Web Security: Injection attacks

CS 161: Computer Security

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Some content adapted from materials by David Wagner or Dan Boneh

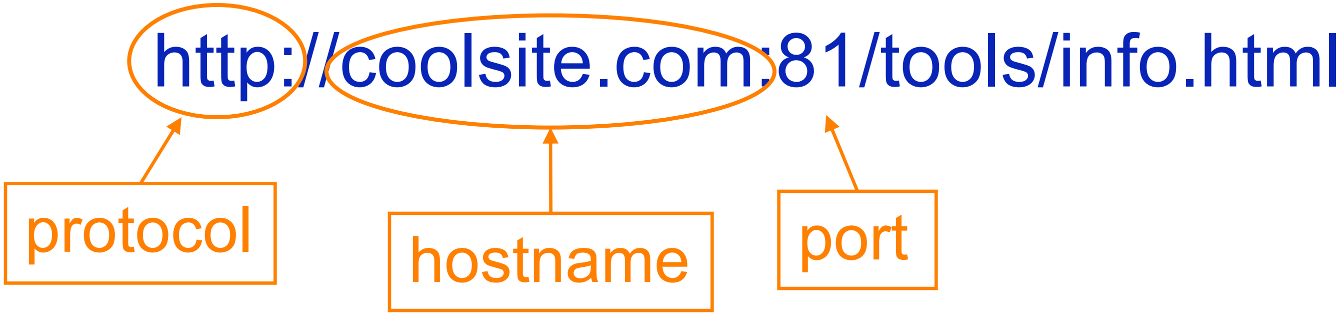
Last time: Same-origin policy

One origin should not be able to access the resources of another origin

Javascript in one origin cannot read or modify pages from different origins

Origin

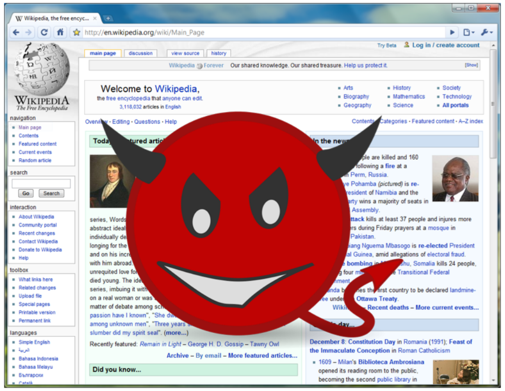
- Granularity of protection for same origin policy
- Origin = (protocol, hostname, port)



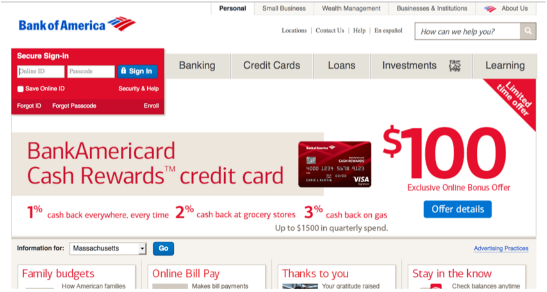
- It is **string matching**! If these match, it is same origin, else it is not. Even though in some cases, it is logically the same origin, if there is no match, it is not

Cross-origin communication

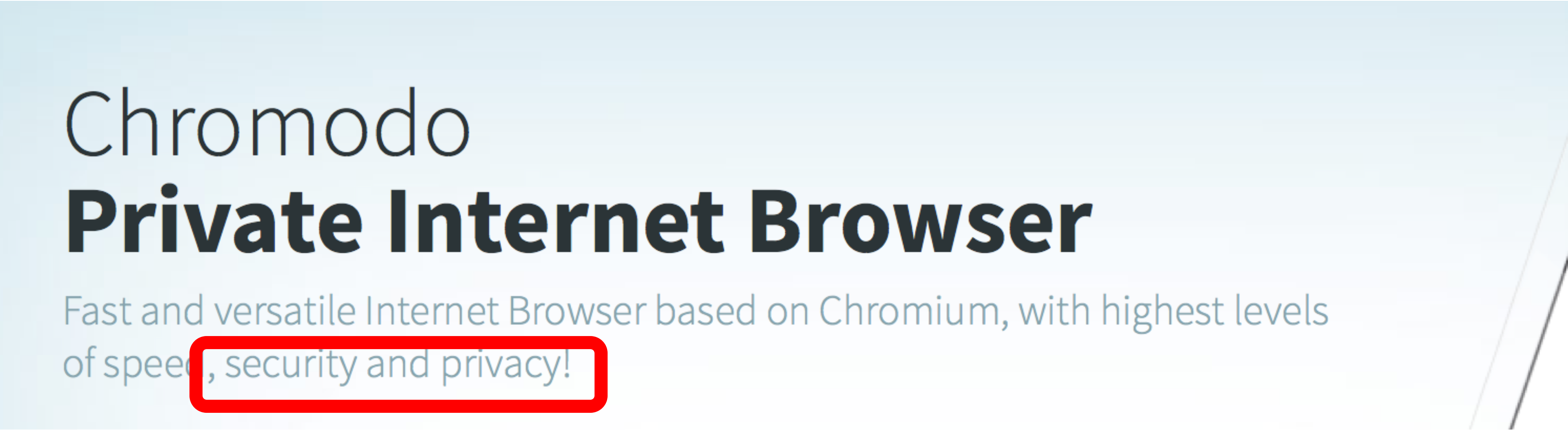
- Allowed through a narrow API: **postMessage**
- Receiving origin decides if to accept the message based on origin (whose correctness is enforced by browser)



```
postMessage
("run this
script",
script)
```



