CSC209 Summer 2015 — Software Tools and Systems Programming

www.cdf.toronto.edu/~csc209h/summer/

Week 13 — August 6, 2015

Peter McCormick
pdm@cs.toronto.edu

Some materials courtesy of Karen Reid

Announcements

- Extra office hours:
  - Friday, August 7, 12:30-3pm (BA3289)
  - Monday, August 10, 1-4pm (BA3201)
- A4 is due tomorrow by 11:59pm

Exam

Evening of
Tuesday, August 11

http://www.artsci.utoronto.ca/current/exams/

3 hours long

7 questions for a total of 80 marks

One double-sided 8.5x11 sheet of paper

No electronic aids

Course Evaluations

Please fill them out! All feedback is welcome and appreciated!

Agenda

- Big Picture Review
- Assignments
- Assorted Comments
- What’s next?

Ask About

- A topic
- A slide
- A code example
- A past exam question
- Suggested exercises
- Anything else…

Fun Statistics

- Code Commits
  - More than **4500** commits made across all student repositories
  - Average of **50** commits per student
  - More than **ten** students with over **100** commits
  - Highest committer with over **500** commits!

Fun Statistics

- Source Code
  - **3000** lines of assignment starter code & headers
  - Almost **7000** lines of lecture example code
  - Over **260,000** lines of student repository code

Big Picture Review

Course Topics

- Using the Shell
- The C language
  - Pointers & memory model
  - Heap allocation
  - Strings
  - File I/O
- Header files and the compilation pipeline
- `Makefile`'s
- Process: `fork`, `wait`, `waitpid` and `exec*`
- Low level I/O: `open`, `close`, `read`, `write`, `seek`
- Pipes (`pipe`) and Redirection (`dup2`)
- Signals handlers and sending with `kill`()
- Sockets
  - Connecting clients
  - Bound and listening servers
  - Multiplexing I/O using `select`

What is systems programming?

A View of the System Stack

Your Python Code

Python Libraries

CPython (compiler & VM)

C Standard Library

Operating System Kernel

Device Drivers

Hardware (CPU & Peripherals)

A View of the System Stack

Low-level C Programs

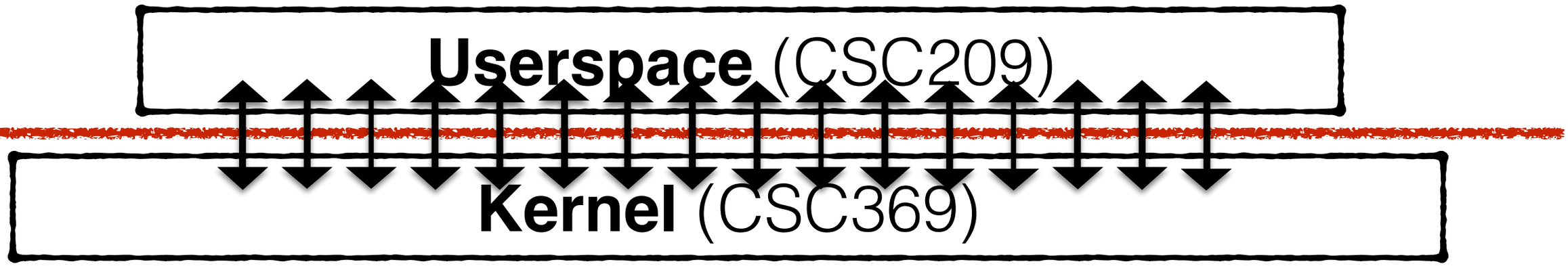
C Standard Library

Operating System Kernel

Device Drivers

Hardware (CPU & Peripherals)

