CSGE602055 Operating Systems
CSF2600505 Sistem Operasi
Week 06: Concurrency: Processes & Threads

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https://os.vlsm.org/
Always check for the latest revision!

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Operating Systems 2020-1

A [08-10, Rm 3114, Mo/We] — B/M [10:10-12, Rm 3114, Mo/We] — C [13-15, Rm 3114, Mo/We]

D [10-12, Rm 2307(Mo), Rm 3113(We)] — E [08-10, Rm 2307(Mo), Rm 3113(We)]

Week	Schedule	Topic	OSC10
Week 00	27 Jan - 02 Feb 2020	Overview 1, Virtualization & Scripting	Ch. 1, 2, 18.
Week 01	03 Feb - 09 Feb 2020	Overview 2, Virtualization & Scripting	Ch. 1, 2, 18.
Week 02	10 Feb - 16 Feb 2020	Security, Protection, Privacy,	Ch. 16, 17
		& C-language	
Week 03	17 Feb - 23 Feb 2020	File System & FUSE	Ch. 13, 14, 15
Week 04	24 Feb - 01 Mar 2020	Addressing, Shared Lib, & Pointer	Ch. 9
Week 05	02 Mar - 08 Mar 2020	Virtual Memory	Ch. 10
Reserved	09 Mar - 13 Mar 2020	Q & E	
MidTerm	14-21 Mar 2020 (TBA)	MidTerm (UTS)	Subject to change.
Week 06	23 Mar - 31 Mar 2020	Concurrency: Processes & Threads	Ch. 3, 4
Week 07	01 Apr - 07 Apr 2020	Synchronization & Deadlock	Ch. 6, 7, 8
Week 08	08 Apr - 14 Apr 2020	Scheduling + W06/W07	Ch. 5
Week 09a	15 Apr - 19 Apr 2020	Storage, Firmware, Bootldr, & Systemd	Ch. 11
OCL	20 Apr - 26 Apr 2020	OnLine & CoLearnIng	
Week 09b	27 Apr - 28 Apr 2020	Storage, Firmware, Bootldr, & Systemd	Ch. 11
Week 10	29 Apr - 05 May 2020	I/O & Programming	Ch. 12
Reserved	06 May - 10 May 2020	Q & A	
Final	11-18 May 2020 (TBA)	Final (UAS)	This schedule is
Extra	25 Jun 2020	Extra assignment confirmation	subject to change.

□ **Text Book** — Any recent/decent OS book. Eg. (**OSC10**)
Silberschatz et. al.: **Operating System Concepts**, 10th Edition,
2018. See also http://codex.cs.yale.edu/avi/os-book/OS10/.

□ **Resources**

    □ **All In One** — BADAK.cs.ui.ac.id:///extra/ (**FASILKOM only!**).

    □ **Download Slides and Demos from GitHub.com**
       https://github.com/UI-FASILKOM-OS/SistemOperasi/

    □ **Problems** — https://rms46.vlsm.org/2/:
       195.pdf (W00), 196.pdf (W01), 197.pdf (W02), 198.pdf (W03),
       199.pdf (W04), 200.pdf (W05), 201.pdf (W06), 202.pdf (W07),
       203.pdf (W08), 204.pdf (W09), 205.pdf (W10).

□ **Try Demos**

    □ Your own Ubuntu system.

    □ Ubuntu on VirtualBox, or VMWare, or . . .

    □ Windows Subsystem for Linux (**Windows 10 only!**).

    □ SSH to BADAK.cs.ui.ac.id (**FASILKOM only!**).

