Chapter 3
Process Description and Control

Seventh Edition
By William Stallings
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
Summary of Earlier Concepts

- A computer platform consists of a collection of hardware resources
- Computer applications are developed to perform some task
- It is inefficient for applications to be written directly for a given hardware platform
- The OS was developed to provide a convenient, feature-rich, secure, and consistent interface for applications to use
- We can think of the OS as providing a uniform, abstract representation of resources that can be requested and accessed by applications
OS Management of Application Execution

- Resources are made available to multiple applications
- The processor is switched among multiple applications so all will appear to be progressing
- The processor and I/O devices can be used efficiently
Two essential elements of a process are:

- **Program code**
  - which may be shared with other processes that are executing the same program

- **A set of data associated with that code**

  When the processor begins to execute the program code, we refer to this executing entity as a *process*
While the program is executing, this process can be uniquely characterized by a number of elements, including:

- identifier
- state
- priority
- program counter
- memory pointers
- context data
- I/O status information
- accounting information
Process Control Block

- Contains the process elements
- It is possible to interrupt a running process and later resume execution as if the interruption had not occurred
- Created and managed by the operating system
- Key tool that allows support for multiple processes

Figure 3.1  Simplified Process Control Block
Process States

**Trace**

the behavior of an individual process by listing the sequence of instructions that execute for that process

**Dispatcher**

small program that switches the processor from one process to another

the behavior of the processor can be characterized by showing how the traces of the various processes are interleaved
Process Execution
Traces of Processes of Figure 3.2

5000 = Starting address of program of Process A
8000 = Starting address of program of Process B
12000 = Starting address of program of Process C

Figure 3.3
Combined Trace of Processes of Figure 3.2

100 = Starting address of dispatcher program

Shaded areas indicate execution of dispatcher process; first and third columns count instruction cycles; second and fourth columns show address of instruction being executed

Figure 3.4
A process may be in one of two states:

- running
- not-running
Queuing Diagram
# Table 3.1 Reasons for Process Creation

<table>
<thead>
<tr>
<th>Reason</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>New batch job</td>
<td>The OS is provided with a batch job control stream, usually on tape or disk. When the OS is prepared to take on new work, it will read the next sequence of job control commands.</td>
</tr>
<tr>
<td>Interactive logon</td>
<td>A user at a terminal logs on to the system.</td>
</tr>
<tr>
<td>Created by OS to provide a service</td>
<td>The OS can create a process to perform a function on behalf of a user program, without the user having to wait (e.g., a process to control printing).</td>
</tr>
<tr>
<td>Spawned by existing process</td>
<td>For purposes of modularity or to exploit parallelism, a user program can dictate the creation of a number of processes.</td>
</tr>
</tbody>
</table>
## Process Creation

<table>
<thead>
<tr>
<th>Process spawning</th>
<th>Parent process</th>
<th>Child process</th>
</tr>
</thead>
<tbody>
<tr>
<td>• when the OS creates a process at the explicit request of another process</td>
<td>• is the original, creating, process</td>
<td>• is the new process</td>
</tr>
</tbody>
</table>
Process Termination

- There must be a means for a process to indicate its completion
- A batch job should include a HALT instruction or an explicit OS service call for termination
- For an interactive application, the action of the user will indicate when the process is completed (e.g. log off, quitting an application)
### Table 3.2

