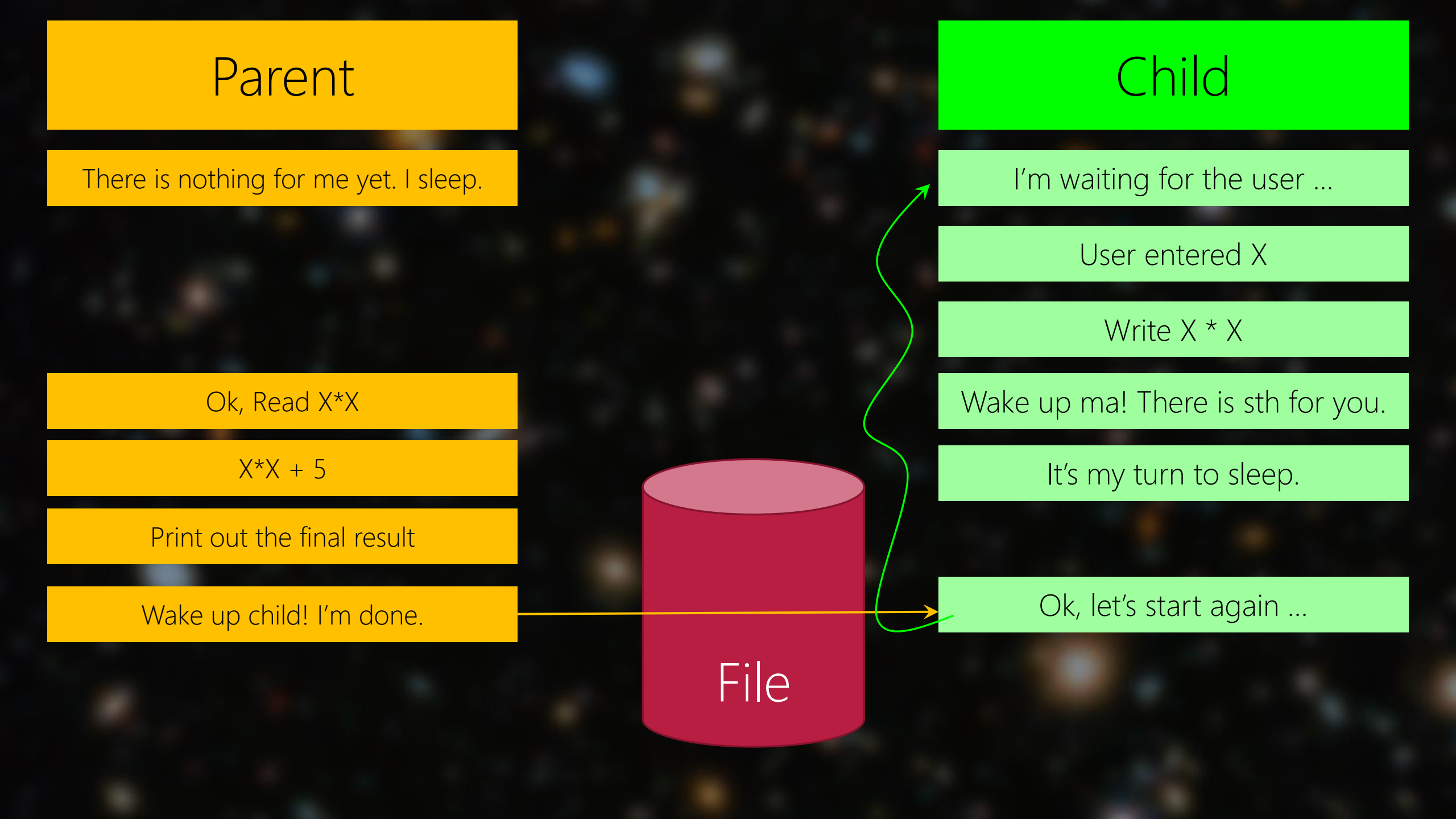
User entered X

Write X * X

Wake up ma! There is sth for you.

It's my turn to sleep.


Parent
Child
There is nothing for me yet. I sleep.
I'm waiting for the user ...
User entered X
Write X * X
Ok, Read X*X
Wake up ma! There is sth for you.
X*X + 5
It's my turn to sleep.
Print out the final result
Wake up child! I'm done.
File


Parent
Child
There is nothing for me yet. I sleep.
I'm waiting for the user ...
User entered X
Write X * X
Ok, Read X*X
Wake up ma! There is sth for you.
X*X + 5
It's my turn to sleep.
Print out the final result
Wake up child! I'm done.
Ok, let's start again ...
File

Example III: Solution B
Same Child

IMPORTANT: the parent does NOT `wait()` for the child to `exit()`!
But `pause()` for the child for another round of conversation.

`sleep(int second)` cannot work because we depend on other process to wake up

```
hfani@charlie:~$ vi parent_child_conv_b.c
int main(int argc, char *argv[]){

        signal(SIGUSR1, parent_signal_handler);

        child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("parent: I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("child: I am the child, pid=%d\n", getpid());
                        signal(SIGUSR2, child_signal_handler);
                        printf("child: I sleep until parent starts the work...\n");
                        pause();
                }
        }

        printf("parent: wake up child. It's time to work...\n");
        kill(child_pid, SIGUSR2);
        printf("parent: I sleep till you wake me up, child.\n");
        pause();
}
```

```
hfani@charlie:~$ vi parent_child_conv_b.c
int main(int argc, char *argv[]){

        signal(SIGUSR1, parent_signal_handler);

        child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("parent: I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("child: I am the child, pid=%d\n", getpid());
                        signal(SIGUSR2, child_signal_handler);
                        printf("child: I sleep until parent starts the work...\n");
                        pause();
                }
        }

        printf("parent: wake up child. It's time to work...\n");
        kill(child_pid, SIGUSR2);
        printf("parent: I sleep till you wake me up, child.\n");
        pause();
}
```

```
hfani@charlie:~$ vi parent_child_conv_b.c
```

```c
void child_signal_handler(int signal){
        printf("child: I received a wake up signal from my parrent. The signal is %d\n", signal);
        int Y[1] = {-1};
        int X;
        printf("child: enter a positive number:\n");
        scanf("%d", &X);
        int fd = open(filename_2_share, O_WRONLY | O_CREAT, S_IRUSR | S_IWUSR);
        printf("child opens the file with fd: %d\n", fd);
        if(X == -1){
                printf("child: the user wants to end the program.\n");
                write(fd, Y, sizeof(Y));
                exit(0);
        }
        Y[0] = X * X;
        int byte_write = write(fd, Y, sizeof(Y));
        close(fd);
        printf("child: write %d bytes.\n", byte_write);
        printf("child: I brought the number to the power 2 and wrote the result: %d.\n", Y[0]);
        printf("child: Ma, wake up ...\n");
        kill(getppid(), SIGUSR1);
        pause();
}
```

```
hfani@charlie:~$ vi parent_child_conv_b.c


void parent_signal_handler(int signal){
        printf("parent: I received a wake up signal from my child. The signal is %d\n", signal);
        int fd = open(filename_2_share, O_RDONLY);
        printf("parent: I opened the file with fd: %d\n", fd);
        int Y[1];
        int byte_read = read(fd, Y, sizeof(Y));
        printf("parent: I read %d bytes\n", byte_read);
        close(fd);
        int result = Y[0] + 5;
        printf("parent: here is the final result: %d\n", result);
        printf("parent: wake up child for another round of work ...");
        kill(SIGUSR2, child_pid);
        printf("parent: I sleep.");
        pause();
}
```

