4.7 `fork` and `exec` Functions

Before describing how to write a concurrent server in the next section, we must describe the Unix `fork` function. This function (including the variants of it provided by some systems) is the only way in Unix to create a new process.

```
#include <unistd.h>

pid_t fork(void);
```

Returns: 0 in child, process ID of child in parent, -1 on error

If you have never seen this function before, the hard part in understanding `fork` is that it is called *once* but it returns *twice*. It returns once in the calling process (called the parent) with a return value that is the process ID of the newly created process (the child). It also returns once in the child, with a return value of 0. Hence, the return value tells the process whether it is the parent or the child.

The reason `fork` returns 0 in the child, instead of the parent's process ID, is because a child has only one parent and it can always obtain the parent's process ID by calling `getppid`. A parent, on the other hand, can have any number of children, and there is no way to obtain the process IDs of its children. If a parent wants to keep track of the process IDs of all its children, it must record the return values from `fork`.

All descriptors open in the parent before the call to `fork` are shared with the child after `fork` returns. We will see this feature used by network servers: The parent calls `accept` and then calls `fork`. The connected socket is then shared between the parent and child. Normally, the child then reads and writes the connected socket and the parent closes the connected socket.

There are two typical uses of `fork`:

1. A process makes a copy of itself so that one copy can handle one operation while the other copy does another task. This is typical for network servers. We will see many examples of this later in the text.
2. A process wants to execute another program. Since the only way to create a new process is by calling `fork`, the process first calls `fork` to make a copy of itself, and then one of the copies (typically the child process) calls `exec` (described next) to replace itself with the new program. This is typical for programs such as shells.

The only way in which an executable program file on disk can be executed by Unix is for an existing process to call one of the six `exec` functions. (We will often refer generically to "the `exec` function" when it does not matter which of the six is called.) `exec` replaces the current process image with the new program file, and this new program normally starts at the `main` function. The process ID does not change. We refer to the process that calls `exec` as the *calling process* and the newly executed program as the *new program*.

> Older manuals and books incorrectly refer to the new program as the *new process*, which is wrong, because a new process is not created.

The differences in the six `exec` functions are: (a) whether the program file to execute is specified by a *filename* or a *pathname*; (b) whether the arguments to the new program are listed one by one or referenced through an array of pointers; and (c) whether the environment of the calling process is passed to the new program or whether a new environment is specified.

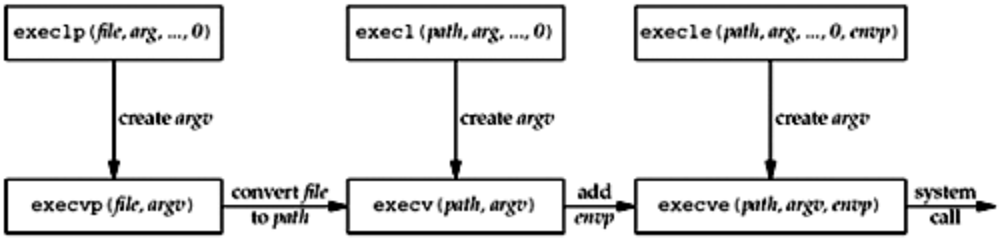
```
#include <unistd.h>

int execl (const char *pathname, const char *arg0, ... /* (char *) 0 */ );

int execv (const char *pathname, char *const argv[]);

int execle (const char *pathname, const char *arg0, ...

                                       /* (char *) 0, char *const envp[] */ );

int execve (const char *pathname, char *const argv[], char *const envp[]);

int execlp (const char *filename, const char *arg0, ... /* (char *) 0 */ );

int execvp (const char *filename, char *const argv[]);
```

All six return: -1 on error, no return on success

These functions return to the caller only if an error occurs. Otherwise, control passes to the start of the new program, normally the `main` function.

The relationship among these six functions is shown in Figure 4.12. Normally, only `execve` is a system call within the kernel and the other five are library functions that call `execve`.

Figure 4.12. Relationship among the six exec functions.



Note the following differences among these six functions:

1. The three functions in the top row specify each argument string as a separate argument to the `exec` function, with a null pointer terminating the variable number of arguments. The three functions in the second row have an *argv* array, containing pointers to the argument strings. This *argv* array must contain a null pointer to specify its end, since a count is not specified.
2. The two functions in the left column specify a *filename* argument. This is converted into a *pathname* using the current `PATH` environment variable. If the *filename* argument to `execlp` or `execvp` contains a slash (/) anywhere in the string, the `PATH` variable is not used. The four functions in the right two columns specify a fully qualified *pathname* argument.
3. The four functions in the left two columns do not specify an explicit environment pointer. Instead, the current value of the external variable `environ` is used for building an environment list that is passed to the new program. The two functions in the right column specify an explicit environment list. The *envp* array of pointers must be terminated by a null pointer.

Descriptors open in the process before calling `exec` normally remain open across the `exec`. We use the qualifier "normally" because this can be disabled using `fcntl` to set the `FD_CLOEXEC` descriptor flag. The `inetd` server uses this feature, as we will describe in Section 13.5.