#### Reasons for Process Termination

<table>
<thead>
<tr>
<th>Reason</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal completion</td>
<td>The process executes an OS service call to indicate that it has completed running.</td>
</tr>
<tr>
<td>Time limit exceeded</td>
<td>The process has run longer than the specified total time limit. There are a number of possibilities for the type of time that is measured. These include total elapsed time (&quot;wall clock time&quot;), amount of time spent executing, and, in the case of an interactive process, the amount of time since the user last provided any input.</td>
</tr>
<tr>
<td>Memory unavailable</td>
<td>The process requires more memory than the system can provide.</td>
</tr>
<tr>
<td>Bounds violation</td>
<td>The process tries to access a memory location that it is not allowed to access.</td>
</tr>
<tr>
<td>Protection error</td>
<td>The process attempts to use a resource such as a file that it is not allowed to use, or it tries to use it in an improper fashion, such as writing to a read-only file.</td>
</tr>
<tr>
<td>Arithmetic error</td>
<td>The process tries a prohibited computation, such as division by zero, or tries to store numbers larger than the hardware can accommodate.</td>
</tr>
<tr>
<td>Time overrun</td>
<td>The process has waited longer than a specified maximum for a certain event to occur.</td>
</tr>
<tr>
<td>I/O failure</td>
<td>An error occurs during input or output, such as inability to find a file, failure to read or write after a specified maximum number of tries (when, for example, a defective area is encountered on a tape), or invalid operation (such as reading from the line printer).</td>
</tr>
<tr>
<td>Invalid instruction</td>
<td>The process attempts to execute a nonexistent instruction (often a result of branching into a data area and attempting to execute the data).</td>
</tr>
<tr>
<td>Privileged instruction</td>
<td>The process attempts to use an instruction reserved for the operating system.</td>
</tr>
<tr>
<td>Data misuse</td>
<td>A piece of data is of the wrong type or is not initialized.</td>
</tr>
<tr>
<td>Operator or OS intervention</td>
<td>For some reason, the operator or the operating system has terminated the process (e.g., if a deadlock exists).</td>
</tr>
<tr>
<td>Parent termination</td>
<td>When a parent terminates, the operating system may automatically terminate all of the offspring of that parent.</td>
</tr>
<tr>
<td>Parent request</td>
<td>A parent process typically has the authority to terminate any of its offspring.</td>
</tr>
</tbody>
</table>
Five-State Process Model

Figure 3.6 Five-State Process Model
Process States for Trace of Figure 3.4

Figure 3.7  Process States for Trace of Figure 3.4
Using Two Queues

(a) Single blocked queue
Multiple Blocked Queues

(b) Multiple blocked queues
Swapping

- involves moving part of all of a process from main memory to disk
- when none of the processes in main memory is in the Ready state, the OS swaps one of the blocked processes out on to disk into a suspend queue
One Suspend State

(a) With One Suspend State
Two Suspend States
Characteristics of a Suspended Process

- The process is not immediately available for execution
- The process was placed in a suspended state by an agent: either itself, a parent process, or the OS, for the purpose of preventing its execution
- The process may or may not be waiting on an event
- The process may not be removed from this state until the agent explicitly orders the removal
# Reasons for Process Suspension

<table>
<thead>
<tr>
<th>Reason</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swapping</td>
<td>The OS needs to release sufficient main memory to bring in a process that is ready to execute.</td>
</tr>
<tr>
<td>Other OS reason</td>
<td>The OS may suspend a background or utility process or a process that is suspected of causing a problem.</td>
</tr>
<tr>
<td>Interactive user request</td>
<td>A user may wish to suspend execution of a program for purposes of debugging or in connection with the use of a resource.</td>
</tr>
<tr>
<td>Timing</td>
<td>A process may be executed periodically (e.g., an accounting or system monitoring process) and may be suspended while waiting for the next time interval.</td>
</tr>
<tr>
<td>Parent process request</td>
<td>A parent process may wish to suspend execution of a descendent to examine or modify the suspended process, or to coordinate the activity of various descendants.</td>
</tr>
</tbody>
</table>
Processes and Resources

Figure 3.10 Processes and Resources (resource allocation at one snapshot in time)
OS
Control
Tables

Figure 3.11 General Structure of Operating System Control Tables
Memory Tables

- Used to keep track of both main (real) and secondary (virtual) memory
- Processes are maintained on secondary memory using some sort of virtual memory or simple swapping mechanism

Must include:

- Allocation of main memory to processes
- Allocation of secondary memory to processes
- Protection attributes of blocks of main or virtual memory
- Information needed to manage virtual memory
I/O Tables

- Used by the OS to manage the I/O devices and channels of the computer system

- At any given time, an I/O device may be available or assigned to a particular process

If an I/O operation is in progress, the OS needs to know:

- the status of the I/O operation
- the location in main memory being used as the source or destination of the I/O transfer
Information may be maintained and used by a file management system in which the OS has little or no knowledge of files.

