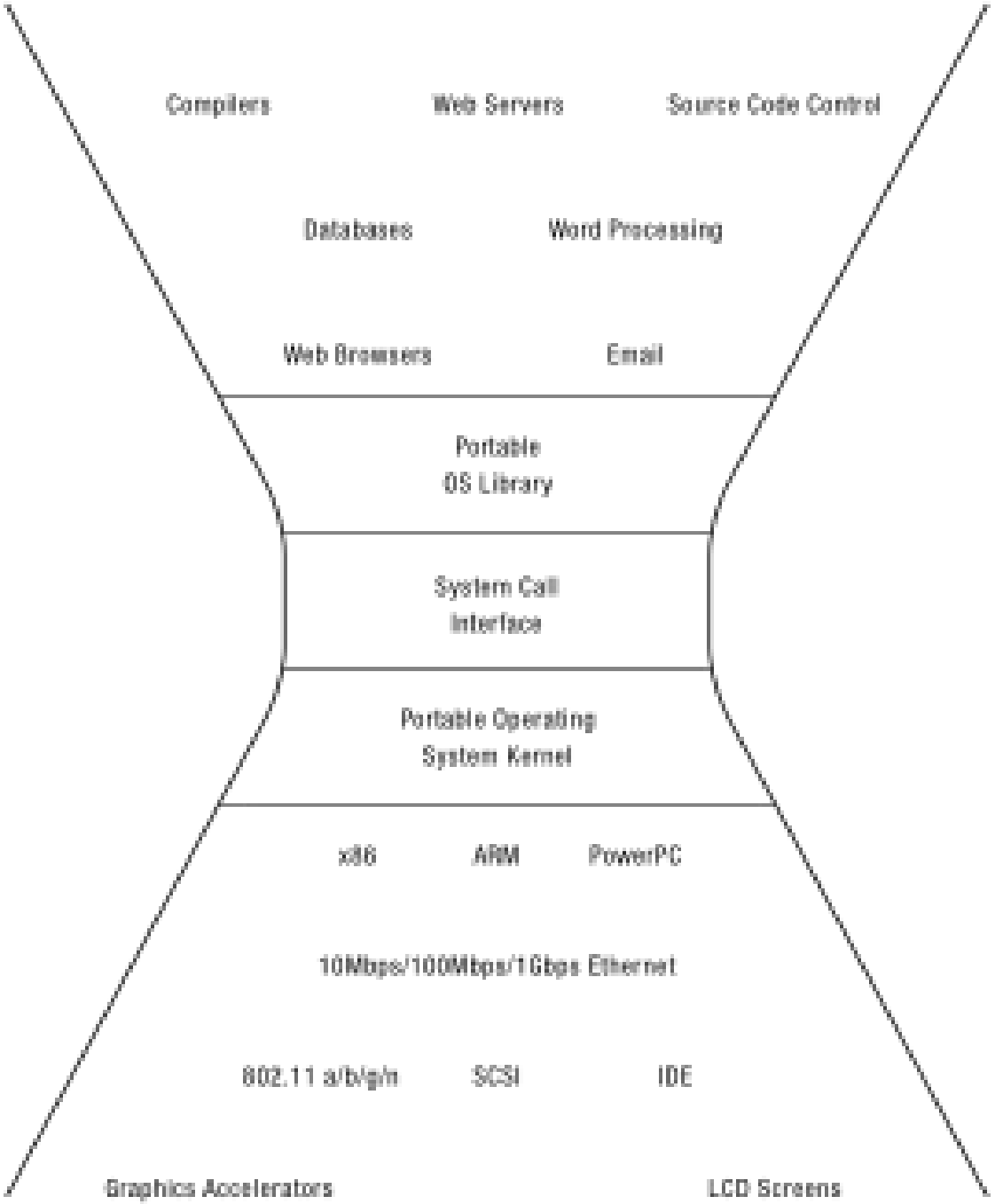
# The Programming Interface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# Main Points