A View of the System Stack

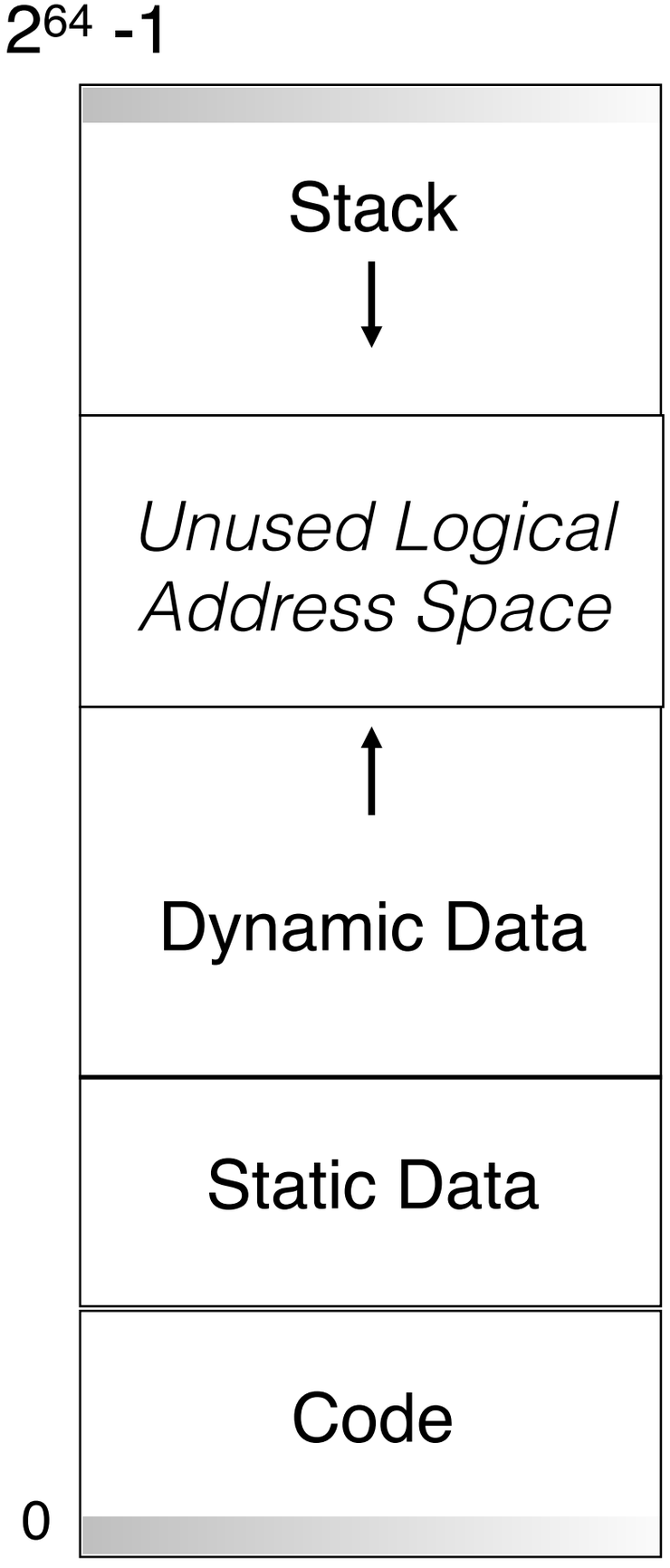


“The Unix philosophy”

- Write programs that do one thing and do it well
- Write programs to work together
- Write programs that handle text streams, because text is a universal interface

The shell is the
connective tissue or *glue*
for the Unix philosophy

Memory Model Address Space



64-bit Logical / Virtual Address

Input/Output
leads to
Computation

- Operating systems organize themselves around concepts such as:
  - Files & Directories
  - Processes
  - Signals
  - Sockets
  - etc.

Files (like memory) consist of a *sequence of bytes*

Processes are a means to co-exist peacefully with other programs

Signals allow programs to be *interrupted* and be informed about unexpected events

Sockets enable co-operating processes to communicate

The Assignments

A1 — `wc209` and `untar`

- Using and writing small Unix utilities in and around the shell
- Reading and processing bytes from file-like inputs
  - Both text and binary files are just *bytes*
- Interpreting a structured file format like **`tar`**

A2 — Dynamic Memory Management

- Investigate behind the scenes how **`malloc`** and **`free`** actually do their work on your behalf
- Simultaneously managing data structures and memory
- Linked list in C using pointers
- Interpreting a design specification and seeing flaws

A3 — Implementing a Shell

- Understanding the Unix system calls mechanisms for process creation (**`fork`**, **`exec*`**) and management (**`wait`**, **`waitpid`**)

- Using pipes (**`pipe`**) and input/output redirections (**`dup2`**)

A4 — Socket Servers

- Socket server setup
- Handling multiple concurrent connections (multiplexing I/O) with a **`select`** event loop
- *Architecture* and associated data structures of a non-trivial server application

Assorted Comments

Starter Code

(the only part you're *not* responsible for is **`lexer.c`** and **`parser.c`** from A3)

Error Handling

vs

Error Recovery

System call return values

`NULL` terminated argument array

Midterm solutions, **`execlp.c`** and **`execvp.c`**

What’s next?

A lot of software is still written (and being written) in C

Systems programming comes in many shapes and sizes

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- Parallel programs using threads and other concurrency primitives

- Programs that can be running simultaneously on more than one CPU/processor/core!!