In other operating systems, much of the detail of file management is managed by the OS itself.

These tables provide information about:

- existence of files
- location on secondary memory
- current status
- other attributes
**Process Tables**

- Must be maintained to manage processes
- There must be some reference to memory, I/O, and files, directly or indirectly
- The tables themselves must be accessible by the OS and therefore are subject to memory management
To manage and control a process the OS must know:

- where the process is located
- the attributes of the process that are necessary for its management
Process Control Structures

Process Location

- A process must include a program or set of programs to be executed
- A process will consist of at least sufficient memory to hold the programs and data of that process
- The execution of a program typically involves a stack that is used to keep track of procedure calls and parameter passing between procedures

Process Attributes

- Each process has associated with it a number of attributes that are used by the OS for process control
- The collection of program, data, stack, and attributes is referred to as the process image
- Process image location will depend on the memory management scheme being used
Typical Elements of a Process Image

User Data
The modifiable part of the user space. May include program data, a user stack area, and programs that may be modified.

User Program
The program to be executed.

Stack
Each process has one or more last-in-first-out (LIFO) stacks associated with it. A stack is used to store parameters and calling addresses for procedure and system calls.

Process Control Block
Data needed by the OS to control the process (see Table 3.5).
Process Attributes

Process Identification

Identifiers
Numeric identifiers that may be stored with the process control block include
- Identifier of this process
- Identifier of the process that created this process (parent process)
- User identifier

Processor State Information

User-Visible Registers
A user-visible register is one that may be referenced by means of the machine language that
the processor executes while in user mode. Typically, there are from 8 to 32 of these
registers, although some RISC implementations have over 100.

Control and Status Registers
These are a variety of processor registers that are employed to control the operation of the
processor. These include
- Program counter: Contains the address of the next instruction to be fetched
- Condition codes: Result of the most recent arithmetic or logical operation (e.g., sign,
  zero, carry, equal, overflow)
- Status information: Includes interrupt enabled/disabled flags, execution mode

Stack Pointers
Each process has one or more last-in-first-out (LIFO) system stacks associated with it. A
stack is used to store parameters and calling addresses for procedure and system calls. The
stack pointer points to the top of the stack.
Process Identification

- Each process is assigned a unique numeric identifier.
- Otherwise, there must be a mapping that allows the OS to locate the appropriate tables based on the process identifier.
- Many of the tables controlled by the OS may use process identifiers to cross-reference process tables.
- Memory tables may be organized to provide a map of main memory with an indication of which process is assigned to each region.
- Similar references will appear in I/O and file tables.
- When processes communicate with one another, the process identifier informs the OS of the destination of a particular communication.
- When processes are allowed to create other processes, identifiers indicate the parent and descendants of each process.
Processor State Information

Consists of the contents of processor registers
- user-visible registers
- control and status registers
- stack pointers

Program status word (PSW)
- contains condition codes plus other status information
- EFLAGS register is an example of a PSW used by any OS running on an x86 processor
X86 EFLAGS Register

**Figure 3.12 Pentium II EFLAGS Register**
### Table 3.6

<table>
<thead>
<tr>
<th>Pentium EFLAGS Register Bits</th>
</tr>
</thead>
</table>

#### Control Bits

**AC (Alignment check)**
Set if a word or doubleword is addressed on a nonword or nondoubleword boundary.

**ID (Identification flag)**
If this bit can be set and cleared, this processor supports the CPUID instruction. This instruction provides information about the vendor, family, and model.

**RF (Resume flag)**
Allows the programmer to disable debug exceptions so that the instruction can be restarted after a debug exception without immediately causing another debug exception.

**IOPL (I/O privilege level)**
When set, causes the processor to generate an exception on all accesses to I/O devices during protected mode operation.

**DF (Direction flag)**
Determines whether string processing instructions increment or decrement the 16-bit half-registers SI and DI (for 16-bit operations) or the 32-bit registers ESI and EDI (for 32-bit operations).

