Programs and Processes

The concept of process is fundamental to the structure of modern computer operating systems. Its evolution in analyzing problems of synchronization, deadlock, and scheduling in operating systems has been a major intellectual contribution of computer science.

WHAT CAN BE AUTOMATED?:
THE COMPUTER SCIENCE AND
ENGINEERING RESEARCH STUDY,
MIT Press, 1980

Objectives

- Define the term process and explain the relationship between processes and process control block
- Explain the concept of a process state and discuss the state transition the process undergoes
- List and describe the purpose of the data structures and data structure elements used by an OS to manage processes
- Assess the requirements for process control by the OS
- Understand the issues involved in the execution of OS code

- multiprogramming
  - one process at a time
- multiprocessing
  - many processes at a time
- process
  - execution environment
    - provided by operating system
  - communicate with OS and with each other
  - system processes
  - user processes

library functions

- library files
  - collection of functions
  - available to programs
  - library function
    - runtime library functions
- static libraries
  - during linking
- shared object libraries
  - at load time
  - shared by many processes

library functions

- library files
  - .a
    - static
    - ar utility
      - examine library functions
      - create library functions

```
linux$  cc -c change_case.c
linux$  cc -c ascii.c
linux$  ar cr libmy_demo.a ascii.o change_case.o
```

```
FILE: main.c
    #include <iostream>
    #include "my_demo.h"
    ...
```

```
linux$  cc -o main main.c -L. -lmy_demo
```

```
FILE: ascii.c
      char *
      ascii( in start, int finish ) {
      char *b = new cha(finish-start+1);
      for ( int i=start; i <= finish; ++i)
            b( i-start ) = char ( i );
      return b;
}

FILE: change_case.c
      #include <ctype.h>
      char *
      change_case ( char *s ) {
      char *t = &s[0];
      while ( *t ) {
            if ( isalpha(*t) 0
                  *t += islower(*t) ? -32 : 32;
            ++t;
      }
      return s;
}

FILE: my_demo.h
      /*
      prototypes for my_demo lirary functions
      */
      #ifndef MY_DEMO_H

      #define MY_DEMO_H
      char * ascii ( int, int );
      char * change_case ( char * );

      #endif
```

- system calls
  - request service from operating system
  - OS performs work on behalf of caller
    - kernel
  - user mode
    - subset of instructions
- system (privileged) mode
  - entire instruction set

```
#apropos  '(2'
```

linking object code

- object code
  - library files and compiled code
    - combined at compile time
  - files not in standard library
    - specified at compile time

```
linux$  cc prgm.c -lm
```

- include math library libm.a

managing failures

- system calls / library function return codes
  - external global **`errno`**
  - defined constants in **`<sys/errno.h>`**
  - always examine return codes!!!!
  - **`perror`**
    - to produce error message

```
void perror ( const char *s );
```

