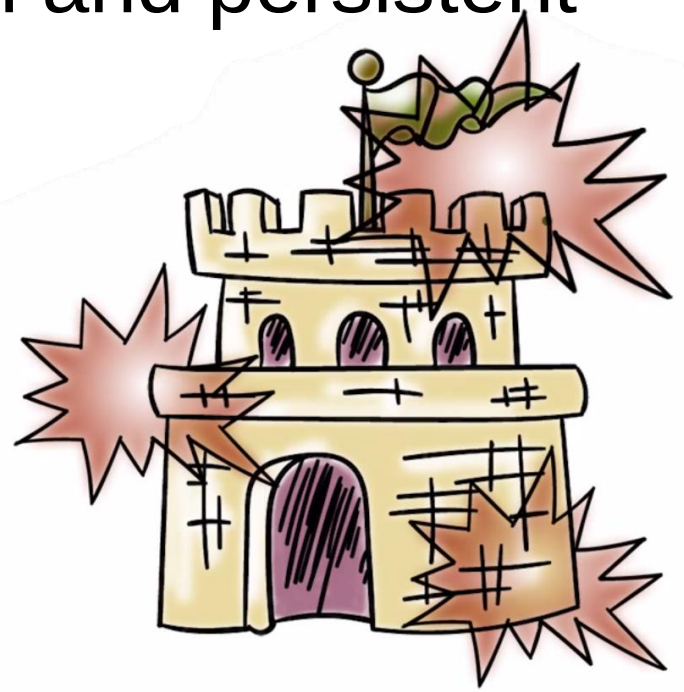
Software Security
Lesson Introduction

- **Software vulnerabilities** and how attackers **exploit them**.
- **Defenses against attacks** that try to exploit buffer overflows.
- **Secure programming:** Code “defensively”, expecting it to be exploited. Do not trust the “inputs” that come from users of the software system.

Software Vulnerabilities & How They Get Exploited

- **Example: Buffer overflow** - a common and persistent vulnerability



- Stack buffer overflows
- **Stacks** are used...
  - in **function/procedure calls**
  - for **allocation of memory** for...
    - local variables
    - parameters
    - control information (return address)

A Vulnerable Password Checking Program

```
#include <stdio.h>
#include <strings.h>

int main(int argc, char *argv[]) {
        int allow_login = 0;
        char pwdstr[12];
        char targetpwd[12] = "MyPwd123";
        gets(pwdstr);
        if (strncmp(pwdstr,targetpwd, 12) == 0)
                allow_login = 1;

        if (allow_login == 0)
                printf("Login request rejected");
        else
                printf("Login request allowed");
}
```