Example III: Solution B

Does not work! Why?

```
hfani@charlie:~$ ./parent_child_conv_b
parent: I am the parent, pid=1023596
parent: wake up child. It's time to work...
parent: I sleep till you wake me up, child.
child: I am the child, pid=1023597
child: I sleep until parent starts the work...
```

Unnamed File → Pipe

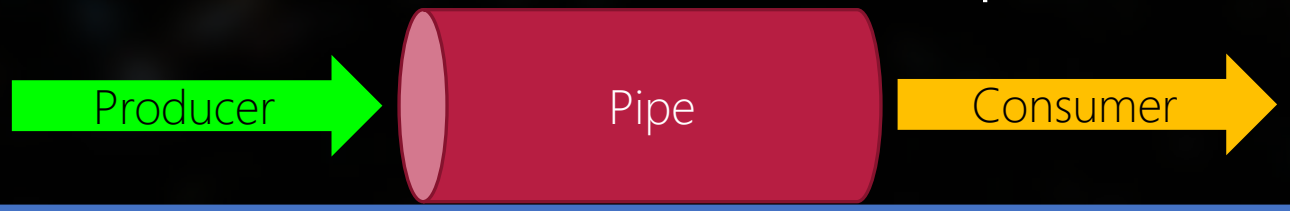
Handles all opening, closing, seeking, pauses, wakeups, ….
Temporary File, Memory, Device, …. (We don't know)

Unnamed File → Pipe

Half Duplex, Unidirectional, Forward Only

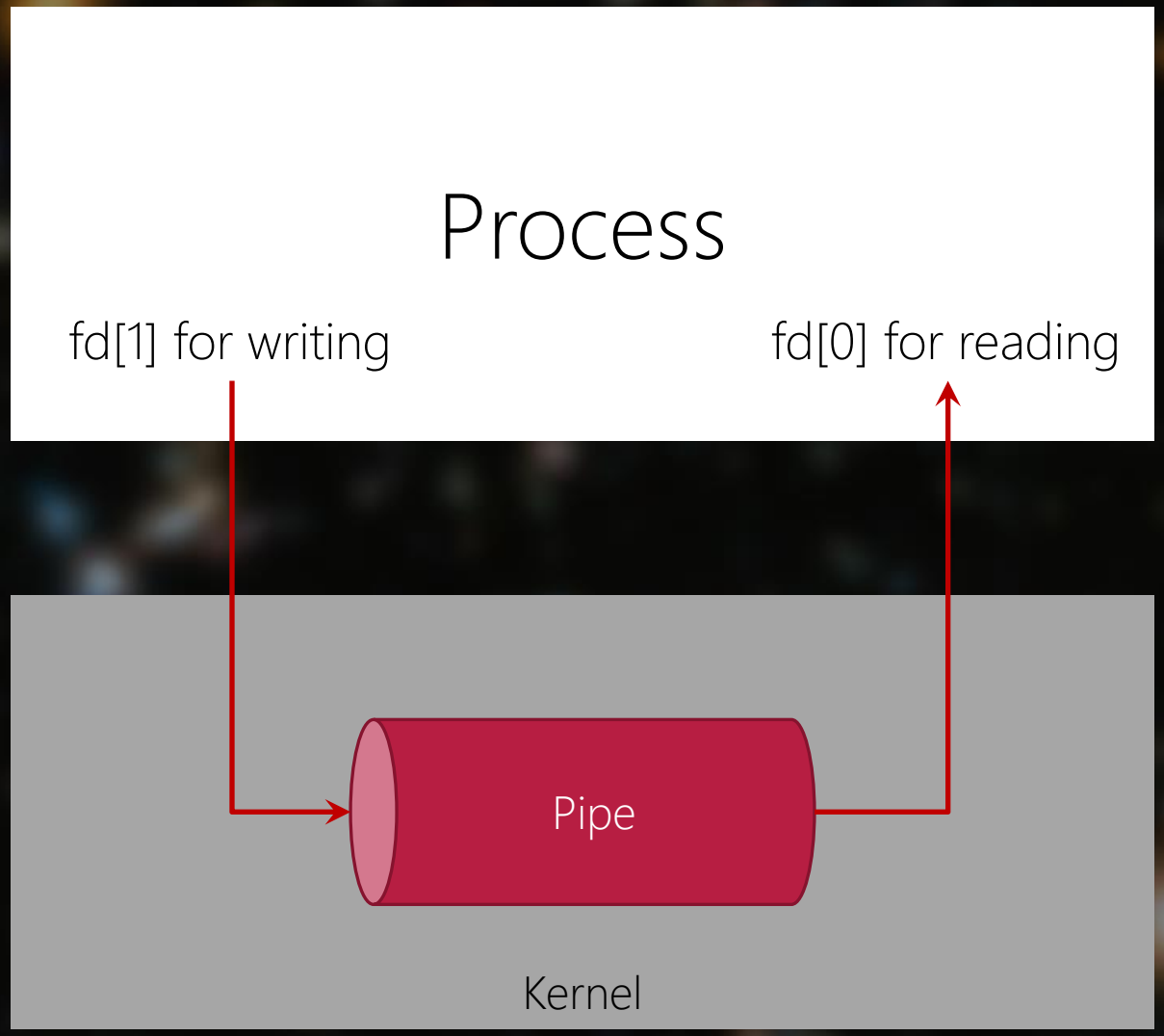
No `lseek()` or rewind!