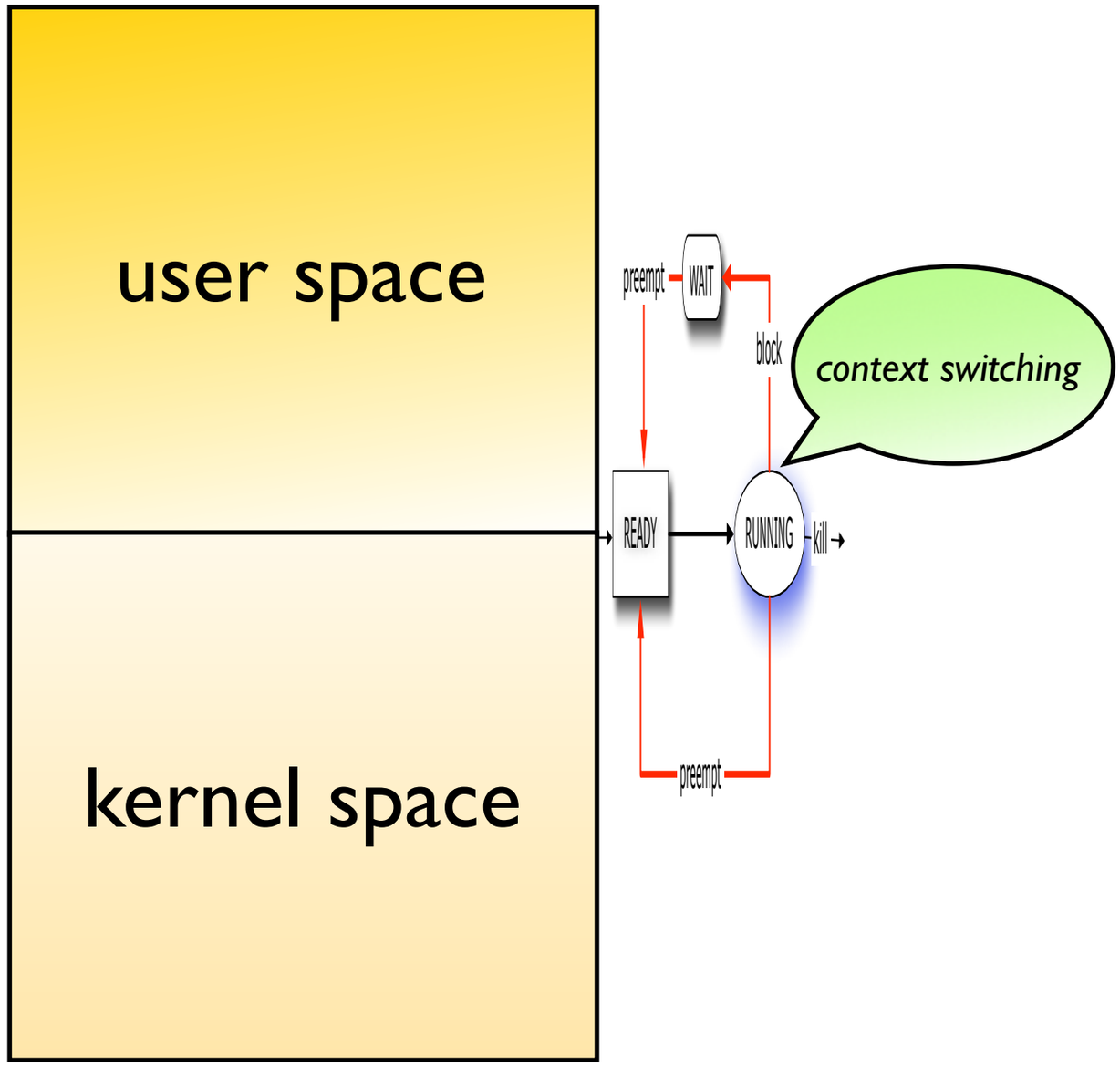
  - review **`strerror`**

execution file format

- ELF (executable and linking format)
  - marked as executable
    - program text
    - data
    - relocation information
    - symbol table
    - string table

old format: `a.out`
Assembler OUtpuT Format

- System memory
  - user space
    - user processes
    - protected
    - run in user mode
  - kernel space
    - kernel execution
    - system processes
    - privileged mode



- process memory
  - private memory
  - divided into three segments
    - text
      - code
    - data
      - initialized variables
      - uninitialized variables
  - stack
    - automatic identifiers
    - function call information

- text segment
  - read-only segment
  - instruction segment
  - constant data
  - can be shared among processes
- different instantiations of same code

- data segment
  - virtually contiguous to text segment
  - initialized/uninitialized data
  - may be expanded at execution time
    - `new, malloc, calloc`

- stack segment
  - automatic identifiers
  - register variables
  - function call information
  - grows towards uninitialized data segment

- u-area
  - maintained by operating system
    - one per process
  - specific process information
    - open files
    - current directory
    - signal actions
    - accounting information
    - a system stack segment
      - system calls
  - process can access information
    - via system calls