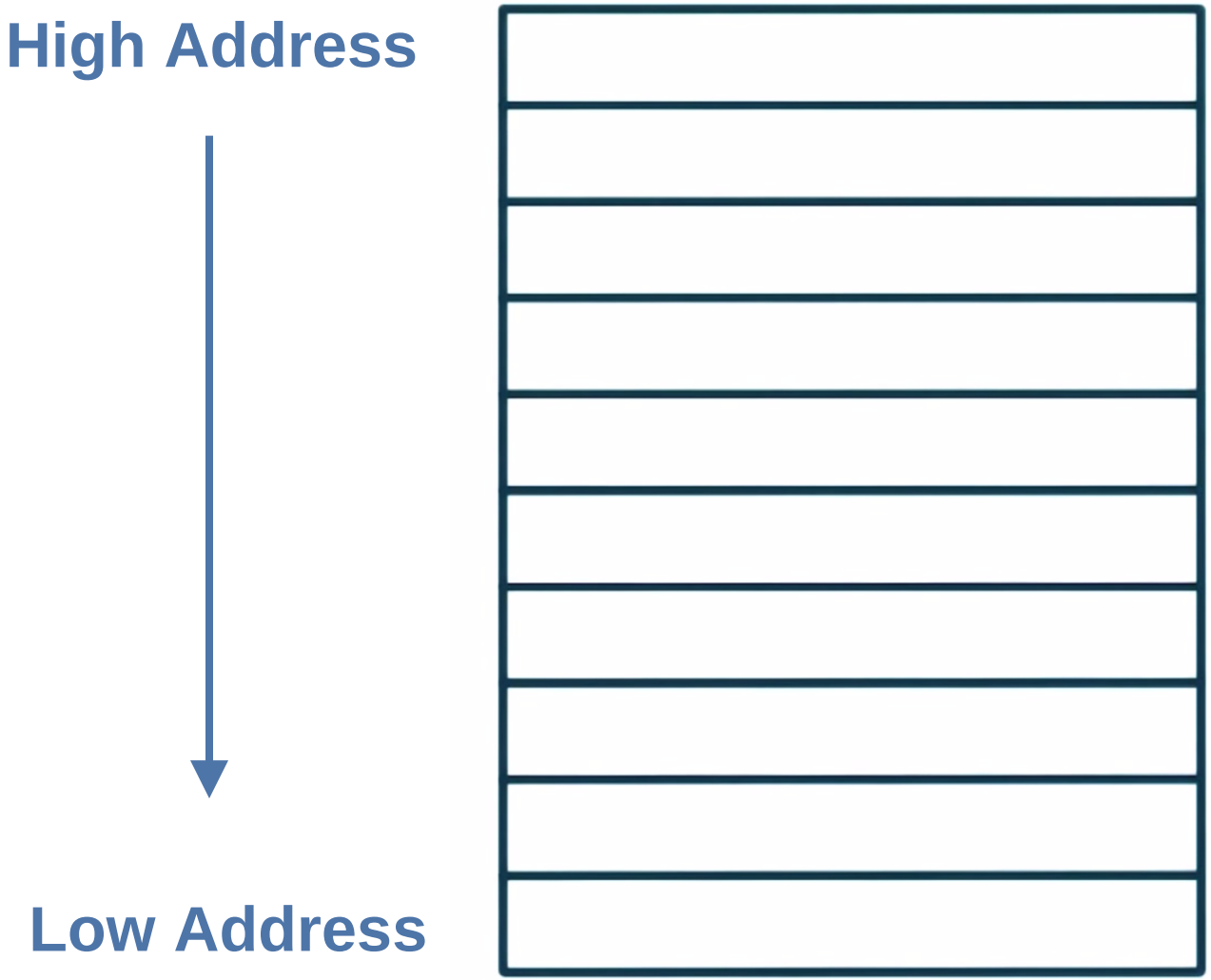
Stack Access Quiz

Check the lines of code, when executed, accesses addresses in the **stack frame for main()**:

```
int main(int argc, char *argv[]) {
    int allow_login = 0;
    char pwdstr[12];
☐   char targetpwd[12] = "MyPwd123";
☐   gets(pwdstr);
☐   if (strncmp(pwdstr,targetpwd, 12) == 0)
        ☐   allow_login = 1;

☐   if (allow_login == 0)
        ☐   printf("Login request rejected");
☐   else
        ☐   printf("Login request allowed");
}
```

Understanding the Stack



Attacker Bad Input Quiz

What **type of password string** could defeat the **password check code**? (Check all that apply)

```
#include <stdio.h>
#include <strings.h>

int main(int argc, char *argv[]) {
        int allow_login = 0;
        char pwdstr[12];
        char targetpwd[12] = "MyPwd123";
        gets(pwdstr);
        if (strncmp(pwdstr,targetpwd, 12) == 0)
                allow_login = 1;

        if (allow_login == 0)
                printf("Login request rejected");
        else
                printf("Login request allowed");
}
```

- ☐ Any password of length greater than **12 bytes that ends in '123'**
- ☐ Any password of length greater than **16 bytes that begins with 'MyPwd123'**
- ☐ Any password of length greater than **8 bytes**