Systems programming comes in many shapes and sizes

- Operating system kernels
- Directly interfacing with the hardware
- Even more cold, harsh reality of the Real World

Systems programming comes in many shapes and sizes

- High performance network servers
    - Handling massive amounts of traffic and a huge number of requests

C++

Other Kinds of C/C++ Usage

- Demanding 3D graphics game engines
- Power (battery) sensitive mobile apps
- Huge applications like web browsers and office suites
- Numerical simulation for scientific computing

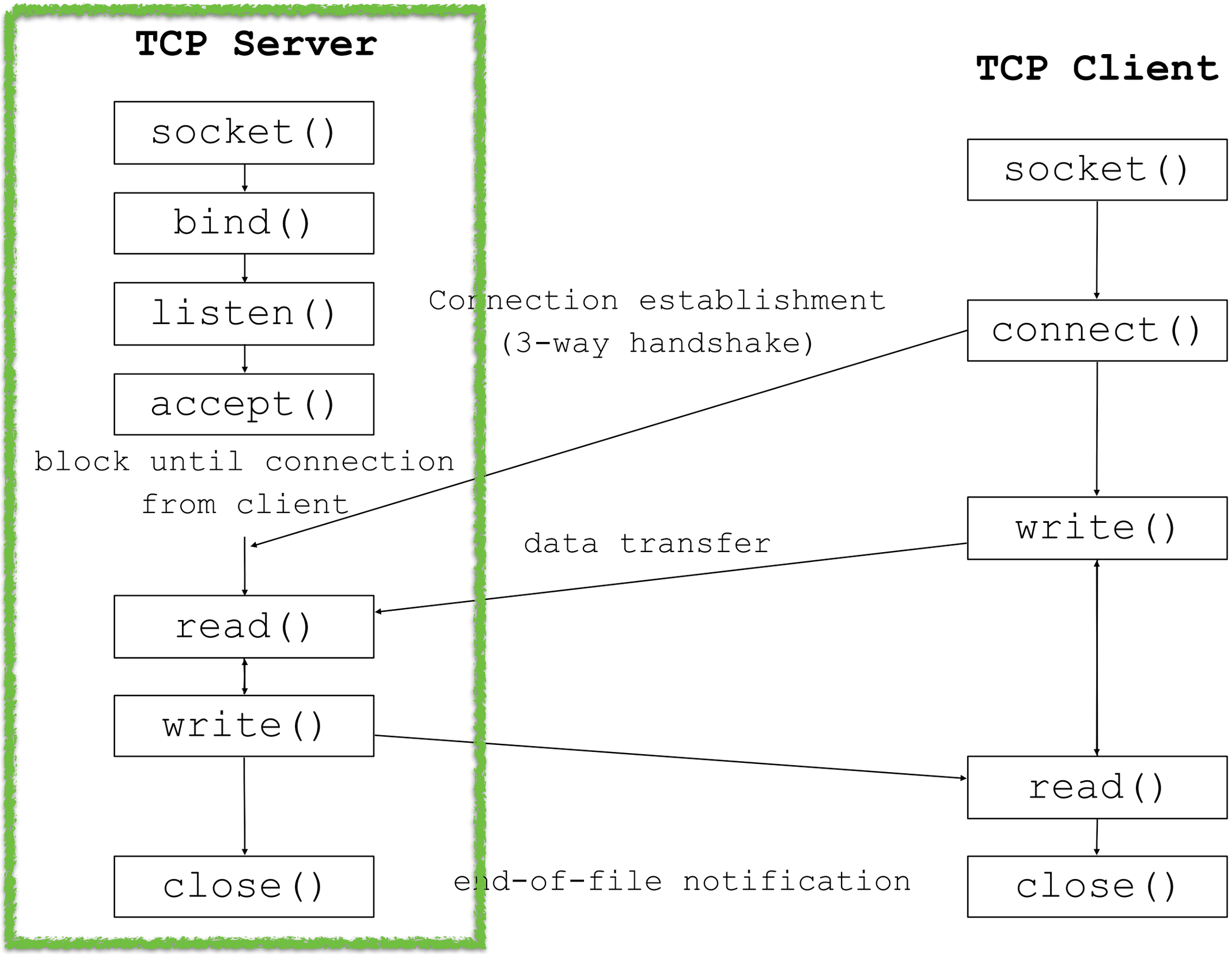
Other Powerful Languages

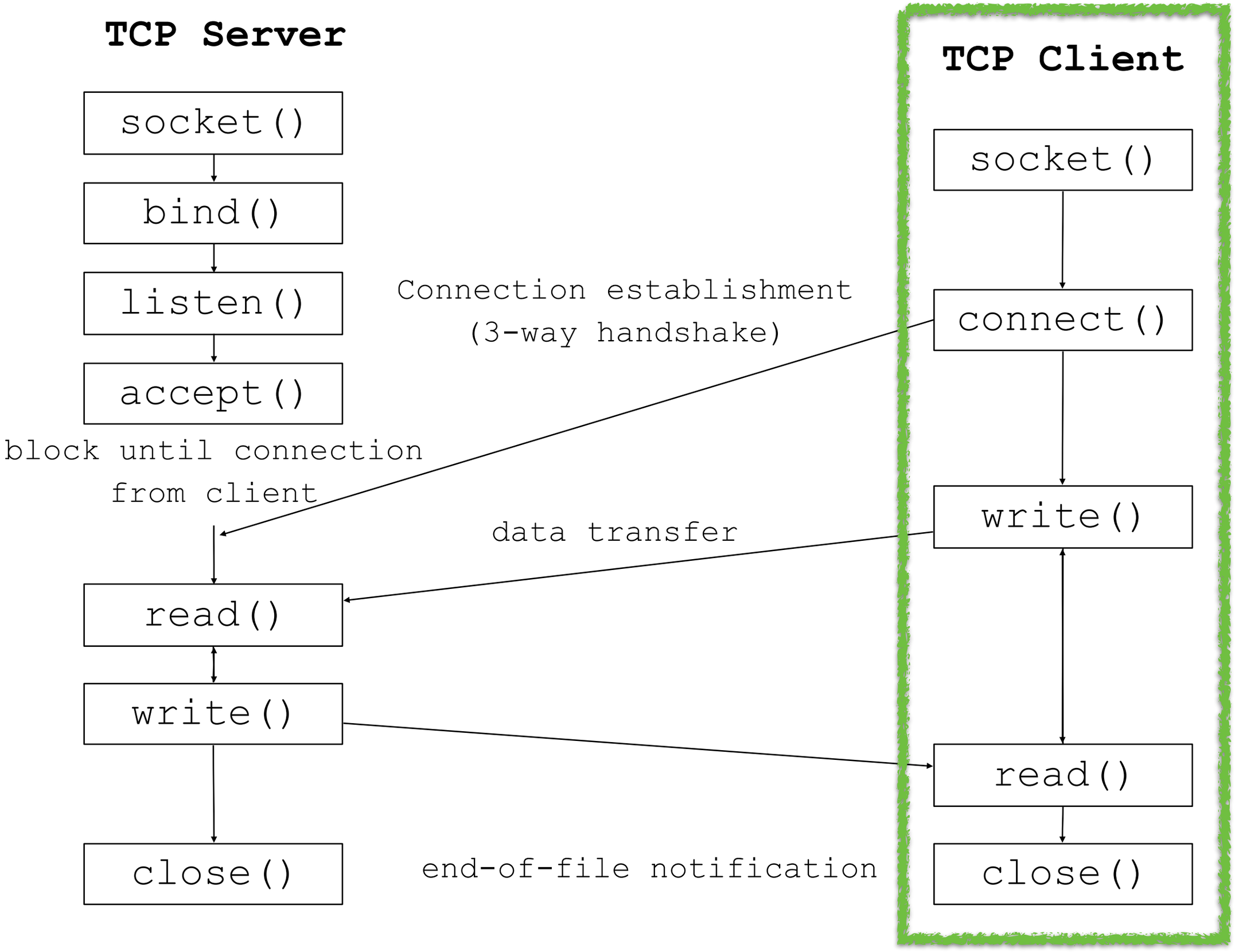
- C++
- Python!
    - Look at the **`socket`** and **`os`** modules
- Go from Google (search for keyword *golang*)
- Rust from Mozilla

The End.

Thank you for a great summer!

Extra Diagram Slides


TCP Server
socket()
bind()
listen()
accept()
block until connection
from client
read()
write()
close()
TCP Client
socket()
connect()
write()
read()
close()
Connection establishment
(3-way handshake)
data transfer
end-of-file notification