Agenda I

Agenda II

- States and state diagrams
- Structures (ready list, process control blocks, and so forth)
- Dispatching and context switching
- The role of interrupts
- Managing atomic access to OS objects
- Implementing synchronization primitives
- Multiprocessor issues (spin-locks, reentrancy)

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[1]Source: ACM IEEE CS Curricula 2013

Week 06 Concurrency: Learning Outcomes (1)[1]

- Describe the need for concurrency within the framework of an operating system. [Familiarity]
- Demonstrate the potential run-time problems arising from the concurrent operation of many separate tasks. [Usage]
- Summarize the range of mechanisms that can be employed at the operating system level to realize concurrent systems and describe the benefits of each. [Familiarity]
- Explain the different states that a task may pass through and the data structures needed to support the management of many tasks. [Familiarity]

[1]Source: ACM IEEE CS Curricula 2013

- Summarize techniques for achieving synchronization in an operating system (e.g., describe how to implement a semaphore using OS primitives). [Familiarity]
- Describe reasons for using interrupts, dispatching, and context switching to support concurrency in an operating system. [Familiarity]
- Create state and transition diagrams for simple problem domains. [Usage]

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[1]Source: ACM IEEE CS Curricula 2013

Week 06: Concurrency: Processes & Threads

- Reference: (OSC10-ch03 OSC10-ch04 demo-w06)
- Process Concept
    - Program (passive) ↔ Process (active)
    - Process in Memory: | *Stack* ⋯ *Heap* | *Data* | *Text* |
    - Process State: | *running* | *waiting* | *ready* |
    - Process Control Block (PCB)
        - /proc/, Process State, Program Counter, Registers, Management Information.
- Process Creation
    - PID: Process Identifier (uniq)
    - The Parent Process forms a tree of Children Processes
    - fork(), new process system call (clone)
    - execlp(), replaces the clone with a new program.
- Process Termination
    - wait(), until the child process is terminated.
- PCB (Context) Switch

A PROCESS IN MEMORY
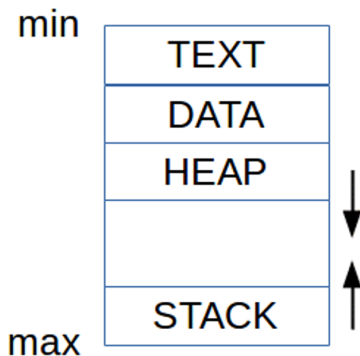
(c) 2017 VauLSMorg

Figure: A Process in (**logical**) Memory

Process State

Figure: A Process State

Process Scheduling

- Scheduling Queue
- Schedulers
  - Long Term (non VM) vs Short Term (CPU)
  - (I/O vs CPU) Bound Processes
- Context Switch
- I/O Queue Scheduling
- Android Systems
  - Dalvik VM Performance Problem: Replaced with ART (Android Runtime).
  - Foreground Processes: with an User Interface (UI) for Videos, Images, Sounds, Texts, etc.
  - Background Processes: with a service with no UI and small memory footprint.

Inter-Process Communication (IPC)

- Independent vs Cooperating Processes.
    - Cooperation: Information Sharing, Computational Speedup, Modularity, Convenience.
- Shared Memory vs Message Passing.
    - Message Passing: Direct vs Indirect Comunication
- Client-Server Systems
    - Sockets
    - RPC: Remote Procedure Calls
    - Pipes

Threads

- Single vs Multithreaded Process
    - MultiT Benefits: Responsiveness, Resource Sharing, Economy, Scalability
- Multicore Programming
    - Concurrency vs. Parallelism
- Multithreading Models (Kernel vs User Thread)
    - Many to One
    - One to One
    - Many to Many
    - Multilevel Models
- Threading Issues
    - Parallelism on a multi-core system.
- Pthreads

Makefile

```
CC=gcc
P00=00-fork
P01=01-fork
...
P14=14-fork
P15=15-fork

EXECS= \
    $(P00) \
    $(P01) \
    ....
    $(P14) \
    $(P15) \

all:  $(EXECS)

$(P00): $(P00).c
    $(CC) $(P00).c -o $(P00)

$(P01): $(P01).c
    $(CC) $(P01).c -o $(P01)

...

$(P14): $(P14).c
    $(CC) $(P14).c -o $(P14)

$(P15): $(P15).c
    $(CC) $(P15).c -o $(P15)

clean:
    rm -f $(EXECS)
```