process memory

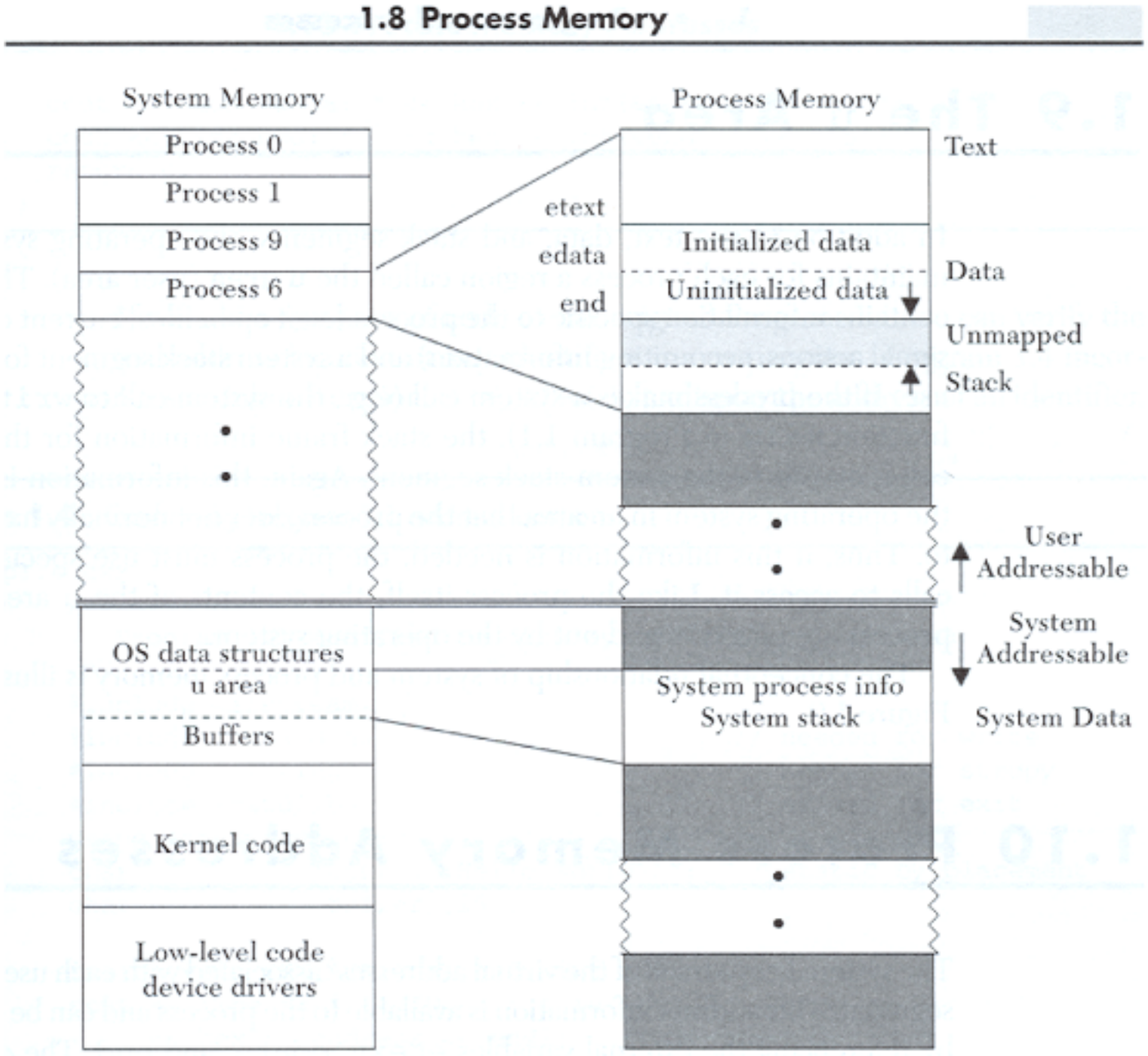


Figure 1.9 System and process memory.