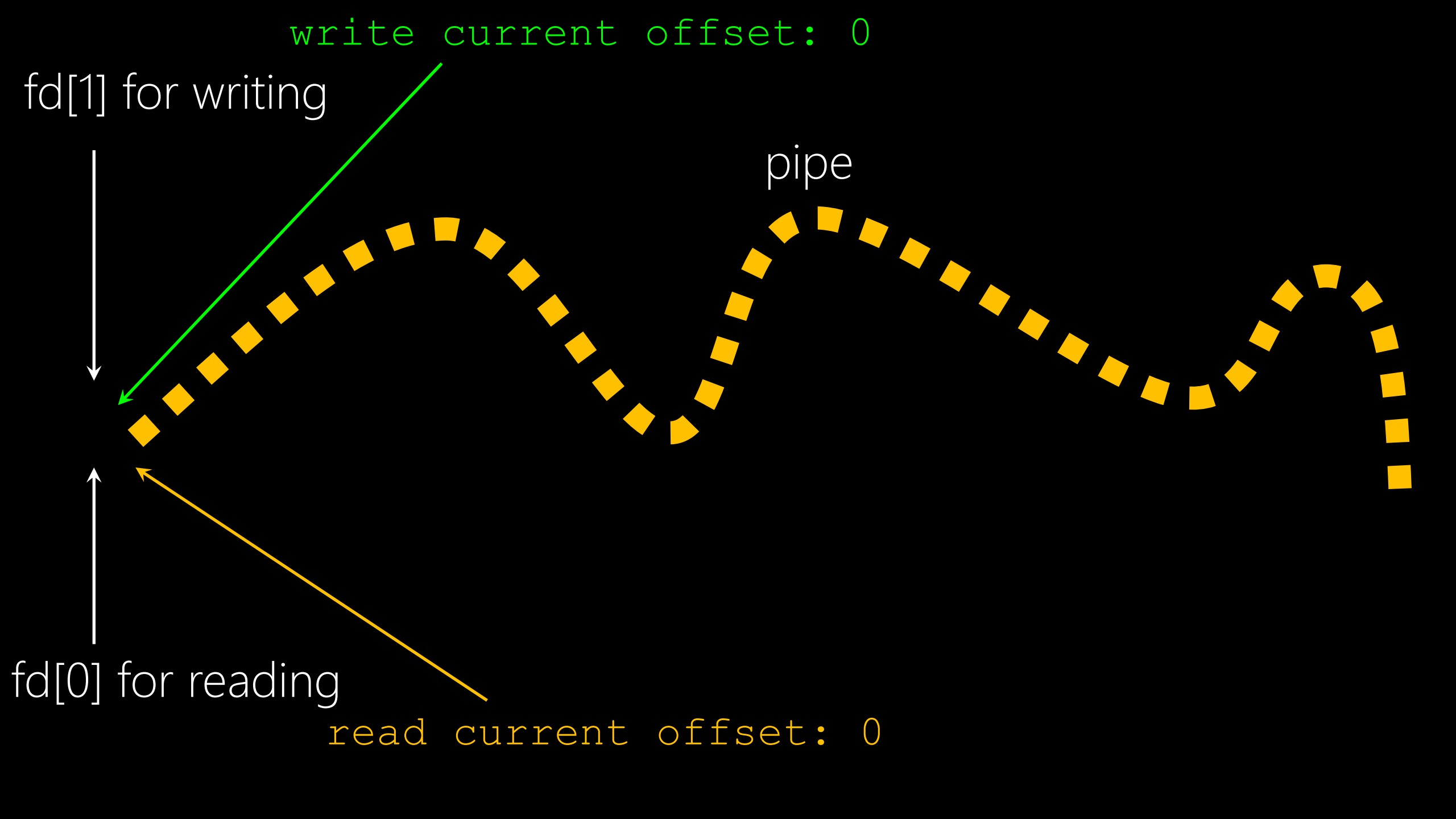
Unnamed File → Pipe

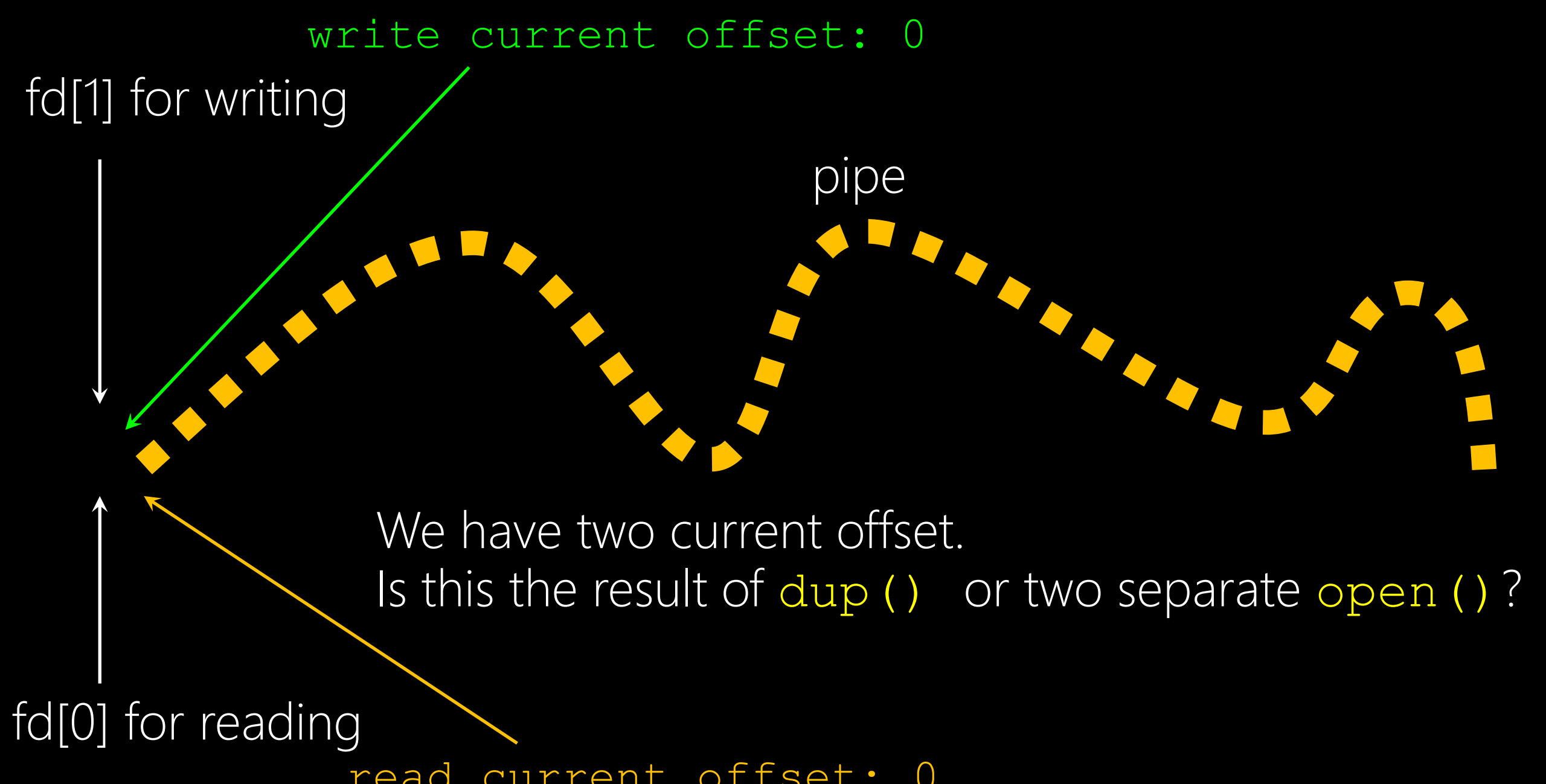