TCP Server
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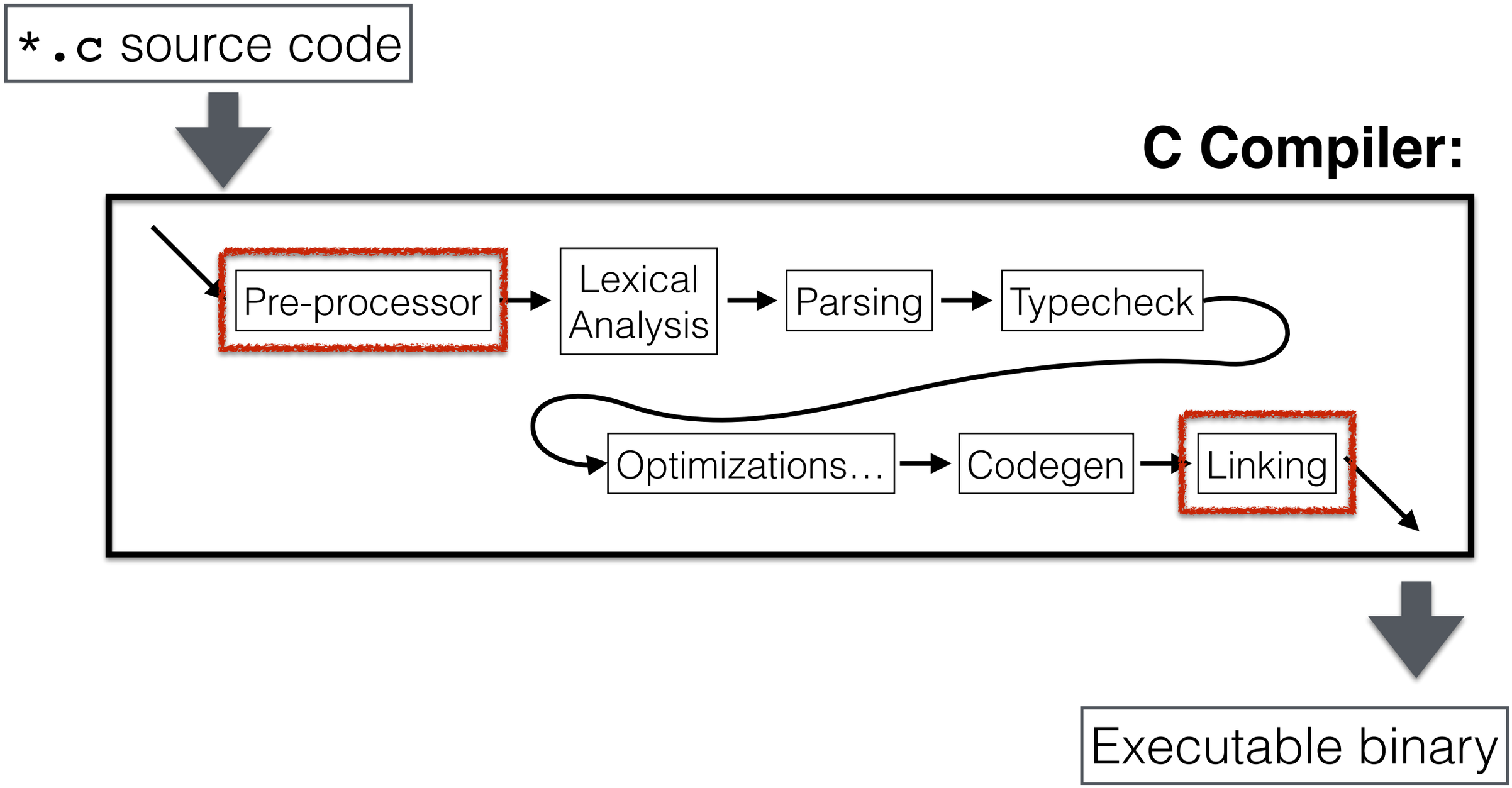