- Creating and managing processes
  - fork, exec, wait
- Performing I/O
  - open, read, write, close
- Communicating between processes
  - pipe, dup, select, connect
- Example: implementing a shell

# Shell

- A shell is a job control system
  - Allows programmer to create and manage a set of programs to do some task
  - Windows, MacOS, Linux all have shells

- Example: to compile a C program

  cc –c sourcefile1.c

  cc –c sourcefile2.c

  ln –o program sourcefile1.o sourcefile2.o

# Question

- If the shell runs at user-level, what system calls does it make to run each of the programs?
  - Ex: cc, ln

# Windows CreateProcess

- System call to create a new process to run a program
  - Create and initialize the process control block (PCB) in the kernel
  - Create and initialize a new address space
  - Load the program into the address space
  - Copy arguments into memory in the address space
  - Initialize the hardware context to start execution at ``start''
  - Inform the scheduler that the new process is ready to run

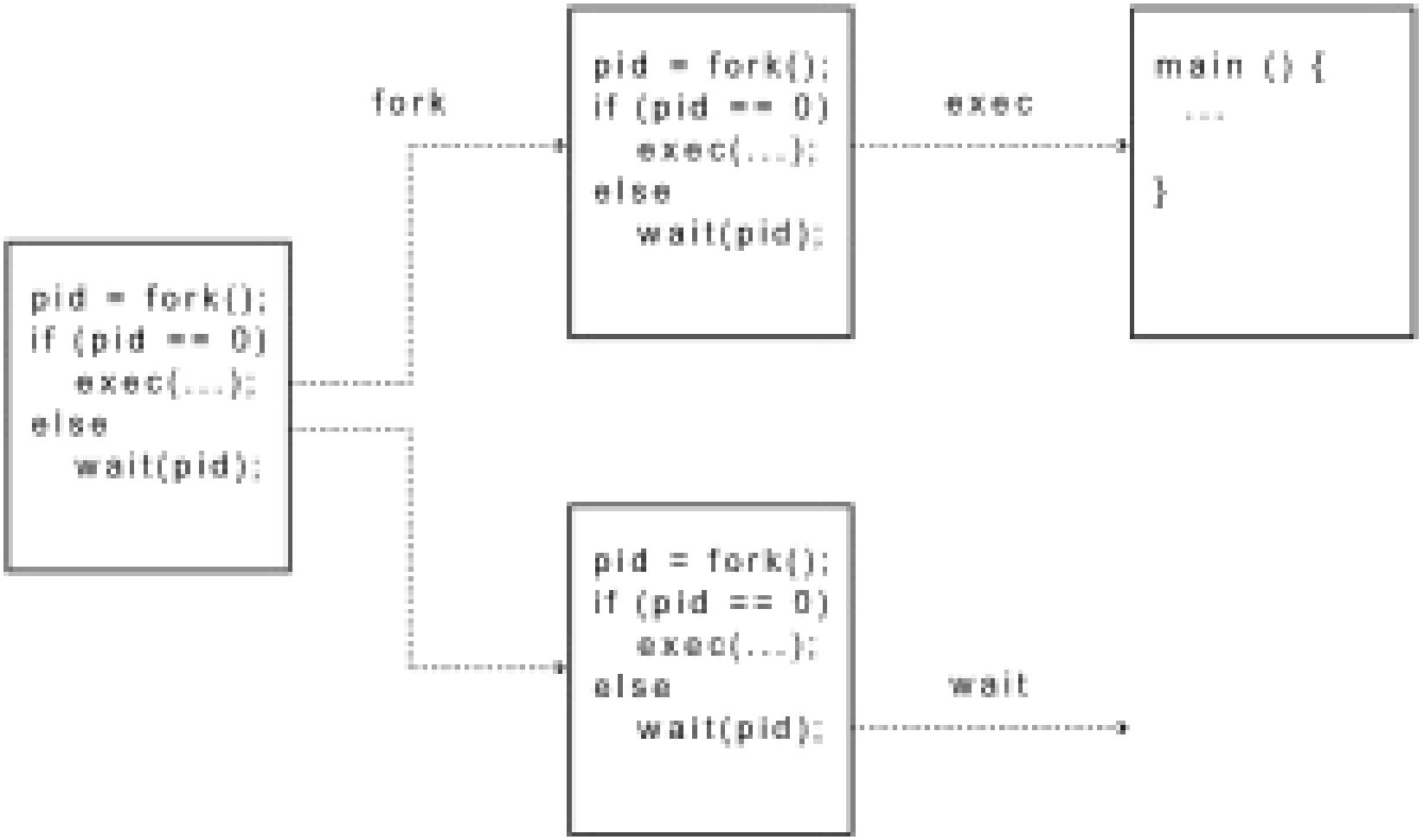
# Windows CreateProcess API (simplified)

```
if (!CreateProcess(
    NULL,           // No module name (use command line)
    argv[1],        // Command line
    NULL,           // Process handle not inheritable
    NULL,           // Thread handle not inheritable
    FALSE,          // Set handle inheritance to FALSE
    0,              // No creation flags
    NULL,           // Use parent's environment block
    NULL,           // Use parent's starting directory
    &si,            // Pointer to STARTUPINFO structure
    &pi )           // Pointer to PROCESS_INFORMATION structure
)
```