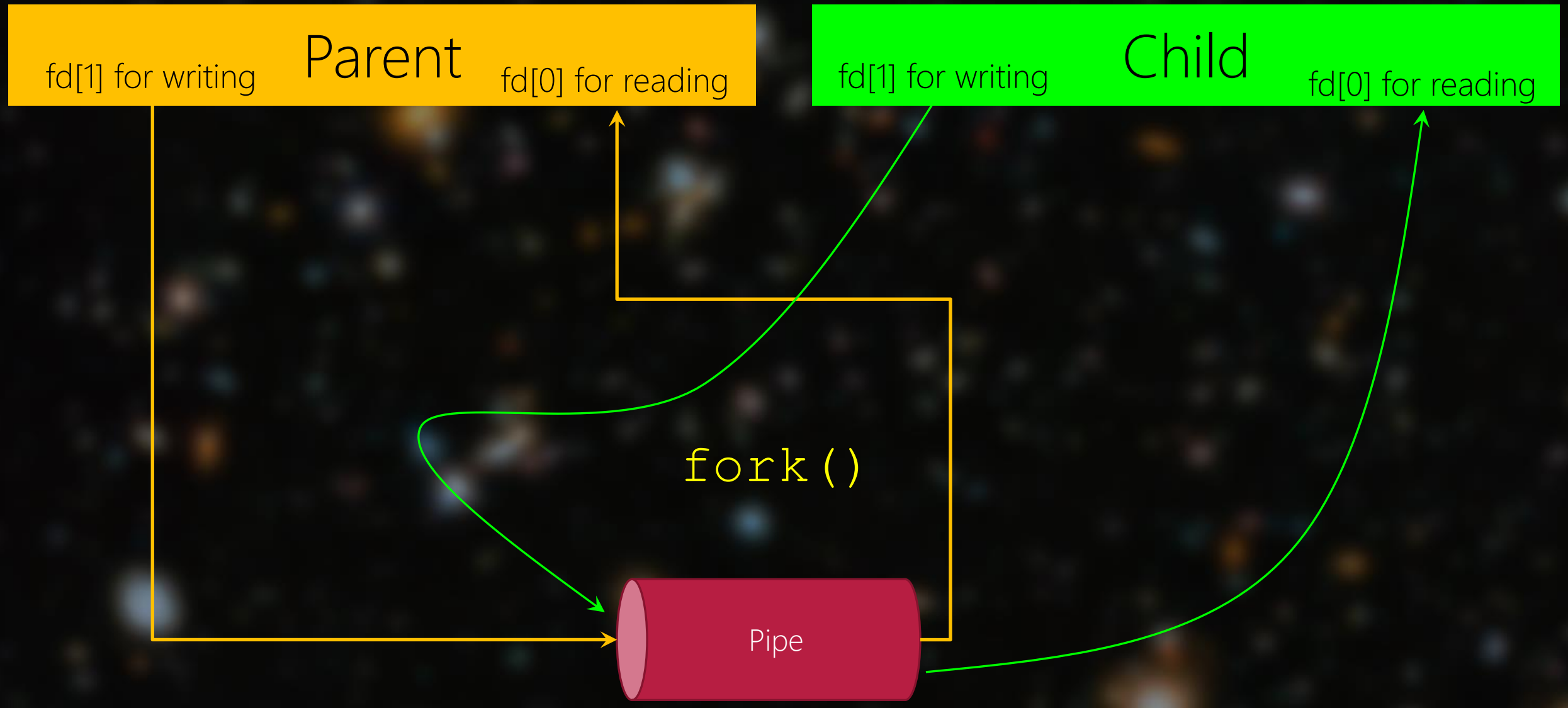

```
#include <unistd.h>
int pipe(int fd[2]);
```