creating a process

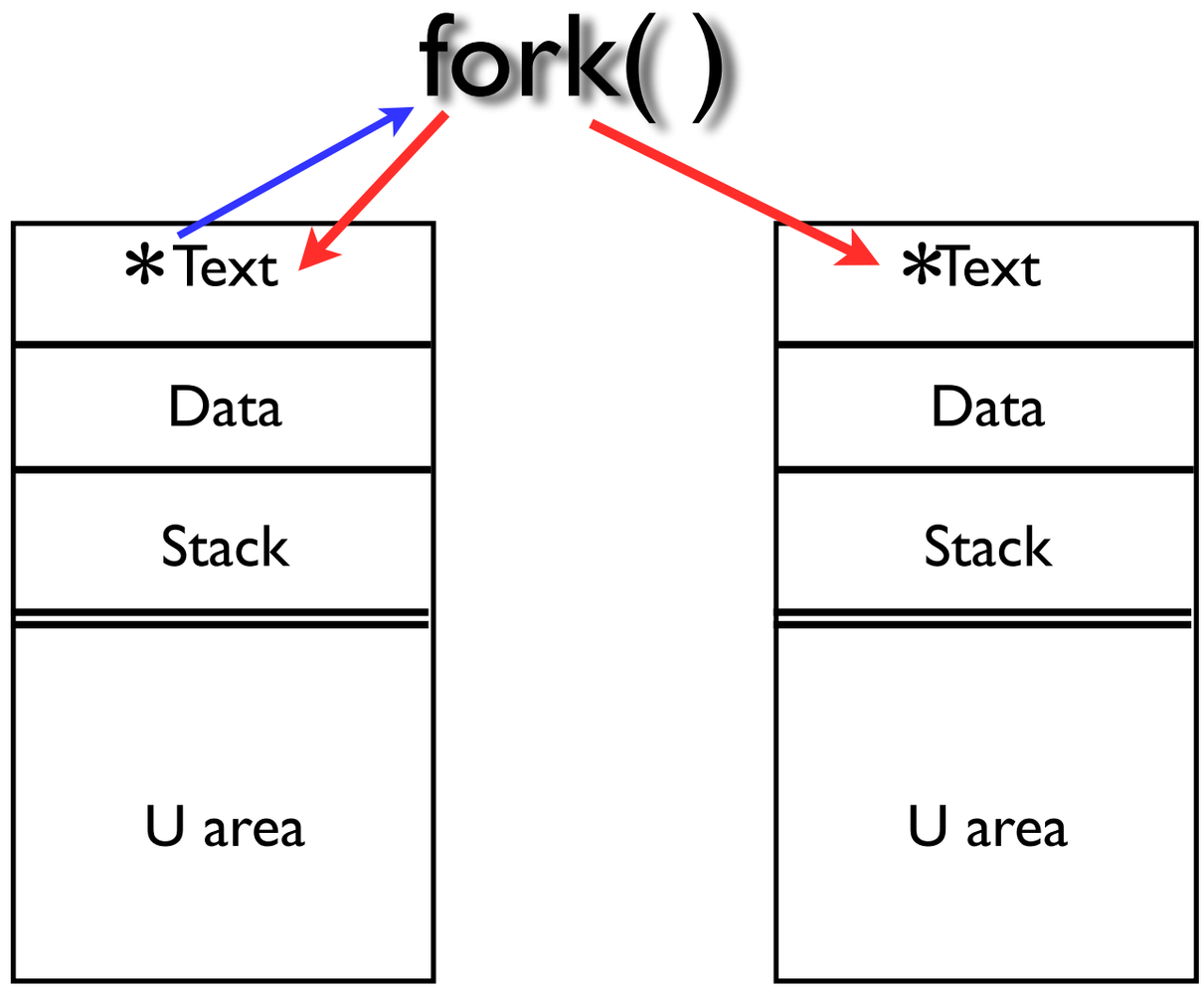
- `fork ()`
  - parent process
    - process executing the `fork()`
  - child process
    - created by `fork()` system call

```
pid_t  fork ( void );
```

Constant	perror Message	Explanation
EAGAIN	Resource temporarily unavailable	No memory to copy parents page table and allocate task structure
ENOMEM	Cannot allocate memory	Insufficient swap space

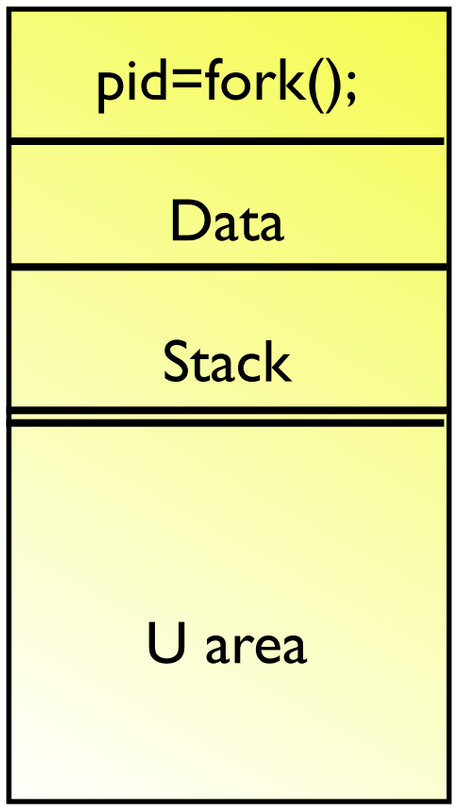
fork( ) System Call

- returns twice
  - in parent
    - returns child PID
  - in child
    - returns 0
- process can identify itself
  - parent or child



fork( ) System Call

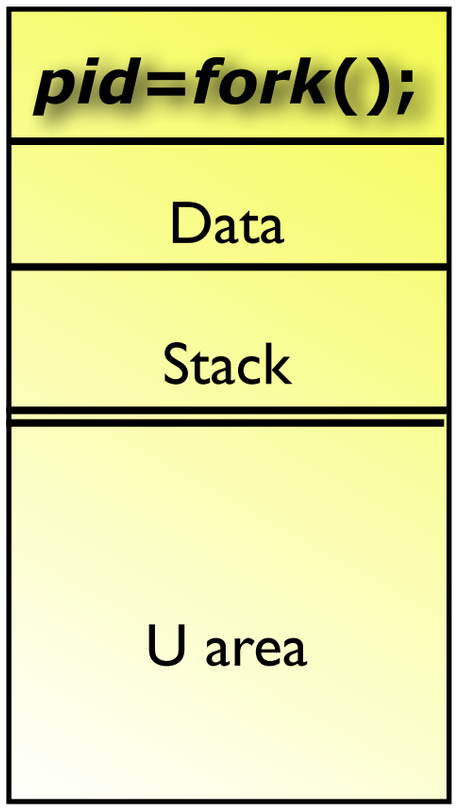
process id=789



process executes a fork():