00-fork

```
/*
 * (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV04 Mon Oct 30 10:28:12 WIB 2017
 * START Mon Oct 24 09:42:05 WIB 2016
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>

void main(void) {
   printf("  [[[ This is 00-fork: PID[%d] PPID[%d] ]]]\n",
           getpid(), getppid());
}

>>>>> $ 00-fork

  [[[ This is 00-fork: PID[5777] PPID[1350] ]]]
```

01-fork

```
>>>>> $ cat 01-fork.c ; echo "======" ; ./01-fork
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
   char *iAM="PARENT";

   printf("PID[%d] PPID[%d] (START:%s)\n", getpid(), getppid(), iAM);
   if (fork() > 0) {
      sleep(1);     /* LOOK THIS ************** */
      printf("PID[%d] PPID[%d] (IFF0:%s)\n", getpid(), getppid(), iAM);
   } else {
      iAM="CHILD";
      printf("PID[%d] PPID[%d] (ELSE:%s)\n", getpid(), getppid(), iAM);
   }
   printf("PID[%d] PPID[%d] (STOP:%s)\n", getpid(), getppid(), iAM);
}

======
PID[5784] PPID[1350] (START:PARENT)
PID[5785] PPID[5784] (ELSE:CHILD)
PID[5785] PPID[5784] (STOP:CHILD)
PID[5784] PPID[1350] (IFF0:PARENT)
PID[5784] PPID[1350] (STOP:PARENT)
>>>>> $
```

02-fork

```
>>>>> $ cat 02-fork.c ; echo "======" ; ./02-fork
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
   char *iAM="PARENT";

   printf("PID[%d] PPID[%d] (START:%s)\n", getpid(), getppid(), iAM);
   if (fork() > 0) {
      printf("PID[%d] PPID[%d] (IFF0:%s)\n", getpid(), getppid(), iAM);
   } else {
      iAM="CHILD";
      printf("PID[%d] PPID[%d] (ELSE:%s)\n", getpid(), getppid(), iAM);
      sleep(1);    /* LOOK THIS ************** */
   }
   printf("PID[%d] PPID[%d] (STOP:%s)\n", getpid(), getppid(), iAM);
}

======
PID[5792] PPID[1350] (START:PARENT)
PID[5792] PPID[1350] (IFF0:PARENT)
PID[5792] PPID[1350] (STOP:PARENT)
PID[5793] PPID[5792] (ELSE:CHILD)
>>>>> $ PID[5793] PPID[1] (STOP:CHILD)
>>>>> $
```

```
>>>>> $ cat 03-fork.c ; echo "======" ; ./03-fork
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
   char *iAM="PARENT";

   printf("PID[%d] PPID[%d] (START:%s)\n", getpid(), getppid(), iAM);
   if (fork() > 0) {
      wait(NULL);      /* LOOK THIS ************** */
      printf("PID[%d] PPID[%d] (IFF0:%s)\n", getpid(), getppid(), iAM);
   } else {
      iAM="CHILD";
      printf("PID[%d] PPID[%d] (ELSE:%s)\n", getpid(), getppid(), iAM);
   }
   printf("PID[%d] PPID[%d] (STOP:%s)\n", getpid(), getppid(), iAM);
}

======
PID[5799] PPID[1350] (START:PARENT)
PID[5800] PPID[5799] (ELSE:CHILD)
PID[5800] PPID[5799] (STOP:CHILD)
PID[5799] PPID[1350] (IFF0:PARENT)
PID[5799] PPID[1350] (STOP:PARENT)
>>>>> $
```

```
>>>>> $ ./01-fork
PID[5803] PPID[1350] (START:PARENT)
PID[5804] PPID[5803] (ELSE:CHILD)
PID[5804] PPID[5803] (STOP:CHILD)
PID[5803] PPID[1350] (IFF0:PARENT)
PID[5803] PPID[1350] (STOP:PARENT)
>>>>> $ ./02-fork
PID[5805] PPID[1350] (START:PARENT)
PID[5805] PPID[1350] (IFF0:PARENT)
PID[5805] PPID[1350] (STOP:PARENT)
PID[5806] PPID[5805] (ELSE:CHILD)
>>>>> $ PID[5806] PPID[1] (STOP:CHILD)

>>>>> $ ./03-fork
PID[5807] PPID[1350] (START:PARENT)
PID[5808] PPID[5807] (ELSE:CHILD)
PID[5808] PPID[5807] (STOP:CHILD)
PID[5807] PPID[1350] (IFF0:PARENT)
PID[5807] PPID[1350] (STOP:PARENT)
>>>>> $
```