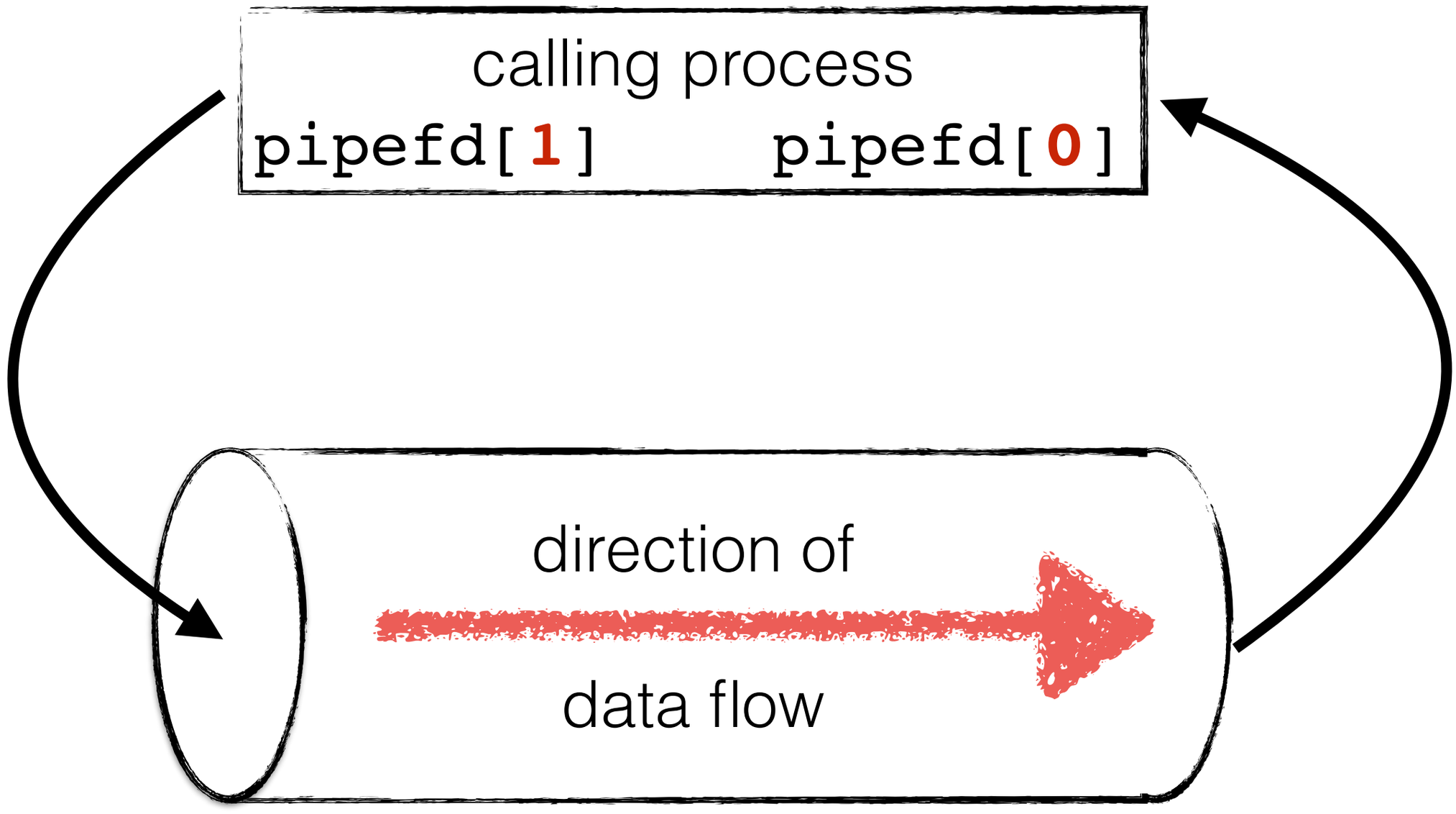
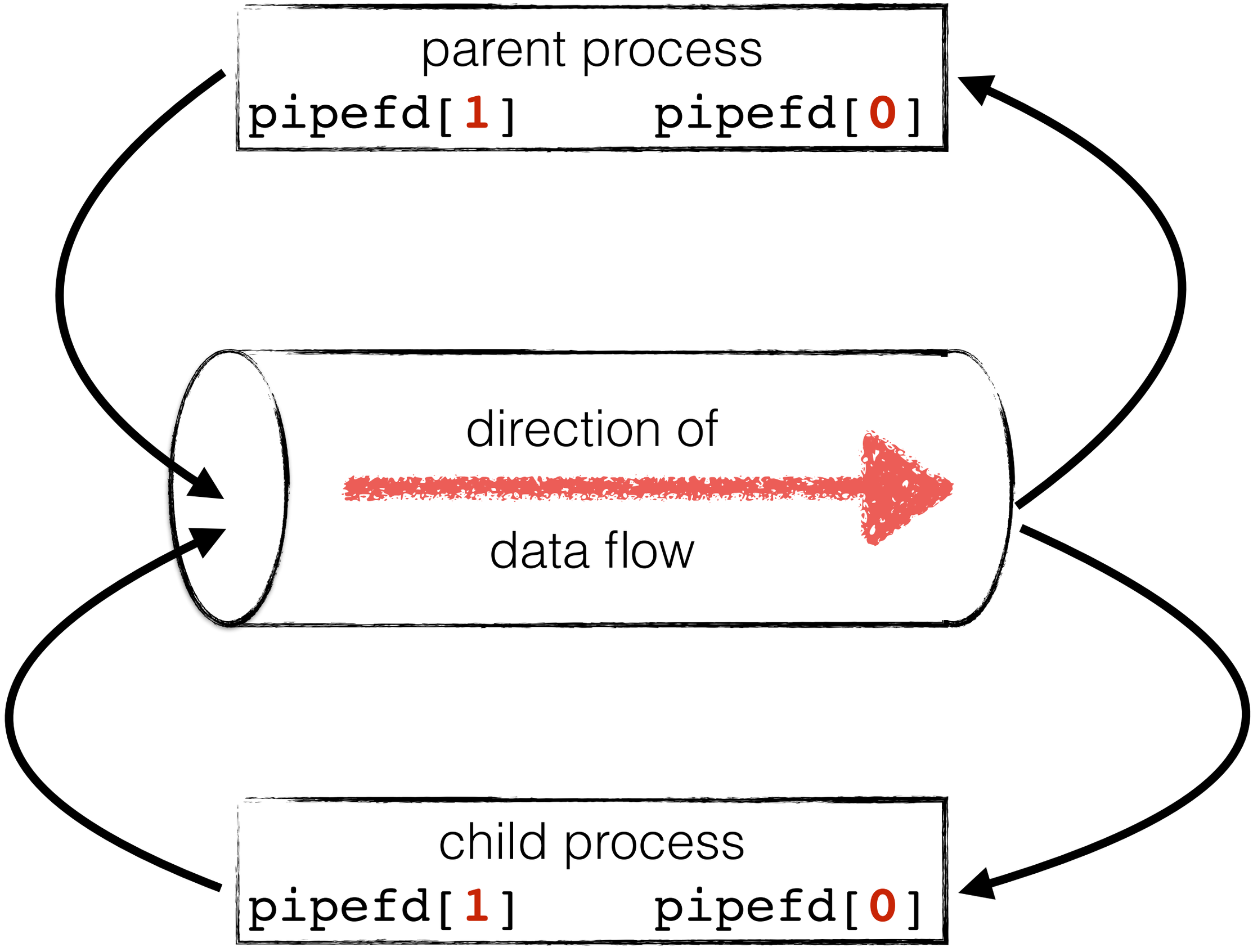
Compilation Process