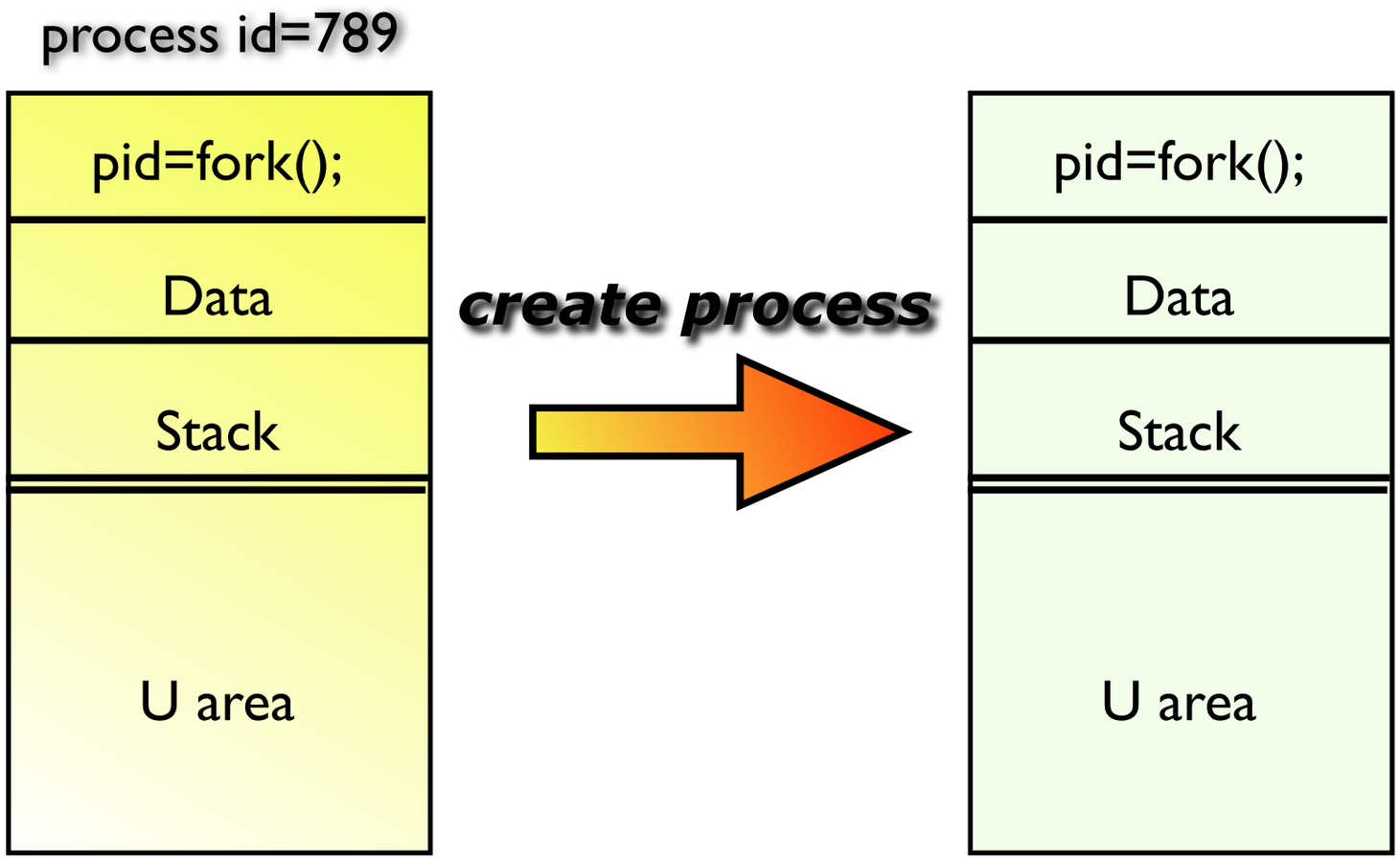
fork( ) System Call

process id=789

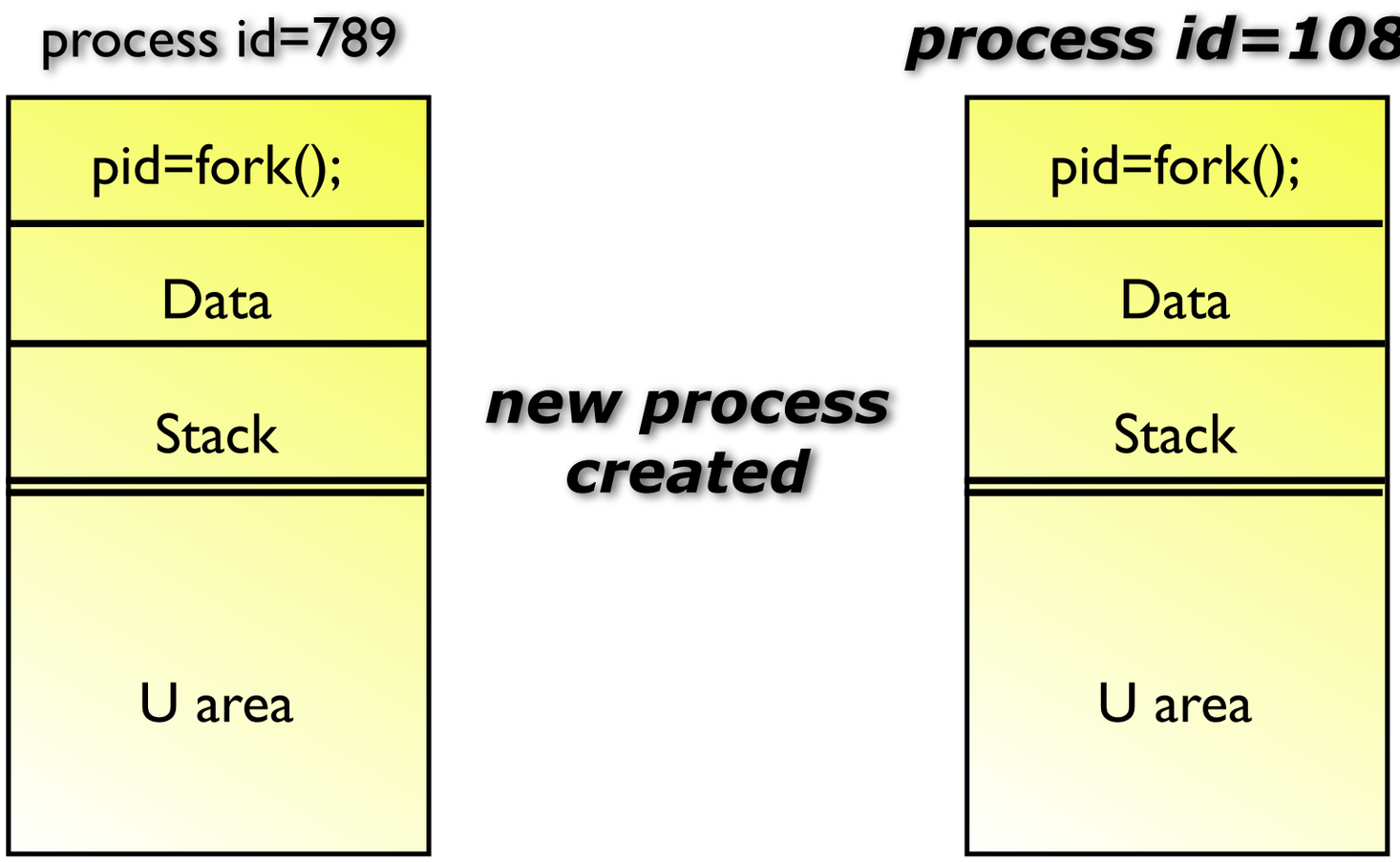


fork system call