04-sleeping

```c
#include <stdio.h>
#include <unistd.h>
void main(void) {
   int ii;
   printf("Sleeping 3s with fflush(): ");
   fflush(NULL);
   for (ii=0; ii < 3; ii++) {
      sleep(1);
      printf("x ");
      fflush(NULL);
   }
   printf("\nSleeping with no fflush(): ");
   for (ii=0; ii < 3; ii++) {
      sleep(1);
      printf("x ");
   }
   printf("\n");
}
Sleeping 3s with fflush(): x x x
Sleeping with no fflush(): x x x
```

```c
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
   printf("Start:          PID[%d] PPID[%d]\n", getpid(), getppid());
   fflush(NULL);
   if (fork() == 0) {
      /* START BLOCK
         END   BLOCK */
      execlp("./00-fork", "00-fork", NULL);
      printf("Child:          ");
   } else {
      wait(NULL);
      printf("Parent:         ");
   }
   printf(        "PID[%d] PPID[%d]  <<< <<< <<<\n", getpid(), getppid());
}
```

```
execlp ====================
Start:          PID[6007] PPID[1350]
  [[[ This is 00-fork: PID[6008] PPID[6007] ]]]
Parent:         PID[6007] PPID[1350]   <<< <<< <<<

no execlp ==================
Start:          PID[6040] PPID[1350]
Child:          PID[6041] PPID[6040]   <<< <<< <<<
Parent:         PID[6040] PPID[1350]   <<< <<< <<<
```

```c
#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
/*************************************************** main ** */
void main(void) {
   pid_t val1, val2, val3;
   val3 = val2 = val1 = 1000;
   printf("PID==%4d ==== ==== ==== ====\n", getpid());
   fflush(NULL);
   val1 = fork();
   wait(NULL);
   val2 = fork();
   wait(NULL);
   val3 = fork();
   wait(NULL);
/* ***** ***** ***** ***** START BLOCK *
   ***** ***** ***** ***** END** BLOCK */
   printf("VAL1=%4d VAL2=%4d VAL3=%4d\n", val1, val2, val3);
}
======
PID==6072 ==== ==== ==== ====
VAL1=   0 VAL2=   0 VAL3=   0
VAL1=   0 VAL2=   0 VAL3=6075
VAL1=   0 VAL2=6074 VAL3=   0
VAL1=   0 VAL2=6074 VAL3=6076
VAL1=6073 VAL2=   0 VAL3=   0
VAL1=6073 VAL2=   0 VAL3=6078
VAL1=6073 VAL2=6077 VAL3=   0
VAL1=6073 VAL2=6077 VAL3=6079
```

```
>>>>> $ cat 07-fork.c
/*
 * (c) 2005-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV05 Mon Oct 30 10:57:02 WIB 2017
 * REV02 Mon Oct 24 10:43:00 WIB 2016
 * REV01 Sun Feb 27 08:31:46 WIB 2011
 * START 2005
 */

#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#define DISPLAY1 "START * PARENT *** ** PID (%4d) ** *********\n"
#define DISPLAY2 "RANDOM: val1(%4d) -- val2(%4d) -- val3(%4d)\n"
/************************************************** main ** */
void main(void) {
    pid_t val1, val2, val3;
    printf(DISPLAY1, getpid());
    val1 = fork();
    val2 = fork();
    val3 = fork();
    printf(DISPLAY2, val1, val2, val3);
    wait(NULL);
    wait(NULL);
    wait(NULL);
/* ********** START BLOCK ***
    ********** END * BLOCK *** */
}
```

```
>>>>> $ 07-fork
START * PARENT *** ** PID (6160) ** **********
RANDOM: val1(6161) -- val2(6162) -- val3(6163)
RANDOM: val1(6161) -- val2(6162) -- val3(   0)
RANDOM: val1(6161) -- val2(   0) -- val3(6165)
RANDOM: val1(6161) -- val2(   0) -- val3(   0)
RANDOM: val1(   0) -- val2(6164) -- val3(6166)
RANDOM: val1(   0) -- val2(6164) -- val3(   0)
RANDOM: val1(   0) -- val2(   0) -- val3(6167)
RANDOM: val1(   0) -- val2(   0) -- val3(   0)
>>>>> $ 07-fork
START * PARENT *** ** PID (6168) ** **********
RANDOM: val1(6169) -- val2(6170) -- val3(6172)
RANDOM: val1(6169) -- val2(   0) -- val3(6173)
RANDOM: val1(6169) -- val2(6170) -- val3(   0)
RANDOM: val1(   0) -- val2(6171) -- val3(6174)
RANDOM: val1(6169) -- val2(   0) -- val3(   0)
RANDOM: val1(   0) -- val2(   0) -- val3(6175)
RANDOM: val1(   0) -- val2(   0) -- val3(   0)
RANDOM: val1(   0) -- val2(6171) -- val3(   0)
>>>>> $ 07-fork
START * PARENT *** ** PID (6176) ** **********
RANDOM: val1(6177) -- val2(6178) -- val3(6181)
RANDOM: val1(   0) -- val2(6179) -- val3(6180)
RANDOM: val1(   0) -- val2(6179) -- val3(   0)
RANDOM: val1(   0) -- val2(   0) -- val3(6182)
RANDOM: val1(6177) -- val2(   0) -- val3(6183)
RANDOM: val1(6177) -- val2(   0) -- val3(   0)
RANDOM: val1(6177) -- val2(6178) -- val3(   0)
RANDOM: val1(   0) -- val2(   0) -- val3(   0)
>>>>> $
```

```
/* (c) 2005-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Thu Oct 26 12:27:30 WIB 2017
 * START 2005
 */
#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
void main(void) {
   int ii=0;
   if (fork() == 0) ii++;
   wait(NULL);
   if (fork() == 0) ii++;
   wait(NULL);
   if (fork() == 0) ii++;
   wait(NULL);
   printf ("Result = %d \n",ii);
   exit(0);
}
======
Result = 3
Result = 2
Result = 2
Result = 1
Result = 2
Result = 1
Result = 1
Result = 0
>>>>> $
```