Attacker Code Execution

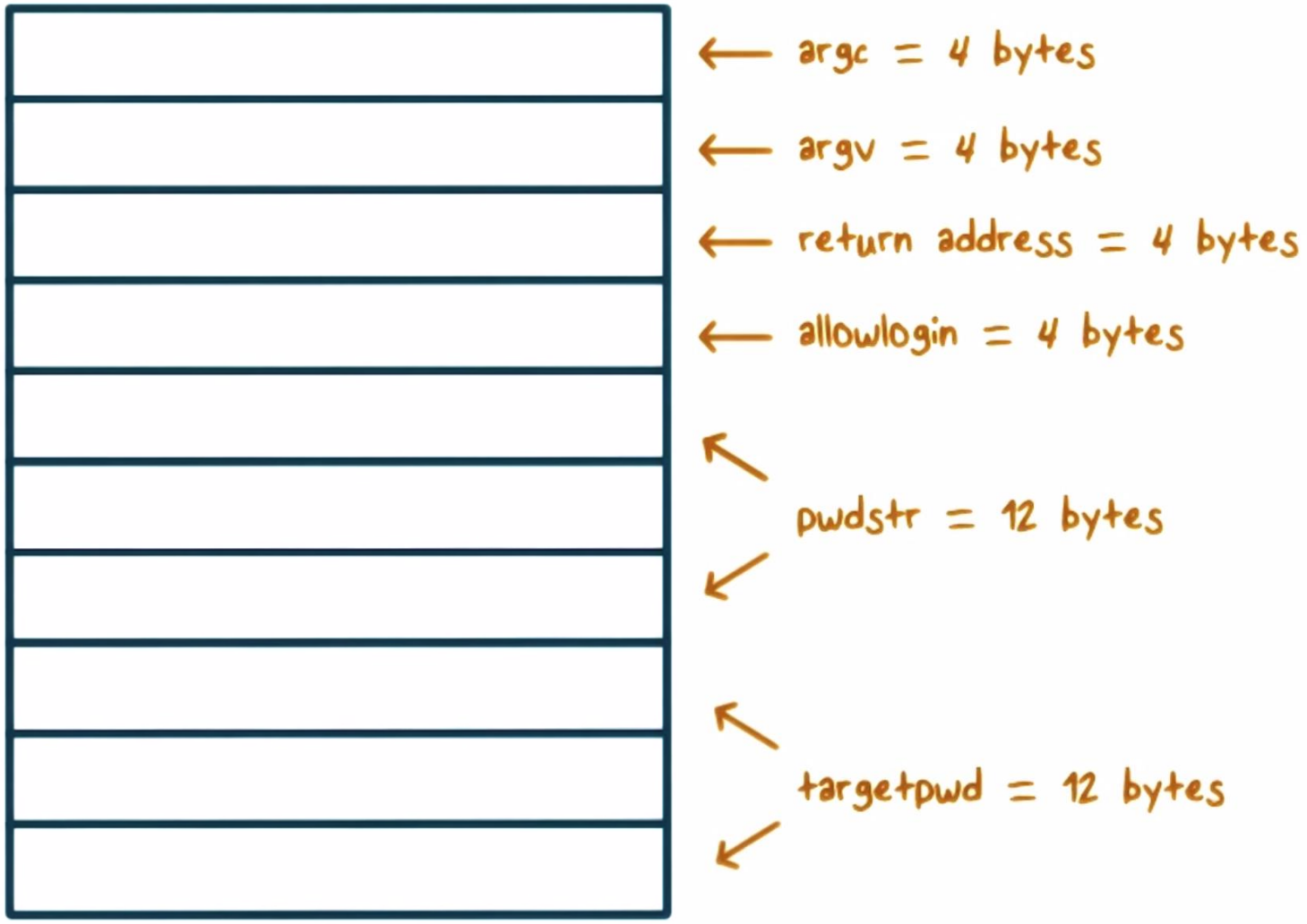
We type a **correct password** (**MyPwd123**) of less than 12 characters:

The login request is allowed.