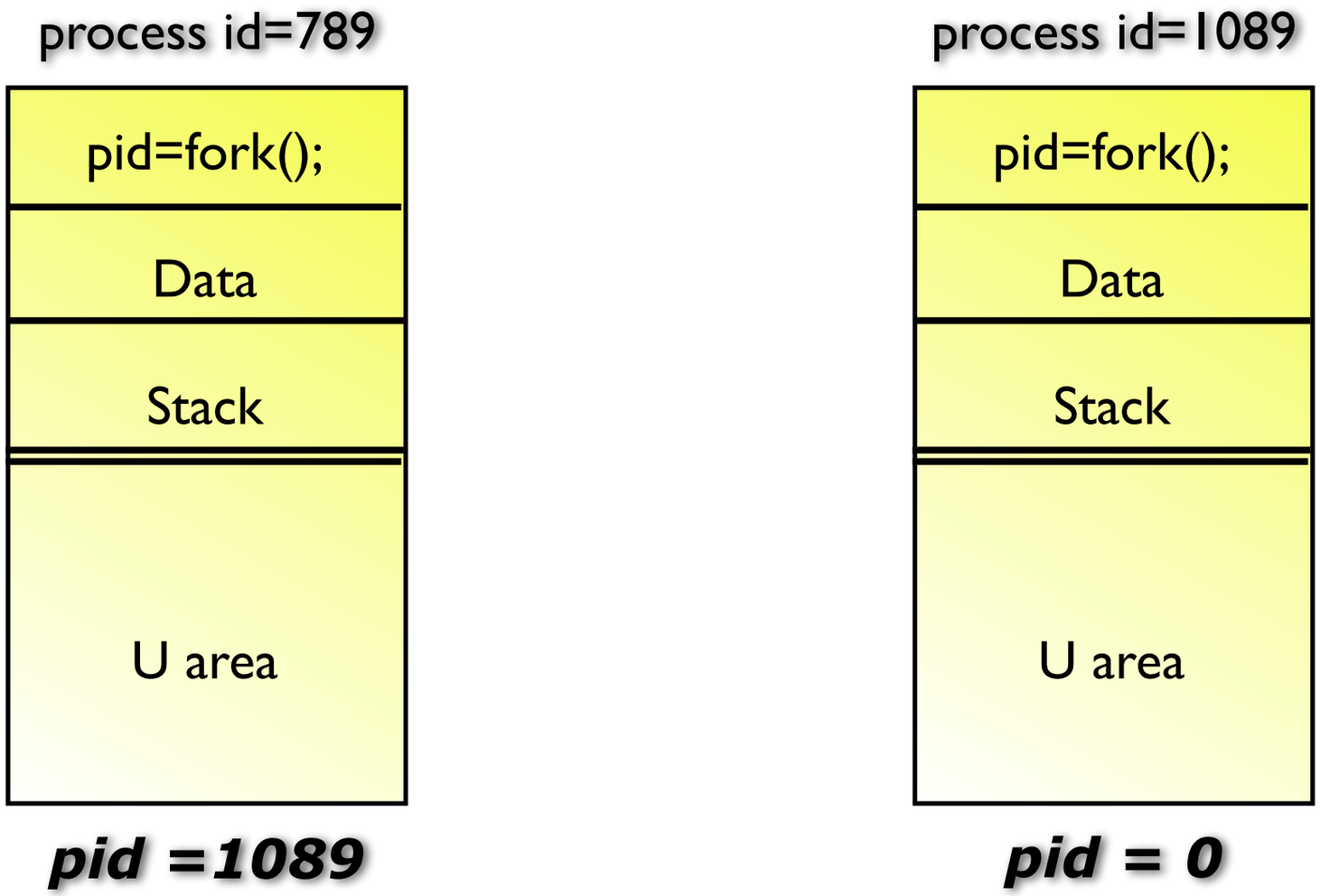
fork( ) System Call



fork( ) System Call



fork( ) System Call