**IF (Interrupt enable flag)**
When set, the processor will recognize external interrupts.

**TF (Trap flag)**
When set, causes an interrupt after the execution of each instruction. This is used for debugging.

#### Operating Mode Bits

**NT (Nested task flag)**
Indicates that the current task is nested within another task in protected mode operation.

**VM (Virtual 8086 mode)**
Allows the programmer to enable or disable virtual 8086 mode, which determines whether the processor runs as an 8086 machine.

**VIP (Virtual interrupt pending)**
Used in virtual 8086 mode to indicate that one or more interrupts are awaiting service.

**VIF (Virtual interrupt flag)**
Used in virtual 8086 mode instead of IF.

#### Condition Codes

**AF (Auxiliary carry flag)**
Represents carrying or borrowing between half-bytes of an 8-bit arithmetic or logic operation using the AL register.

**CF (Carry flag)**
Indicates carrying out or borrowing into the leftmost bit position following an arithmetic operation. Also modified by some of the shift and rotate operations.

**OF (Overflow flag)**
Indicates an arithmetic overflow after an addition or subtraction.

**PF (Parity flag)**
Parity of the result of an arithmetic or logic operation. 1 indicates even parity; 0 indicates odd parity.

**SF (Sign flag)**
Indicates the sign of the result of an arithmetic or logic operation.

**ZF (Zero flag)**
Indicates that the result of an arithmetic or logic operation is 0.
Process Control Information

- The additional information needed by the OS to control and coordinate the various active processes
**Typical Elements of a Process Control Block**

**Process Control Information**

**Scheduling and State Information**
This is information that is needed by the operating system to perform its scheduling function. Typical items of information:

- **Process state**: Defines the readiness of the process to be scheduled for execution (e.g., running, ready, waiting, halted).
- **Priority**: One or more fields may be used to describe the scheduling priority of the process. In some systems, several values are required (e.g., default, current, highest-allowable).
- **Scheduling-related information**: This will depend on the scheduling algorithm used. Examples are the amount of time that the process has been waiting and the amount of time that the process executed the last time it was running.
- **Event**: Identity of event the process is awaiting before it can be resumed.

**Data Structuring**
A process may be linked to other process in a queue, ring, or some other structure. For example, all processes in a waiting state for a particular priority level may be linked in a queue. A process may exhibit a parent-child (creator-created) relationship with another process. The process control block may contain pointers to other processes to support these structures.

**Interprocess Communication**
Various flags, signals, and messages may be associated with communication between two independent processes. Some or all of this information may be maintained in the process control block.

**Process Privileges**
Processes are granted privileges in terms of the memory that may be accessed and the types of instructions that may be executed. In addition, privileges may apply to the use of system utilities and services.

**Memory Management**
This section may include pointers to segment and/or page tables that describe the virtual memory assigned to this process.

**Resource Ownership and Utilization**
Resources controlled by the process may be indicated, such as opened files. A history of utilization of the processor or other resources may also be included; this information may be needed by the scheduler.
Structure of Process
Images in Virtual Memory

Figure 3.13  User Processes in Virtual Memory
Process List Structures

Figure 3.14 Process List Structures
Role of the Process Control Block

- The most important data structure in an OS
  - contains all of the information about a process that is needed by the OS
  - blocks are read and/or modified by virtually every module in the OS
  - defines the state of the OS

- Difficulty is not access, but protection
  - a bug in a single routine could damage process control blocks, which could destroy the system’s ability to manage the affected processes
  - a design change in the structure or semantics of the process control block could affect a number of modules in the OS
Modes of Execution