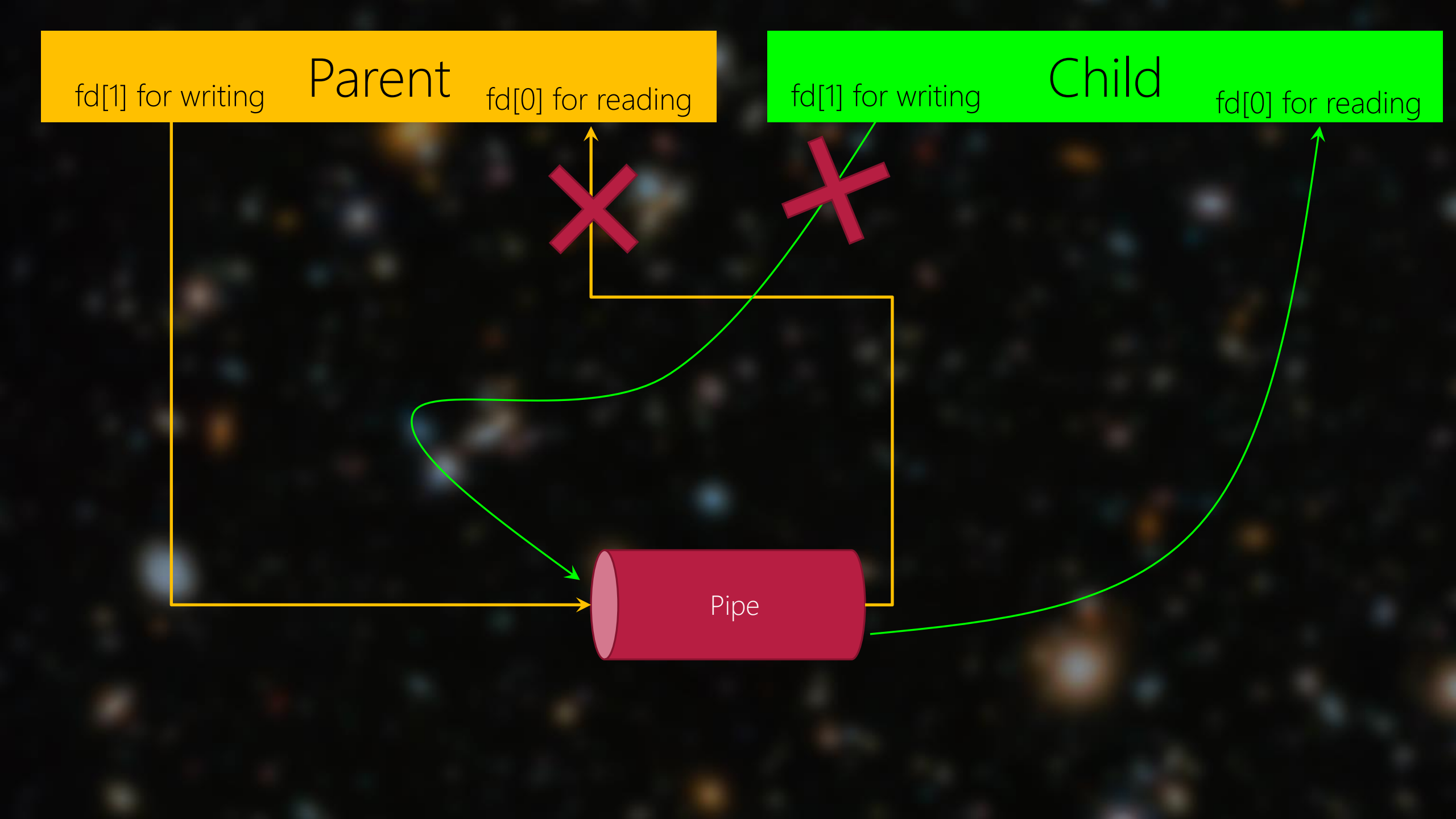
Returns 0 if OK, -1 on error

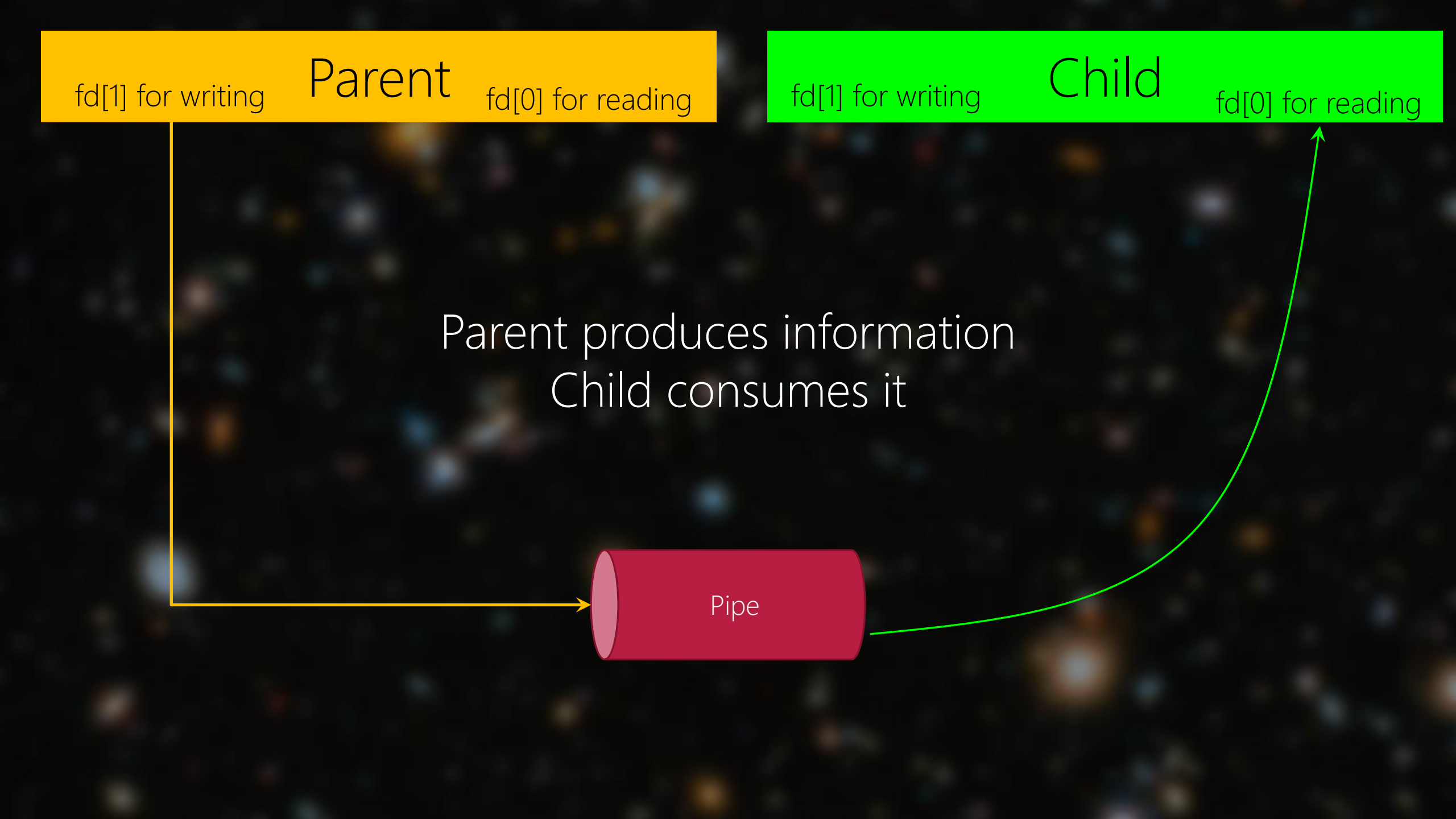

Process
fd[1] for writing
fd[0] for reading
Pipe
Kernel

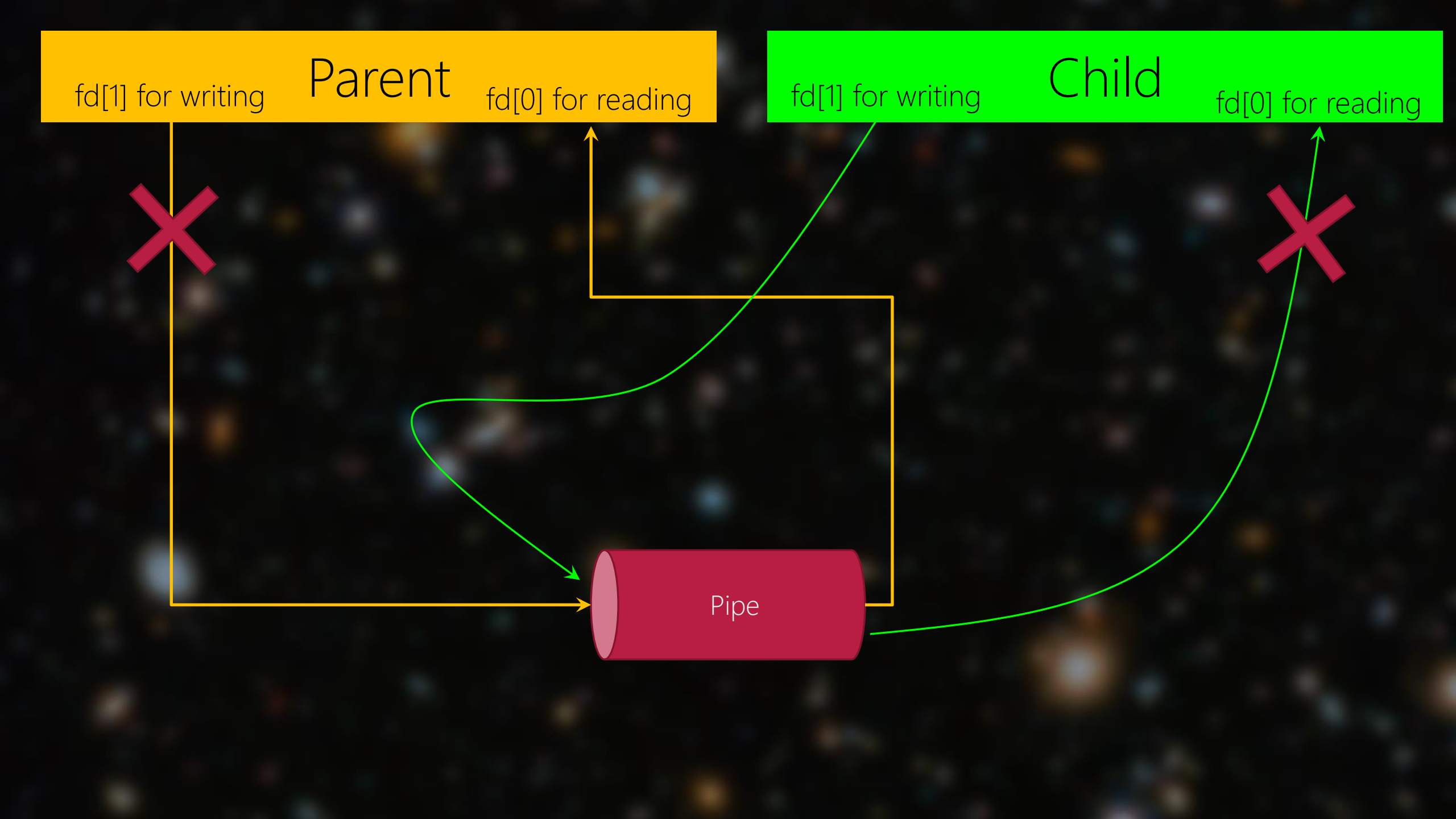

write current offset: 0
fd[1] for writing
pipe
fd[0] for reading
read current offset: 0

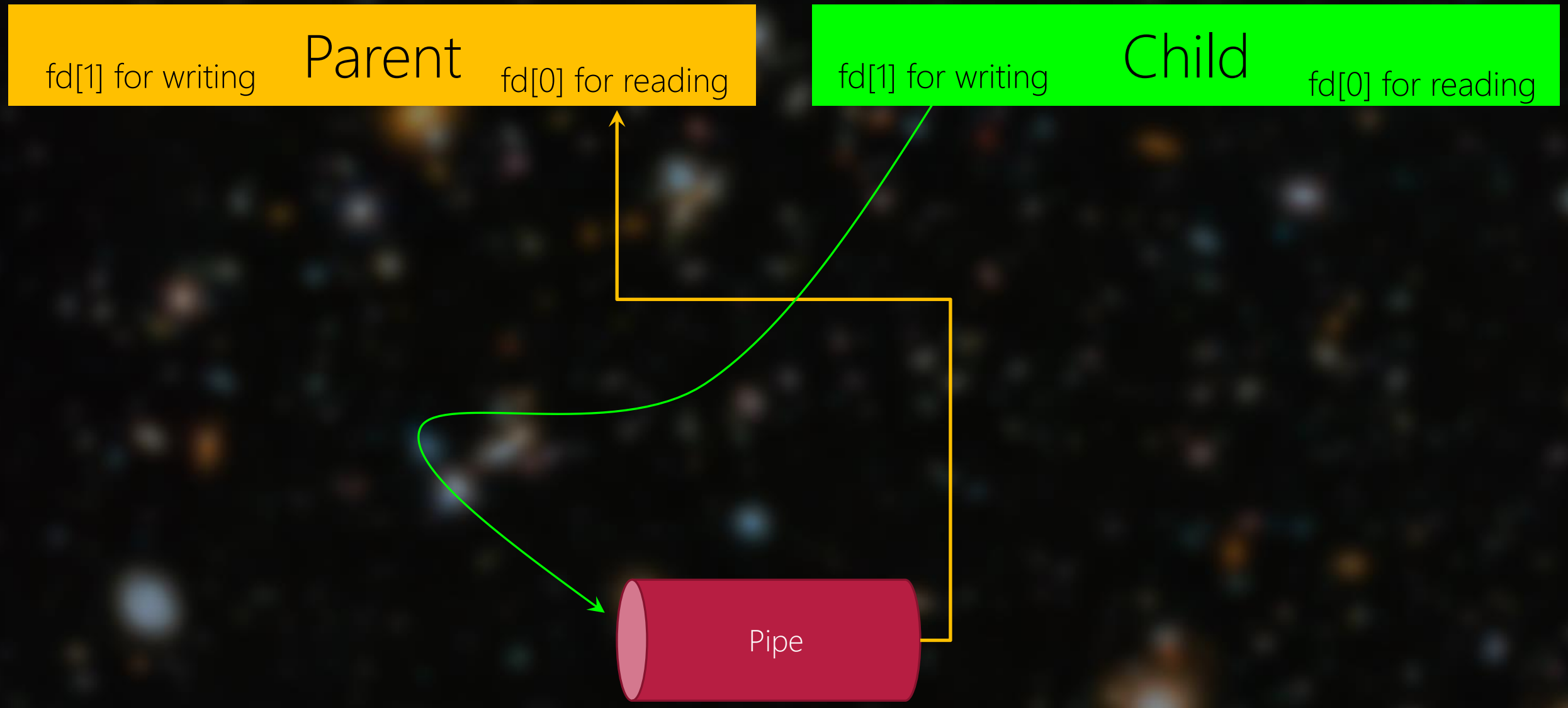

write current offset: 0
fd[1] for writing
pipe
We have two current offset.
Is this the result of dup() or two separate open()?
fd[0] for reading