Now let us type “**BadPassWd**” when we are asked to provide the password:

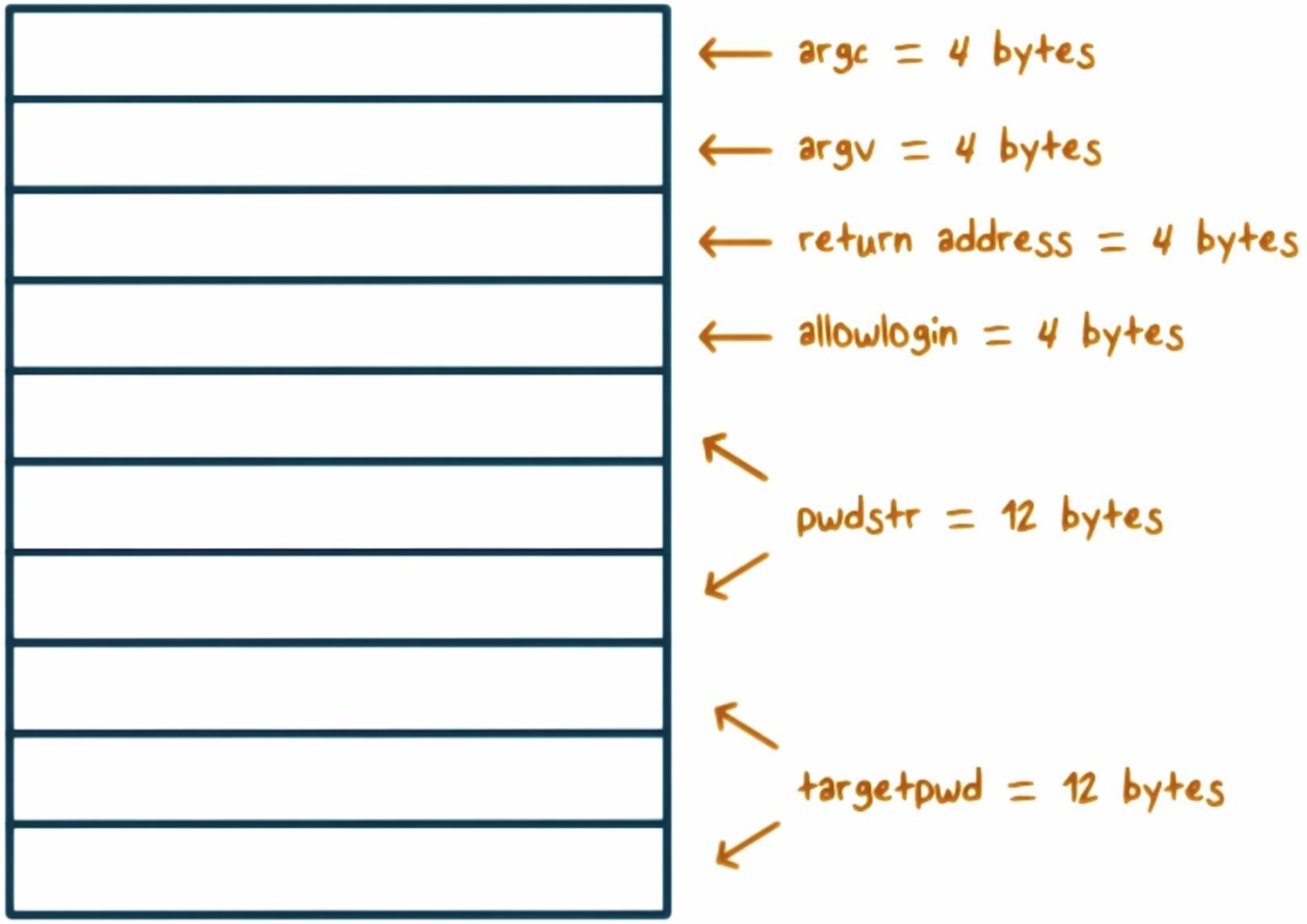
The login request is rejected.