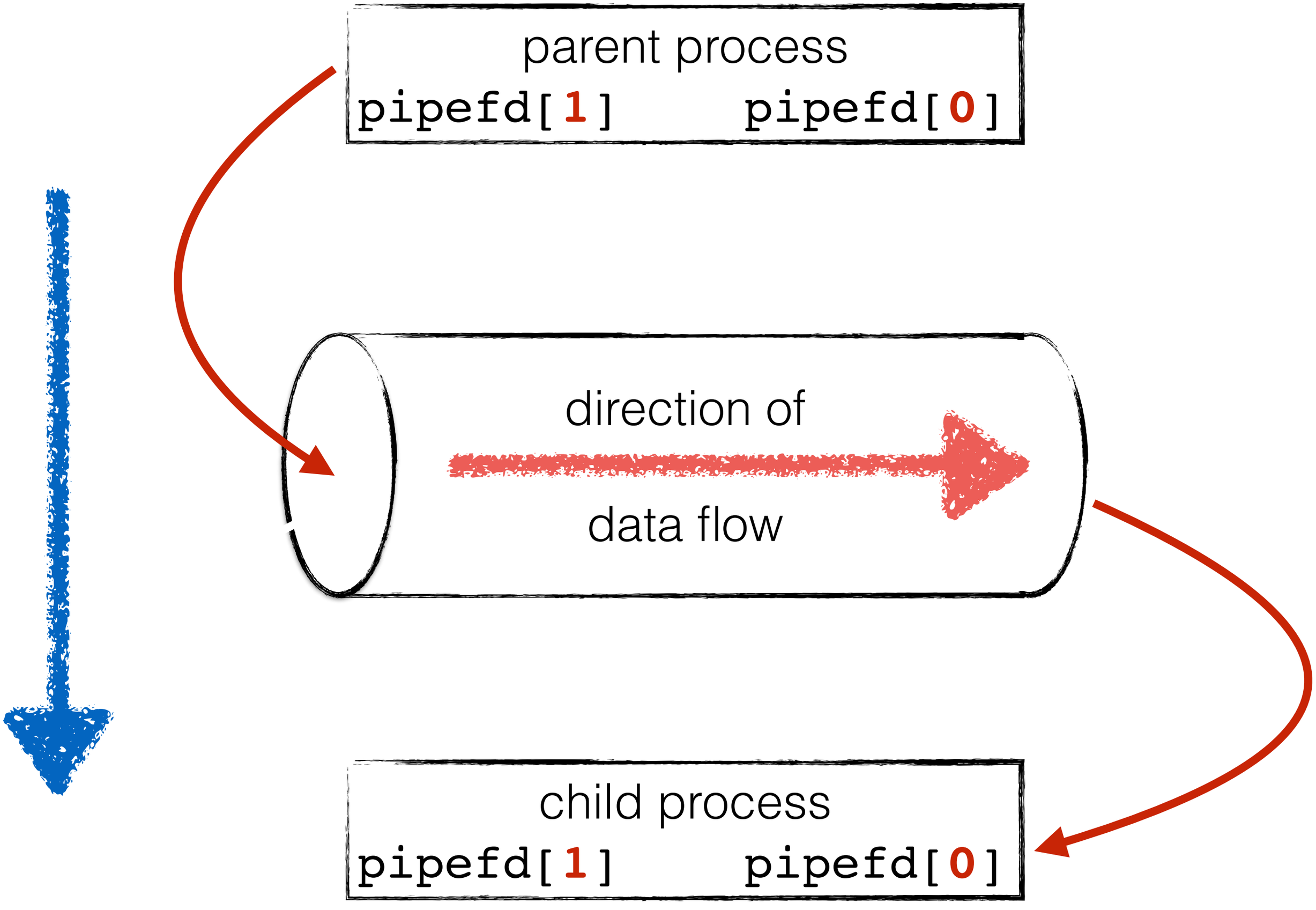




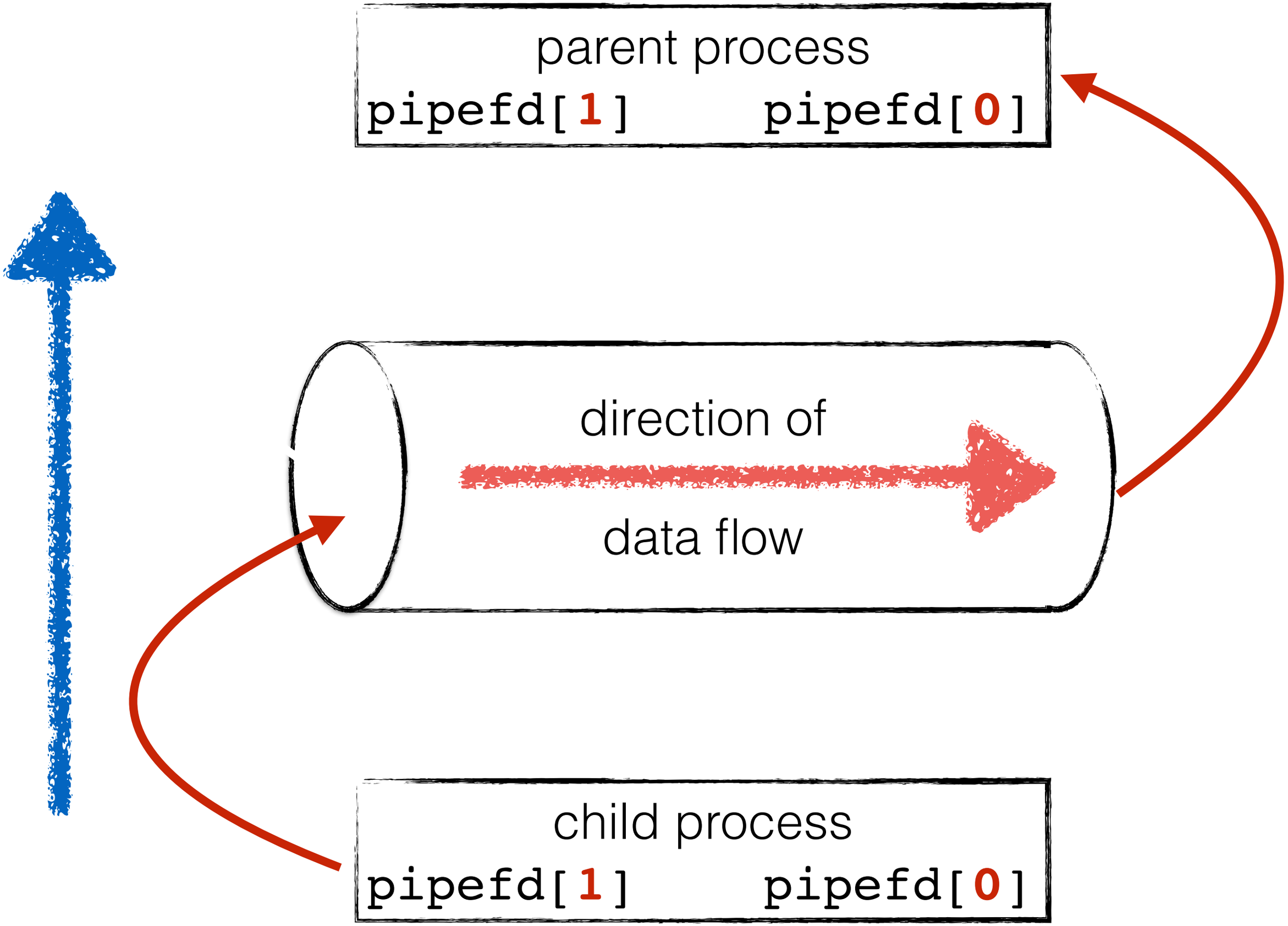
Kerrisk figure 44-2



Kerrisk figure 44-3a: After ***`fork`***



Kerrisk figure 44-3b: After closing unused descriptors



Kerrisk figure 44-3b: After closing unused descriptors