read current offset: 0


fd[1] for writing
Parent
fd[0] for reading
fd[1] for writing
Child
fd[0] for reading
fork()
Pipe

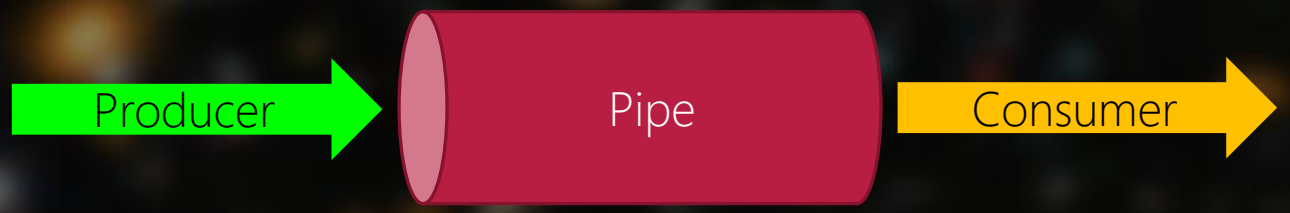

fd[1] for writing
Parent
fd[0] for reading
fd[1] for writing
Child
fd[0] for reading
Pipe


fd[1] for writing
Parent
fd[0] for reading
fd[1] for writing
Child
fd[0] for reading
Parent produces information
Child consumes it
Pipe


Parent
fd[1] for writing
fd[0] for reading
Child
fd[1] for writing
fd[0] for reading
Pipe