Attacker Code Execution



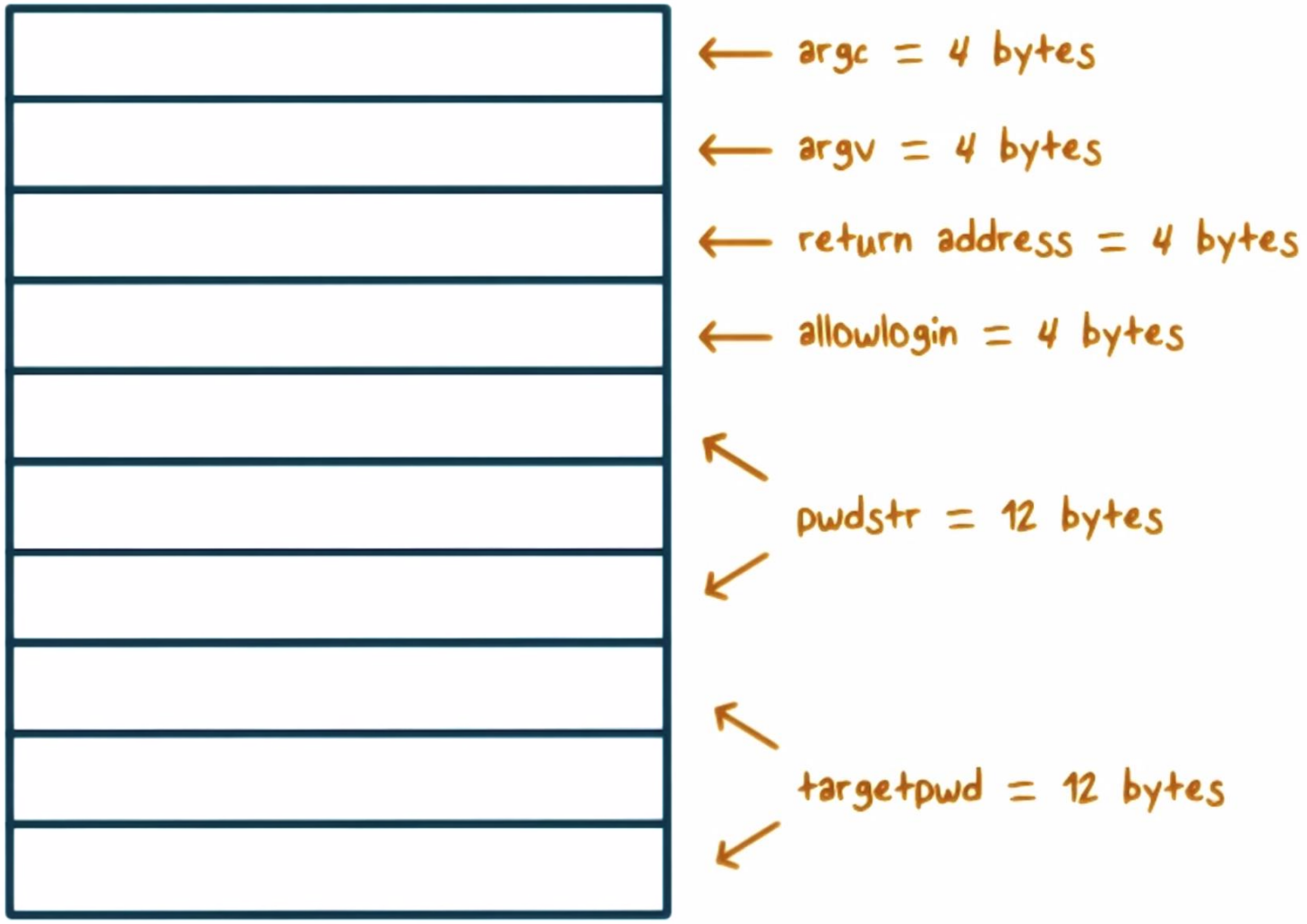
Attacker Code Execution

If we type a really long string, we will **overflow** into the return address space.



Attacker Code Execution

We can carefully **overflow the return address** so it contains the value of an address where we put some code we want executed.



Buffer Overflow Quiz

Which of these **vulnerabilities** applies to the code:

- [ ] The target password was too short, this made it easy to overflow the buffer.
- [ ] The code did not check the input and reject password strings longer than 12 bytes.
- [ ] The code did not add extra, unused variables. If this is done then when the user inputs a long password, it won't overflow into the return address.

ShellCode

Shell Code: creates a shell which allows it to execute any code the attacker wants.

Whose **privileges** are used when attacker code is executed?