User Mode
- less-privileged mode
- user programs typically execute in this mode

System Mode
- more-privileged mode
- also referred to as control mode or kernel mode
- kernel of the operating system
<table>
<thead>
<tr>
<th>Table 3.7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical Functions of an Operating System</strong></td>
</tr>
<tr>
<td><strong>Kernel</strong></td>
</tr>
<tr>
<td><strong>Process Management</strong></td>
</tr>
<tr>
<td>• Process creation and termination</td>
</tr>
<tr>
<td>• Process scheduling and dispatching</td>
</tr>
<tr>
<td>• Process switching</td>
</tr>
<tr>
<td>• Process synchronization and support for interprocess communication</td>
</tr>
<tr>
<td>• Management of process control blocks</td>
</tr>
<tr>
<td><strong>Memory Management</strong></td>
</tr>
<tr>
<td>• Allocation of address space to processes</td>
</tr>
<tr>
<td>• Swapping</td>
</tr>
<tr>
<td>• Page and segment management</td>
</tr>
<tr>
<td><strong>I/O Management</strong></td>
</tr>
<tr>
<td>• Buffer management</td>
</tr>
<tr>
<td>• Allocation of I/O channels and devices to processes</td>
</tr>
<tr>
<td><strong>Support Functions</strong></td>
</tr>
<tr>
<td>• Interrupt handling</td>
</tr>
<tr>
<td>• Accounting</td>
</tr>
<tr>
<td>• Monitoring</td>
</tr>
</tbody>
</table>
Process Creation

Once the OS decides to create a new process it:
- assigns a unique process identifier to the new process
- allocates space for the process
- initializes the process control block
- sets the appropriate linkages
- creates or expands other data structures
Process Switching

A process switch may occur any time that the OS has gained control from the currently running process. Possible events giving OS control are:

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Cause</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interrupt</td>
<td>External to the execution of the current instruction</td>
<td>Reaction to an asynchronous external event</td>
</tr>
<tr>
<td>Trap</td>
<td>Associated with the execution of the current instruction</td>
<td>Handling of an error or an exception condition</td>
</tr>
<tr>
<td>Supervisor call</td>
<td>Explicit request</td>
<td>Call to an operating system function</td>
</tr>
</tbody>
</table>
System Interrupts

**Interrupt**
- Due to some sort of event that is external to and independent of the currently running process
  - clock interrupt
  - I/O interrupt
  - memory fault
- Time slice
  - the maximum amount of time that a process can execute before being interrupted

**Trap**
- An error or exception condition generated within the currently running process
- OS determines if the condition is fatal
  - moved to the Exit state and a process switch occurs
  - action will depend on the nature of the error
Mode Switching

If no interrupts are pending the processor:

- proceeds to the fetch stage and fetches the next instruction of the current program in the current process

If an interrupt is pending the processor:

- sets the program counter to the starting address of an interrupt handler program
- switches from user mode to kernel mode so that the interrupt processing code may include privileged instructions
The steps in a full process switch are:

1. Save the context of the processor
2. Update the process control block of the process currently in the Running state
3. Move the process control block of this process to the appropriate queue
4. Select another process for execution
5. Update memory management data structures
6. Restore the context of the processor to that which existed at the time the selected process was last switched out

If the currently running process is to be moved to another state (Ready, Blocked, etc.), then the OS must make substantial changes in its environment.
Execution of the Operating System

Figure 3.15 Relationship Between Operating System and User Processes
Execution *Within* User Processes

![Diagram of process image showing process control block, process identification, processor state information, user stack, private user address space, kernel stack, shared address space.]

*Figure 3.16* Process Image: Operating System Executes within User Space
Security Issues

- An OS associates a set of privileges with each process
- Typically a process that executes on behalf of a user has the privileges that the OS recognizes for that user
- Highest level of privilege is referred to as administrator, supervisor, or root access
- A key security issue in the design of any OS is to prevent, or at least detect, attempts by a user or malware from gaining unauthorized privileges on the system and from gaining root access
## System Access Threats

### Intruders
- Often referred to as a hacker or cracker
- Objective is to gain access to a system or to increase the range of privileges accessible on a system
- Attempts to acquire information that should have been protected

<table>
<thead>
<tr>
<th>Classes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Masquerader</td>
</tr>
<tr>
<td>• Misfeasar</td>
</tr>
<tr>
<td>• Clandestine user</td>
</tr>
</tbody>
</table>

### Malicious Software
- Most sophisticated types of threats to computer systems
- Can be relatively harmless or very damaging

<table>
<thead>
<tr>
<th>Categories:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• those that need a host program (parasitic)</td>
</tr>
<tr>
<td>• viruses, logic bombs, backdoors</td>
</tr>
<tr>
<td>• those that are independent</td>
</tr>
<tr>
<td>• worms, bots</td>
</tr>
</tbody>
</table>