# UNIX Process Management

- UNIX fork – system call to create a copy of the current process, and start it running
  - No arguments!
- UNIX exec – system call to change the program being run by the current process
- UNIX wait – system call to wait for a process to finish
- UNIX signal – system call to send a notification to another process

# UNIX Process Management



# Question: What does this code print?

```
int child_pid = fork();
if (child_pid == 0) {          // I'm the child process
    printf("I am process #%d\n", getpid());
    return 0;
} else {                       // I'm the parent process
    printf("I am parent of process #%d\n", child_pid);
    return 0;
}
```

# Questions

- Can UNIX fork() return an error?  Why?
- Can UNIX exec() return an error?  Why?
- Can UNIX wait() ever return immediately?  Why?

# Implementing UNIX fork

Steps to implement UNIX fork

- Create and initialize the process control block (PCB) in the kernel
- Create a new address space
- Initialize the address space with a copy of the entire contents of the address space of the parent
- Inherit the execution context of the parent (e.g., any open files)
- Inform the scheduler that the new process is ready to run

# Implementing UNIX exec

- Steps to implement UNIX fork
  - Load the program into the current address space
  - Copy arguments into memory in the address space
  - Initialize the hardware context to start execution at ``start''

# UNIX I/O

- Uniformity
  - All operations on all files, devices use the same set of system calls: open, close, read, write
- Open before use
  - Open returns a handle (file descriptor) for use in later calls on the file
- Byte-oriented
- Kernel-buffered read/write
- Explicit close
  - To garbage collect the open file descriptor

# UNIX File System Interface

- UNIX file open is a Swiss Army knife:
  - Open the file, return file descriptor
  - Options:
    - if file doesn't exist, return an error
    - If file doesn't exist, create file and open it
    - If file does exist, return an error
    - If file does exist, open file
    - If file exists but isn't empty, nix it then open
    - If file exists but isn't empty, return an error
    - …

# Interface Design Question

- Why not separate syscalls for open/create/exists?

```
if (!exists(name))
    create(name);   // can create fail?
fd = open(name);   // does the file exist?
```

# Implementing a Shell

```
char *prog, **args;
int child_pid;

// Read and parse the input a line at a time
while (readAndParseCmdLine(&prog, &args)) {
   child_pid = fork();      // create a child process
    if (child_pid == 0) {
       exec(prog, args);       // I'm the child process.  Run program
      // NOT REACHED
    } else {
       wait(child_pid);       // I'm the parent, wait for child
       return 0;
    }
}
```