- The host program's
- System service or OS root privileges

LEAST Privilege is IMPORTANT

National Vulnerability Database (NVD) Quiz

- **How many CVE (Common Vulnerability and Exposure) vulnerabilities do you think NVD will have?** ☐
  [1] Close to 500, [2] A few thousand, [3] Close to 70000

- **If you search the NVD, how many buffer overflow vulnerabilities will be reported from the last three months?** ☐
  [1] less than 10, [2] Several hundred, [3] Close to one hundred

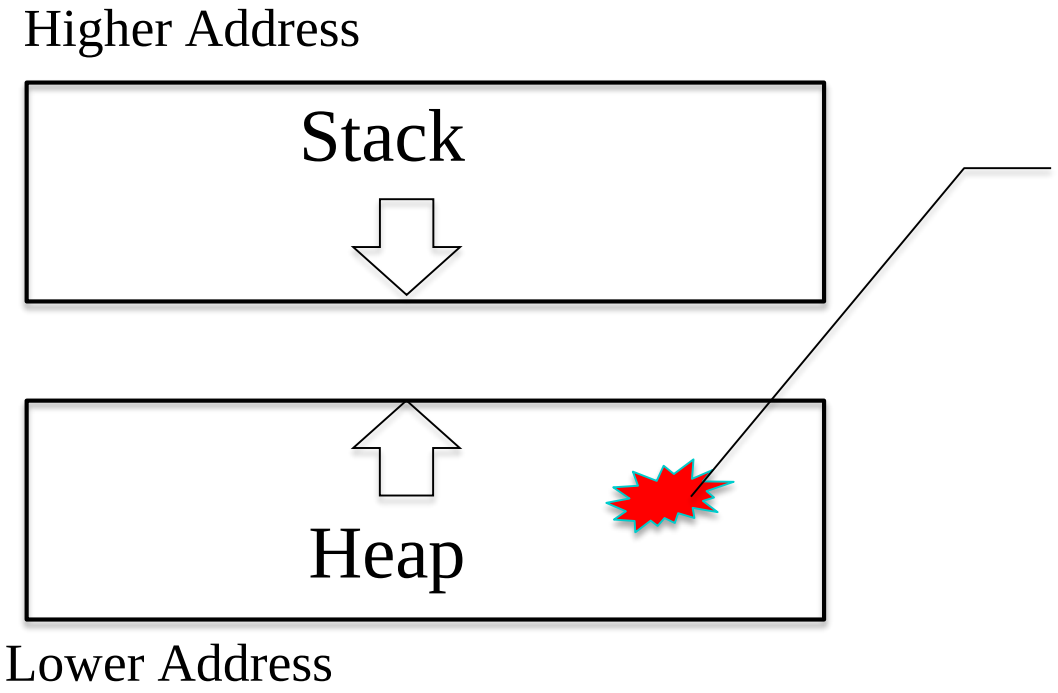
- **How many buffer overflow vulnerabilities in the last 3 years?** ☐
  [1] Over a thousand, [2] fifty thousand, [3] five hundred

Variations of Buffer Overflow

- **Return-to-libc**: the return address is overwritten to point to a standard library function.
- **Heap Overflows**: data stored in the heap is overwritten. Data can be tables of function pointers.
- **OpenSSL Heartbleed Vulnerability**: read much more of the buffer than just the data, which may include sensitive data.