For use by students enrolled in #71251 CSE430 Fall 2012 at Arizona State University. Do not use if not enrolled.
“A security service that monitors and analyzes system events for the purpose of finding, and providing real-time or near real-time warning of, attempts to access system resources in an unauthorized manner” (RFC 2828)

- May be host or network based

- An intrusion detection system (IDS) comprises three logical components:
  - sensors
  - analyzers
  - user interface

- IDSs are typically designed to detect human intruder behavior as well as malicious software behavior
“The process of verifying an identity claimed by or for a system entity.” (RFC2828)

An authentication process consists of two steps:
- Identification
- Verification

Four general means of authenticating a user’s identity:
Countermeasures: Access Control

- Implements a security policy that specifies who or what may have access to each specific system resource and the type of access that is permitted in each instance.
- Mediates between a user and system resources.
- A security administrator maintains an authorization database.
- An auditing function monitors and keeps a record of user accesses to system resources.
Countermesures: Firewalls

A dedicated computer that:
- interfaces with computers outside a network
- has special security precautions built into it to protect sensitive files on computers within the network

Design goals of a firewall:
- all traffic must pass through the firewall
- only authorized traffic will be allowed to pass
- immune to penetration
Unix SVR4

- Uses the model where most of the OS executes within the environment of a user process

- System processes run in kernel mode
  - executes operating system code to perform administrative and housekeeping functions

- User Processes
  - operate in user mode to execute user programs and utilities
  - operate in kernel mode to execute instructions that belong to the kernel
  - enter kernel mode by issuing a system call, when an exception is generated, or when an interrupt occurs
# UNIX Process States

<table>
<thead>
<tr>
<th>State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Running</td>
<td>Executing in user mode.</td>
</tr>
<tr>
<td>Kernel Running</td>
<td>Executing in kernel mode.</td>
</tr>
<tr>
<td>Ready to Run, in Memory</td>
<td>Ready to run as soon as the kernel schedules it.</td>
</tr>
<tr>
<td>Asleep in Memory</td>
<td>Unable to execute until an event occurs; process is in main memory (a blocked state).</td>
</tr>
<tr>
<td>Ready to Run, Swapped</td>
<td>Process is ready to run, but the swapper must swap the process into main memory before the kernel can schedule it to execute.</td>
</tr>
<tr>
<td>Sleeping, Swapped</td>
<td>The process is awaiting an event and has been swapped to secondary storage (a blocked state).</td>
</tr>
<tr>
<td>Preempted</td>
<td>Process is returning from kernel to user mode, but the kernel preempts it and does a process switch to schedule another process.</td>
</tr>
<tr>
<td>Created</td>
<td>Process is newly created and not yet ready to run.</td>
</tr>
<tr>
<td>Zombie</td>
<td>Process no longer exists, but it leaves a record for its parent process to collect.</td>
</tr>
</tbody>
</table>
UNIX Process State Transition Diagram

Figure 3.17 UNIX Process State Transition Diagram
## A Unix Process

<table>
<thead>
<tr>
<th><strong>User-Level Context</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Process text</td>
</tr>
<tr>
<td>Process data</td>
</tr>
<tr>
<td>User stack</td>
</tr>
<tr>
<td>Shared memory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Register Context</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Program counter</td>
</tr>
<tr>
<td>Processor status register</td>
</tr>
<tr>
<td>Stack pointer</td>
</tr>
<tr>
<td>General-purpose registers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>System-Level Context</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Process table entry</td>
</tr>
<tr>
<td>U (user) area</td>
</tr>
<tr>
<td>Per process region table</td>
</tr>
<tr>
<td>Kernel stack</td>
</tr>
</tbody>
</table>
Table 3.11 UNIX Process Table Entry