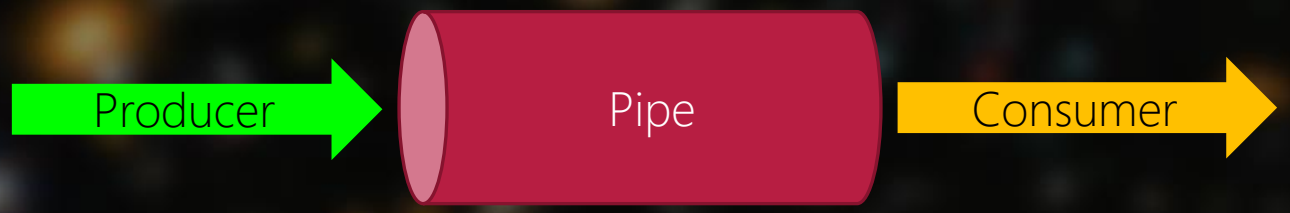


Child produces information
Parent consumes it



Situations:

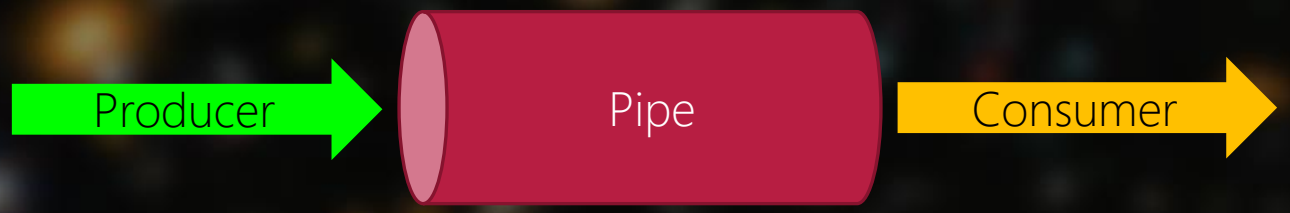
1) If the consumer wants to `read()` N bytes but there less data
2) If the consumer wants to `read()` but there is no data (empty pipe)
3) If the consumer wants to `read()` but there is no producer anymore
4) If the producer wants to `write()` but there is no consumer
5) If the producer wants to `write()` but pipe is full



Situations:

1) If the consumer wants to `read()` N bytes but there less data

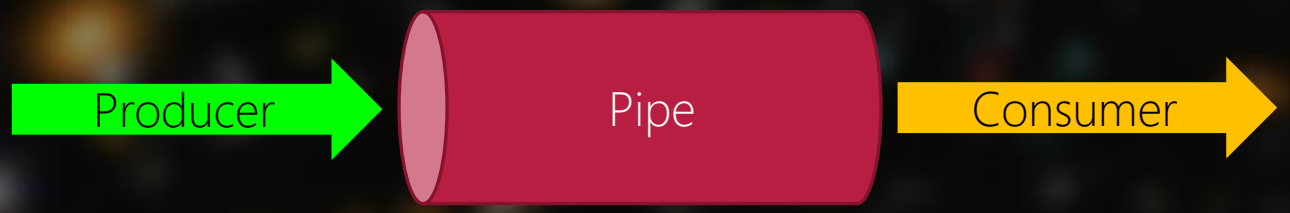
We already saw this when reading from a file while giving large buffer
Only the available data will be read



Situations:

2) If the consumer wants to `read()` but there is no data (empty pipe)

If a producer exists, the consumer `pause()` till the kernel SIGNALs it when at least 1 byte become available



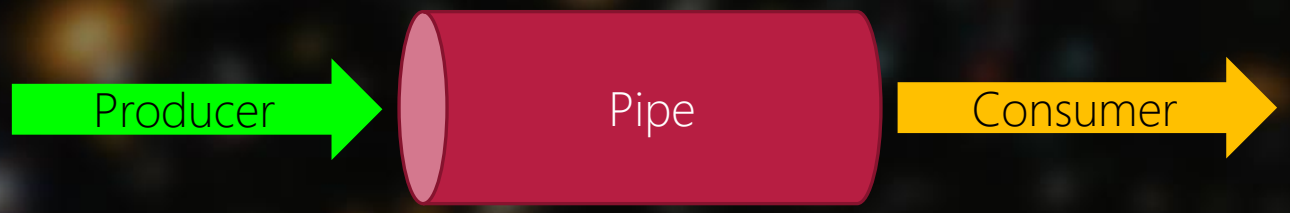
Situations:

3) If the consumer wants to `read()` but there is no producer anymore

The consumer can continue to read until there is no information left

The consumer does NOT `pause()`

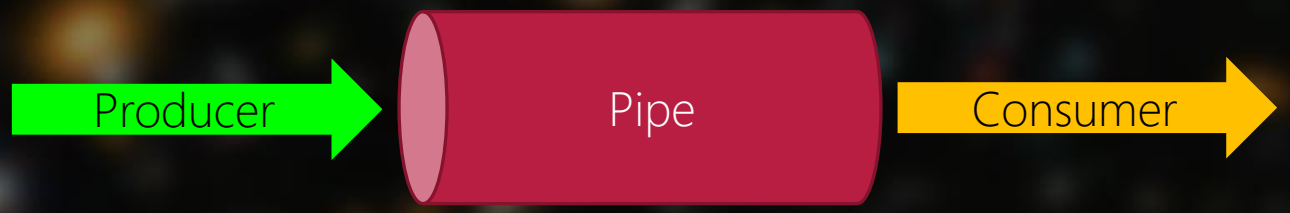
The last read returns `0` (EOF) and consumer decides to exit



Situations:

4) If the producer wants to `write()` but there is no consumer

The producer fails and receives SIGPIPE by the kernel



Situations:

5) If the producer wants to `write()` but pipe is full

Any idea?

```
hfani@charlie:~$ vi pipe.c
int main(void)
{
        int fd[2];

        if (pipe(fd) < 0){
                printf("pipe error.\n");
                exit(1);
        }

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("chile: I am the child, pid=%d and given the fd %d\n", getpid(), fd);
                        printf("child: I want to be the producer.\n");
                        close(fd[0]);
                        int Y[1] = {-1};
                        int X;
                        while(1){
                                printf("child: enter a positive number:\n");
                                scanf("%d", &X);
                                if(X == -1){
                                        printf("child: the user wants to end the program.\n");
                                        exit(0);
                                }
                                Y[0] = X * X;
                                int byte_write = write(fd[1], Y, sizeof(Y));
                                printf("child write %d bytes.\n", byte_write);
                                printf("child: I brought the number to the power 2 and wrote the result: %d.\n", Y[0]);
                        }
                }
        }
        printf("parent: I want to be the consumer.\n");
        close(fd[1]);
        while(1){
                int Y[1];
                int byte_read = read(fd[0], Y, sizeof(Y));
                if (byte_read == 0){
                        printf("parent: there is no more data and no producer. I exit.\n");
                        exit(0);
                }
                printf("parent read %d bytes\n", byte_read);
                int result = Y[0] + 5;
                printf("here is the result: %d\n", result);
        }
}
```