●Heap Overflow

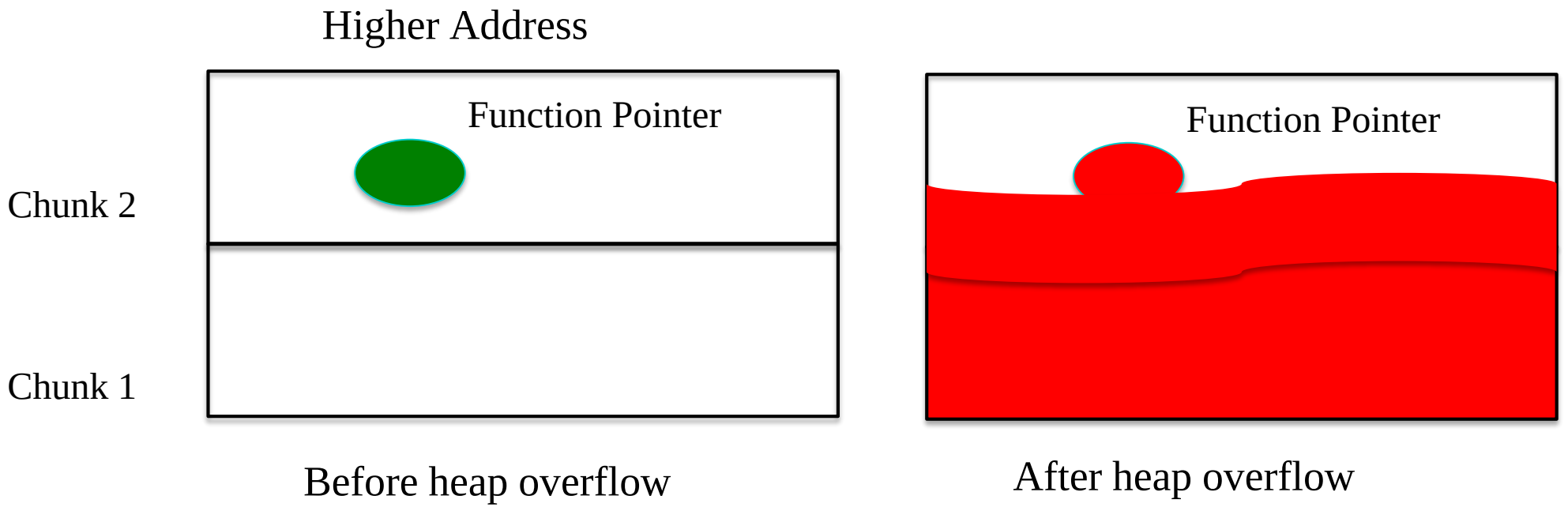
- Buffer overflows that occur in the heap data area.
  - Typical heap manipulation functions: malloc()/free()




```
char* p = malloc (256);
memset (p, 'A', 1024);
```

●Heap Overflow – Example

- Overwrite the function pointer in the adjacent buffer



Defense Against Buffer Overflow Attacks

Programming language choice is crucial.

The language...

- Should be **strongly typed**
- Should do **automatic bounds checks**
- Should do **automatic memory management**

Examples of **Safe languages**: Java, C++, Python

Defense Against Buffer Overflow Attacks

Why are some languages safe?

- Buffer overflow becomes impossible due to runtime system checks

The drawback of secure languages

- Possible performance degradation

Defense Against Buffer Overflow Attacks

When Using Unsafe Languages:

- Check input (**ALL input is EVIL**)
- Use safer functions that do **bounds checking**
- Use **automatic tools** to analyze code for potential unsafe functions.

Defense Against Buffer Overflow Attacks

Analysis Tools…

- Can **flag** potentially unsafe functions/constructs
- Can **help mitigate security lapses**, but it is really hard to eliminate all buffer overflows.

Examples of analysis tools can be found at:

https://www.owasp.org/index.php/Source_Code_Analysis_Tools

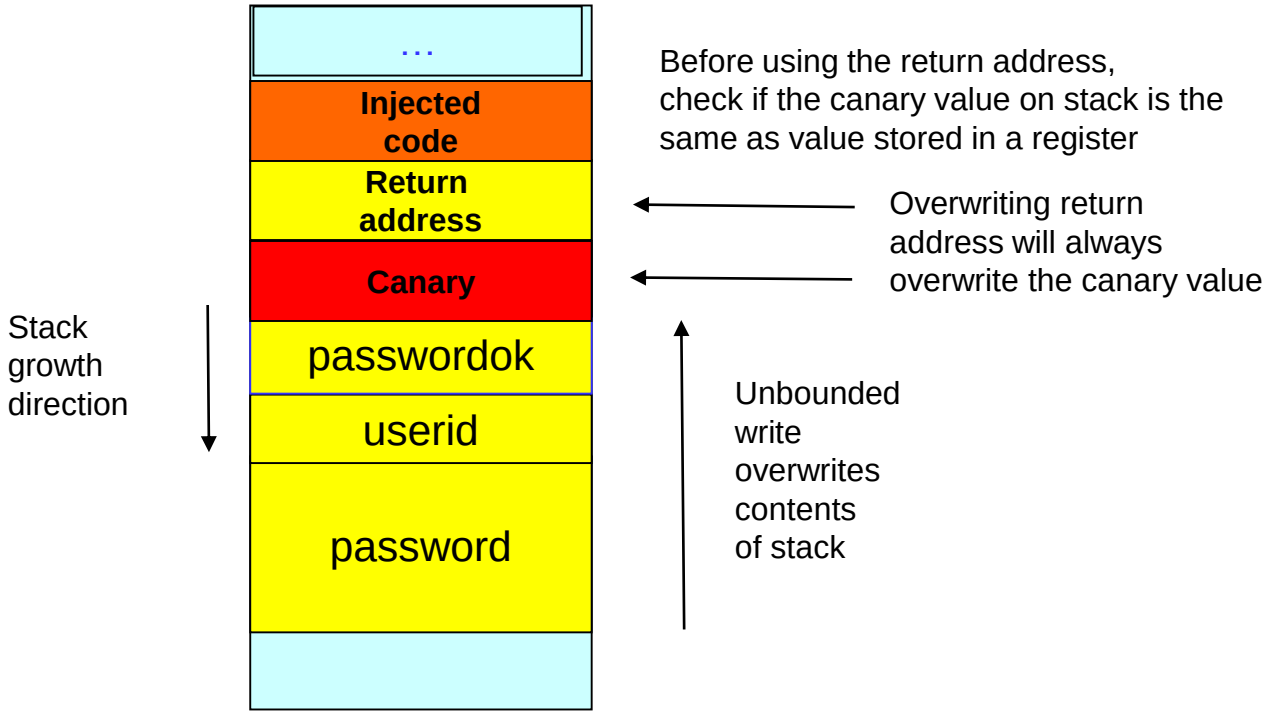
Thwarting Buffer Overflow Attacks

Stack Canaries:

- When a return address is stored in a stack frame, a random **canary value** is written just before it. Any attempt to rewrite the address using buffer overflow will result in the canary being rewritten and an overflow will be detected.

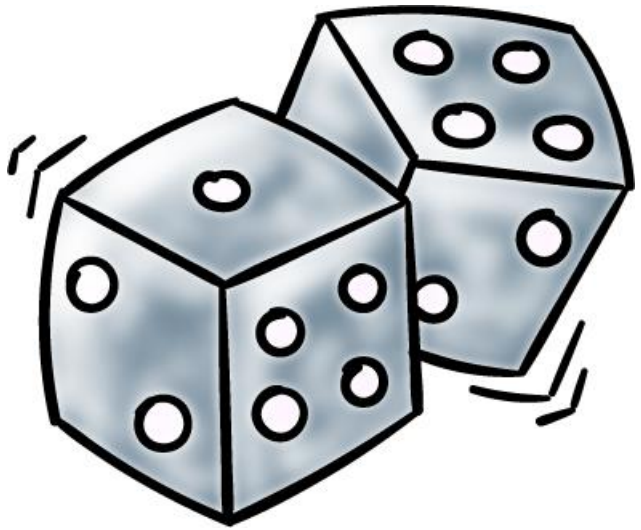
●Countermeasure – Stack Protection

- Canary for tamper detection



- No code execution on stack

Thwarting Buffer Overflow Attacks



- **Address Space Layout Randomization (ASLR)** randomizes stack, heap, libc, etc. This makes it harder for the attacker to find important locations (e.g., libc function address).

- Use a **non-executable stack** coupled with ASLR. This solution uses OS/hardware support.

Buffer Overflow Attacks Quiz

- Do **stack canaries** prevent return-to-libc buffer overflow attacks?

  ◯ **Yes** ◯ **No**

- Does **ASLR** protect against read-only buffer overflow attacks?

  ◯ **Yes** ◯ **No**

- Can the **OpenSSL heartbleed vulnerability** be avoided with non-executable stack?

  ◯ **Yes** ◯ **No**

Software Security
Lesson Summary

- Understand how software **bug/ vulnerabilities can be exploited**
- **Several defenses** possible against attacks
- **Buffer overflows** remain a problem
- **Web security:** Important for web
- **Secure coding -- check all input!**