09-fork

```
/*
 * (c) 2015-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * REV03 Mon Oct 30 11:04:10 WIB 2017
 * REV00 Mon Oct 24 10:43:00 WIB 2016
 * START 2015
 */

#include <stdio.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>

void main(void) {
   int value;

   value=fork();
   wait(NULL);
   printf("I am PID[%4d] -- The fork() return value is: %4d)\n", getpid(), value);

   value=fork();
   wait(NULL);
   printf("I am PID[%4d] -- The fork() return value is: %4d)\n", getpid(), value);
}
======
I am PID[6225] -- The fork() return value is:    0)
I am PID[6226] -- The fork() return value is:    0)
I am PID[6225] -- The fork() return value is: 6226)
I am PID[6224] -- The fork() return value is: 6225)
I am PID[6227] -- The fork() return value is:    0)
I am PID[6224] -- The fork() return value is: 6227)
>>>>> $
```

10-fork

```
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Mon Oct 30 20:25:44 WIB 2017
 */

#include <stdio.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>

void procStatus(int level) {
   printf("L%d: PID[%d] (PPID[%d])\n", level, getpid(), getppid());
   fflush(NULL);
}

int addLevelAndFork(int level) {
   if (fork() == 0) level++;
   wait(NULL);
   return level;
}

void main(void) {
   int level = 0;
   procStatus(level);
   level = addLevelAndFork(level);
   procStatus(level);
}
======
L0: PID[7540] (PPID[1350])
L1: PID[7541] (PPID[7540])
L0: PID[7540] (PPID[1350])
```