Passing an array of `fd[2]` to `pipe()` and receiving separate read and write file descriptors.

```
hfani@charlie:~$ vi pipe.c
int main(void)
{
        int fd[2];

        if (pipe(fd) < 0){
                printf("pipe error.\n");
                exit(1);
        }

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("chile: I am the child, pid=%d and given the fd %d\n", getpid(), fd);
                        printf("child: I want to be the producer.\n");
                        close(fd[0]);
                        int Y[1] = {-1};
                        int X;
                        while(1){
                                printf("child: enter a positive number:\n");
                                scanf("%d", &X);
                                if(X == -1){
                                        printf("child: the user wants to end the program.\n");
                                        exit(0);
                                }
                                Y[0] = X * X;
                                int byte_write = write(fd[1], Y, sizeof(Y));
                                printf("child write %d bytes.\n", byte_write);
                                printf("child: I brought the number to the power 2 and wrote the result: %d.\n", Y[0]);
                        }
                }
        }
        printf("parent: I want to be the consumer.\n");
        close(fd[1]);
        while(1){
                int Y[1];
                int byte_read = read(fd[0], Y, sizeof(Y));
                if (byte_read == 0){
                        printf("parent: there is no more data and no producer. I exit.\n");
                        exit(0);
                }
                printf("parent read %d bytes\n", byte_read);
                int result = Y[0] + 5;
                printf("here is the result: %d\n", result);
        }
}
```

Child is the producer.
So, it closes the read descriptor `fd[0]`

Parent is the consumer.
So, it closes the write descriptor `fd[1]`

```
hfani@charlie:~$ vi pipe.c
int main(void)
{
        int fd[2];

        if (pipe(fd) < 0){
                printf("pipe error.\n");
                exit(1);
        }

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("chile: I am the child, pid=%d and given the fd %d\n", getpid(), fd);
                        printf("child: I want to be the producer.\n");
                        close(fd[0]);
                        int Y[1] = {-1};
                        int X;
                        while(1){
                                printf("child: enter a positive number:\n");
                                scanf("%d", &X);
                                if(X == -1){
                                        printf("child: the user wants to end the program.\n");
                                        exit(0);
                                }
                                Y[0] = X * X;
                                int byte_write = write(fd[1], Y, sizeof(Y));
                                printf("child write %d bytes.\n", byte_write);
                                printf("child: I brought the number to the power 2 and wrote the result: %d.\n", Y[0]);
                        }
                }
        }
        printf("parent: I want to be the consumer.\n");
        close(fd[1]);
        while(1){
                int Y[1];
                int byte_read = read(fd[0], Y, sizeof(Y));
                if (byte_read == 0){
                        printf("parent: there is no more data and no producer. I exit.\n");
                        exit(0);
                }
                printf("parent read %d bytes\n", byte_read);
                int result = Y[0] + 5;
                printf("here is the result: %d\n", result);
        }
}
```

Child produces forever until the user enters -1

Parent consumes forever until the child is working

If the child exits, the parent make sure to consume all the data first and then exits.

```
hfani@charlie:~$ vi pipe.c
int main(void)
{
        int fd[2];

        if (pipe(fd) < 0){
                printf("pipe error.\n");
                exit(1);
        }

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("chile: I am the child, pid=%d and given the fd %d\n", getpid(), fd);
                        printf("child: I want to be the producer.\n");
                        close(fd[0]);
                        int Y[1] = {-1};
                        int X;
                        while(1){
                                printf("child: enter a positive number:\n");
                                scanf("%d", &X);
                                if(X == -1){
                                        printf("child: the user wants to end the program.\n");
                                        exit(0);
                                }
                                Y[0] = X * X;
                                int byte_write = write(fd[1], Y, sizeof(Y));
                                printf("child write %d bytes.\n", byte_write);
                                printf("child: I brought the number to the power 2 and wrote the result: %d.\n", Y[0]);
                        }
                }
        }
        printf("parent: I want to be the consumer.\n");
        close(fd[1]);
        while(1){
                int Y[1];
                int byte_read = read(fd[0], Y, sizeof(Y));
                if (byte_read == 0){
                        printf("parent: there is no more data and no producer. I exit.\n");
                        exit(0);
                }
                printf("parent read %d bytes\n", byte_read);
                int result = Y[0] + 5;
                printf("here is the result: %d\n", result);
        }
}
```

If child wants to write but the pipe is full, it pauses

Synchronization

If parent wants to consume but there is no data, it pauses

```
hfani@charlie:~$ vi pipe.c
int main(void)
{
        int fd[2];

        if (pipe(fd) < 0){
                printf("pipe error.\n");
                exit(1);
        }

        int child_pid = fork();
        if(child_pid == -1){
                perror("impossible to have a child!\n");
                exit(1);
        }
        if(child_pid >= 0){//(child_pid != -1)
                if(child_pid > 0)
                        printf("I am the parent, pid=%d\n", getpid());
                else{//(child_pid == 0)
                        printf("chile: I am the child, pid=%d and given the fd %d\n", getpid(), fd);
                        printf("child: I want to be the producer.\n");
                        close(fd[0]);
                        int Y[1] = {-1};
                        int X;
                        while(1){
                                printf("child: enter a positive number:\n");
                                scanf("%d", &X);
                                if(X == -1){
                                        printf("child: the user wants to end the program.\n");
                                        exit(0);
                                }
                                Y[0] = X * X;
                                int byte_write = write(fd[1], Y, sizeof(Y));
                                printf("child write %d bytes.\n", byte_write);
                                printf("child: I brought the number to the power 2 and wrote the result, %d.\n", Y[0]);
                        }
                }
        }
        printf("parent: I want to be the consumer.\n");
        close(fd[1]);
        while(1){
                int Y[1];
                int byte_read = read(fd[0], Y, sizeof(Y));
                if (byte_read == 0){
                        printf("parent: there is no more data and no producer. I exit.\n");
                        exit(0);
                }
                printf("parent read %d bytes\n", byte_read);
                int result = Y[0] + 5;
                printf("here is the result: %d\n", result);
        }
}
```

There is no `wait()` system call for parent!

```
hfani@charlie:~$ cc pipe.c -o pipe
hfani@charlie:~$ ./pipe
I am the parent, pid=1041949
parent: I want to be the consumer.
chile: I am the child, pid=1041950 and given the fd 318395608
child: I want to be the producer.
child: enter a positive number:
2
child write 4 bytes.
child: I brought the number to the power 2 and wrote the result: 4.
child: enter a positive number:
parent read 4 bytes
here is the result: 9
3
child write 4 bytes.
child: I brought the number to the power 2 and wrote the result: 9.
child: enter a positive number:
parent read 4 bytes
here is the result: 14
-1
child: the user wants to end the program.
parent: there is no more data and no producer. I exit.
```

Appreciate the benefit of processor sharing: While the child is waiting for user input, the parent does the addition with 5

How big is the pipe?

Shell's Pipe (vertical bar `|')

`top | grep hfani |` {another program}

Named Pipe → FIFO

Like Pipe but …

```
mkfifo(const char *path, mode_t mode)
```

Pipe	FIFO
Unamed File, cannot be found in File System	Named File, should be **`open()`** like a regular to read or write
Between processes with the *same ancestor*	Between *any* processes
It is *deleted* after processes are terminated.	It *exists* even after processes termination. Should be explicitly deleted.