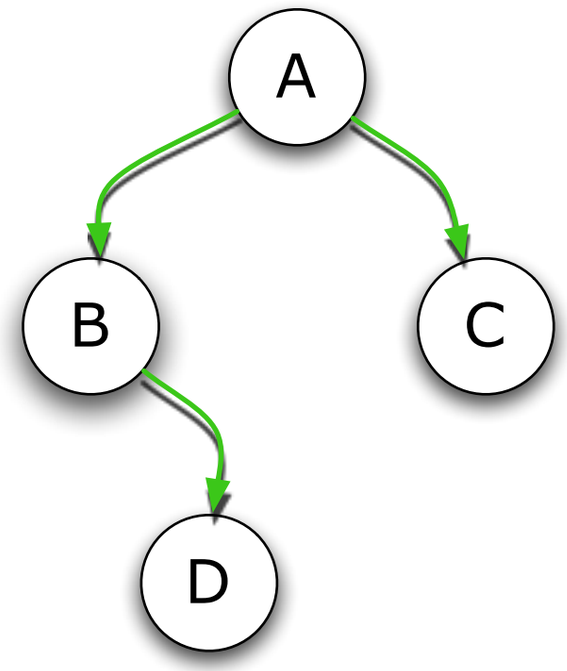
fork( ) System Call


```
pid  = fork ();
if ( pid == 0 ){
   // in child process
}
// in parent process
```