11-fork

```
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Mon Oct 30 20:27:24 WIB 2017
 * START Mon Oct 24 09:42:05 WIB 2016
 */

#define  LOOP    3
#include <stdio.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>

void procStatus(int level) {
   printf("L%d: PID[%d] (PPID[%d])\n", level, getpid(), getppid());
   fflush(NULL);
}

int addLevelAndFork(int level) {
   if (fork() == 0) level++;
   wait(NULL);
   return level;
}

void main(void) {
   int ii, level = 0;
   procStatus(level);
   for (ii=0;ii<LOOP;ii++) {
      level = addLevelAndFork(level);
      procStatus(level);
   }
}
```

```
L0: PID[7548] (PPID[1350])
L1: PID[7549] (PPID[7548])
L2: PID[7550] (PPID[7549])
L3: PID[7551] (PPID[7550])
L2: PID[7550] (PPID[7549])
L1: PID[7549] (PPID[7548])
L2: PID[7552] (PPID[7549])
L1: PID[7549] (PPID[7548])
L0: PID[7548] (PPID[1350])
L1: PID[7553] (PPID[7548])
L2: PID[7554] (PPID[7553])
L1: PID[7553] (PPID[7548])
L0: PID[7548] (PPID[1350])
L1: PID[7555] (PPID[7548])
L0: PID[7548] (PPID[1350])
```

12-fork

```c
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void waitAndPrintPID(void) {
    wait(NULL);
    printf("PID: %d\n", getpid());
    fflush(NULL);
}
void main(int argc, char *argv[]) {
    int rc, status;

    waitAndPrintPID();
    rc = fork();
    waitAndPrintPID();
    if (rc == 0) {
        fork();
        waitAndPrintPID();
        execlp("./00-fork", "00-fork", NULL);
    }
    waitAndPrintPID();
}
======
PID: 7614
PID: 7615
PID: 7616
  [[[ This is 00-fork: PID[7616] PPID[7615] ]]]
PID: 7615
  [[[ This is 00-fork: PID[7615] PPID[7614] ]]]
PID: 7614
PID: 7614
>>>>> $
```

14-fork

```c
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <stdlib.h>

void main(void) {
   int firstPID = (int) getpid();
   int    RelPID;

   fork();
   wait(NULL);
   fork();
   wait(NULL);
   fork();
   wait(NULL);

   RelPID=(int)getpid()-firstPID+1000;
   printf("RelPID: %d\n", RelPID);
   fflush(NULL);
}
======
RelPID: 1003
RelPID: 1002
RelPID: 1004
RelPID: 1001
RelPID: 1006
RelPID: 1005
RelPID: 1007
RelPID: 1000
>>>>> $
```

```c
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
#include <sys/wait.h>
#define  NN 2

void main (void) {
   int ii, id1000=getpid()-1000;
   for (ii=1; ii<=NN; ii++) {
       fork();
       wait(NULL);
       int rPID = getpid()-id1000; // "relative"
       int rPPID=getppid()-id1000; // "relative"
       if (rPPID < 1 || rPID < rPPID) rPPID=999;
       printf("Loop [%d] - rPID[%d] - rPPID[%4d]\n", ii, rPID, rPPID);
       fflush(NULL);
   }
}
======
Loop [1] - rPID[1001] - rPPID[1000]
Loop [2] - rPID[1002] - rPPID[1001]
Loop [2] - rPID[1001] - rPPID[1000]
Loop [1] - rPID[1000] - rPPID[ 999]
Loop [2] - rPID[1003] - rPPID[1000]
Loop [2] - rPID[1000] - rPPID[ 999]
>>>>> $
```

The End

- ☐ This is the end of the presentation.
- ☒ This is the end of the presentation.
- This is the end of the presentation.