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process status</td>
<td>Current state of process.</td>
</tr>
<tr>
<td>Pointers</td>
<td>To U area and process memory area (text, data, stack).</td>
</tr>
<tr>
<td>Process size</td>
<td>Enables the operating system to know how much space to allocate the process.</td>
</tr>
<tr>
<td>User identifiers</td>
<td>The <strong>real user ID</strong> identifies the user who is responsible for the running process. The <strong>effective user ID</strong> may be used by a process to gain temporary privileges associated with a particular program; while that program is being executed as part of the process, the process operates with the effective user ID.</td>
</tr>
<tr>
<td>Process identifiers</td>
<td>ID of this process; ID of parent process. These are set up when the process enters the Created state during the fork system call.</td>
</tr>
<tr>
<td>Event descriptor</td>
<td>Valid when a process is in a sleeping state; when the event occurs, the process is transferred to a ready-to-run state.</td>
</tr>
<tr>
<td>Priority</td>
<td>Used for process scheduling.</td>
</tr>
<tr>
<td>Signal</td>
<td>Enumerates signals sent to a process but not yet handled.</td>
</tr>
<tr>
<td>Timers</td>
<td>Include process execution time, kernel resource utilization, and user-set timer used to send alarm signal to a process.</td>
</tr>
<tr>
<td>P_link</td>
<td>Pointer to the next link in the ready queue (valid if process is ready to execute).</td>
</tr>
<tr>
<td>Memory status</td>
<td>Indicates whether process image is in main memory or swapped out. If it is in memory, this field also indicates whether it may be swapped out or is temporarily locked into main memory.</td>
</tr>
<tr>
<td><strong>Table 3.12</strong></td>
<td><strong>UNIX U Area</strong></td>
</tr>
<tr>
<td>----------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Process table pointer</td>
<td>Indicates entry that corresponds to the U area.</td>
</tr>
<tr>
<td>User identifiers</td>
<td>Real and effective user IDs. Used to determine user privileges.</td>
</tr>
<tr>
<td>Timers</td>
<td>Record time that the process (and its descendants) spent executing in user mode and in kernel mode.</td>
</tr>
<tr>
<td>Signal-handler array</td>
<td>For each type of signal defined in the system, indicates how the process will react to receipt of that signal (exit, ignore, execute specified user function).</td>
</tr>
<tr>
<td>Control terminal</td>
<td>Indicates login terminal for this process, if one exists.</td>
</tr>
<tr>
<td>Error field</td>
<td>Records errors encountered during a system call.</td>
</tr>
<tr>
<td>Return value</td>
<td>Contains the result of system calls.</td>
</tr>
<tr>
<td>I/O parameters</td>
<td>Describe the amount of data to transfer, the address of the source (or target) data array in user space, and file offsets for I/O.</td>
</tr>
<tr>
<td>File parameters</td>
<td>Current directory and current root describe the file system environment of the process.</td>
</tr>
<tr>
<td>User file descriptor table</td>
<td>Records the files the process has opened.</td>
</tr>
<tr>
<td>Limit fields</td>
<td>Restrict the size of the process and the size of a file it can write.</td>
</tr>
<tr>
<td>Permission modes fields</td>
<td>Mask mode settings on files the process creates.</td>
</tr>
</tbody>
</table>
Process Creation

- Process creation is by means of the kernel system call, `fork()`.

- This causes the OS, in Kernel Mode, to:
  1. Allocate a slot in the process table for the new process
  2. Assign a unique process ID to the child process
  3. Make a copy of the process image of the parent, with the exception of any shared memory
  4. Increments counters for any files owned by the parent, to reflect that an additional process now also owns those files
  5. Assigns the child process to the Ready to Run state
  6. Returns the ID number of the child to the parent process, and a 0 value to the child process
After creating the process the Kernel can do one of the following, as part of the dispatcher routine:

- stay in the parent process
- transfer control to the child process
- transfer control to another process
Summary

- The most fundamental concept in a modern OS is the process
- The principal function of the OS is to create, manage, and terminate processes
- Process control block contains all of the information that is required for the OS to manage the process, including its current state, resources allocated to it, priority, and other relevant data
- The most important states are Ready, Running and Blocked
- The running process is the one that is currently being executed by the processor
- A blocked process is waiting for the completion of some event
- A running process is interrupted either by an interrupt or by executing a supervisor call to the OS