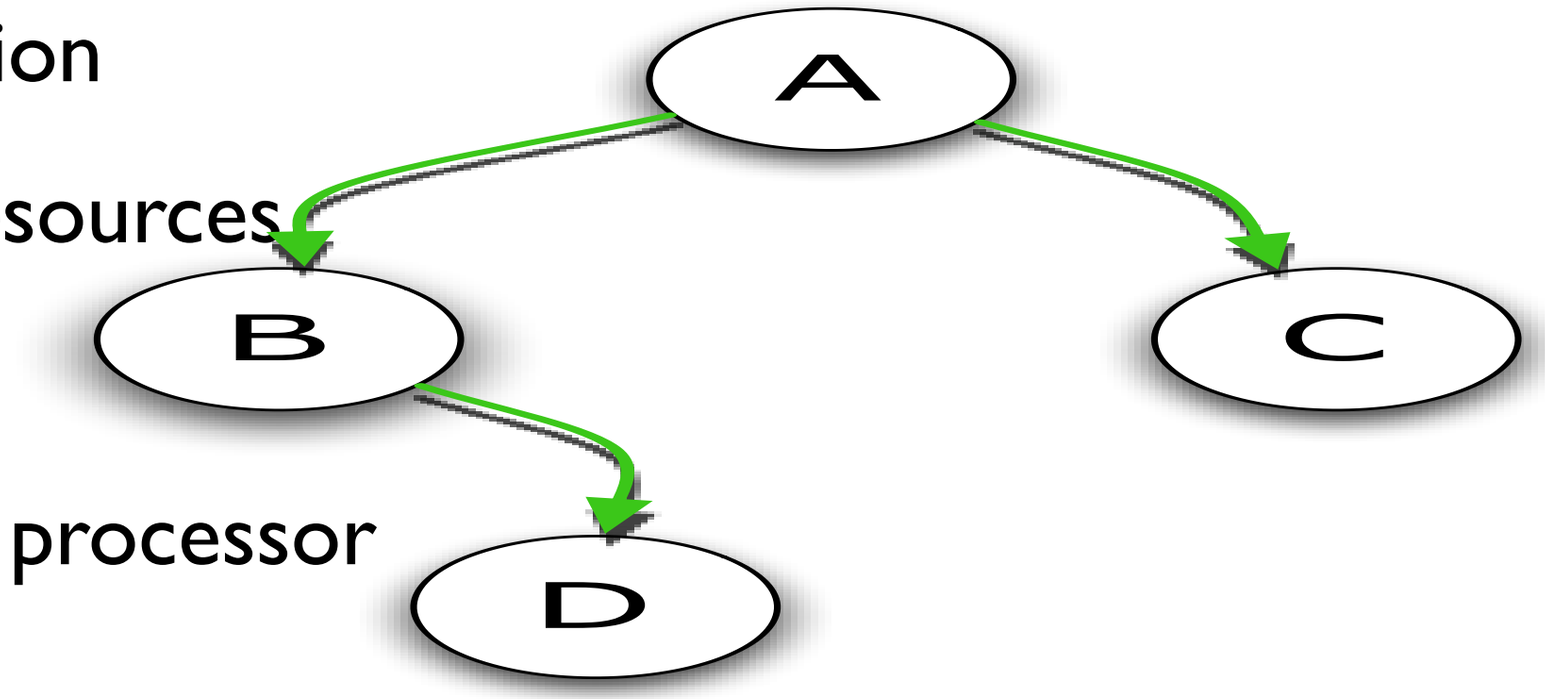
- Unique to process
  - PID
  - PPID
  - System imposed process limits are reset
    - CPU allocation time
  - File record locks are reset
  - Signal actions

- Share
  - real UID
  - real GID
  - effective UID
  - effective GID
  - process GUI
  - controlling terminal
  - set-user-id flag and set-group-id flag
  - current working directory
  - root directory
  - file mode creation mask
  - signal mask and dispositions
  - the close-on-exec flag for any open file descriptors
  - attached shared memory segments
  - open file descriptors
  - Environment information

- processes may create other processes
  - parent - child relation
    - A parent of B and C
    - B parent of D



- Process States
  - Ready
    - ready for execution
    - has all needed resources
  - Running
    - in control of the processor
  - Wait
    - waiting for an event to occur
      - waiting for a resource



- Process Control Block (PCB)
  - data structure created by the Operating System
    - one entry per process
      - create a process ⟶ entry in PCB
    - all information about a process
      - process id (PID)
      - dispatching information
        - priority
          - CPU time
      - resources
        - allocated
        - outstanding

A process is known through its PCB