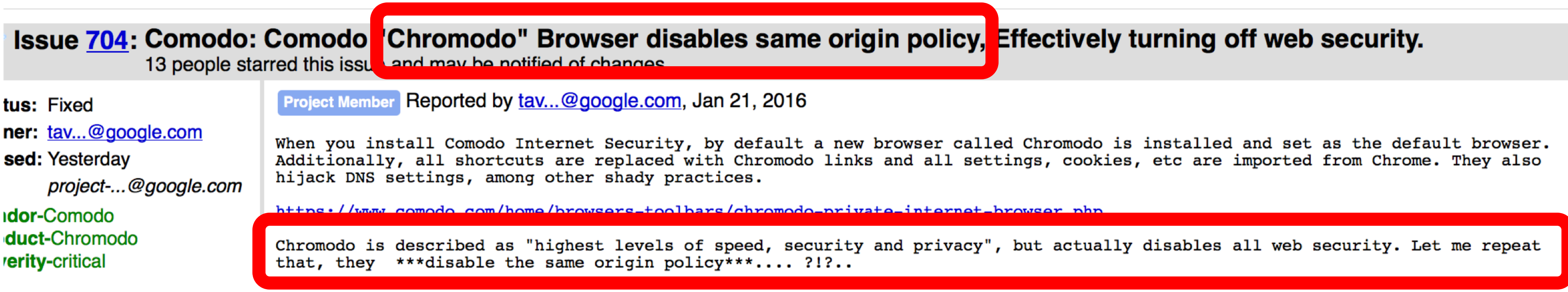
Check origin, and request!



Chromodo

Private Internet Browser

Fast and versatile Internet Browser based on Chromium, with highest levels of speed, security and privacy!



Issue 704: Comodo: Comodo "Chromodo" Browser disables same origin policy, Effectively turning off web security.

13 people starred this issue and may be notified of changes.

tus: Fixed
ner: tav...@google.com
sed: Yesterday
project-...@google.com
dor-Comodo
duct-Chromodo
erity-critical

Reported by tav...@google.com, Jan 21, 2016

When you install Comodo Internet Security, by default a new browser called Chromodo is installed and set as the default browser. Additionally, all shortcuts are replaced with Chromodo links and all settings, cookies, etc are imported from Chrome. They also hijack DNS settings, among other shady practices.

https://www.comodo.com/home/browsers-toolbars/chromodo-private-internet-browser.php

Chromodo is described as "highest levels of speed, security and privacy", but actually disables all web security. Let me repeat that, they ***disable the same origin policy***.... ?!?..

Web security attacks

What can go bad if a web server is compromised?

- Steal sensitive data (e.g., data from many users)
- Change server data (e.g., affect users)
- Gateway to enabling attacks on clients
- Impersonation (of users to servers, or vice versa)
- Others

A set of common attacks

- SQL Injection
  - Browser sends malicious input to server
  - Bad input checking leads to malicious SQL query
- XSS – Cross-site scripting
  - Attacker inserts client-side script into pages viewed by other users, script runs in the users' browsers
- CSRF – Cross-site request forgery
  - Bad web site sends request to good web site, using credentials of an innocent victim who "visits" site

SQL injection attacks

Historical perspective

- The first public discussions of SQL injection started appearing around 1998

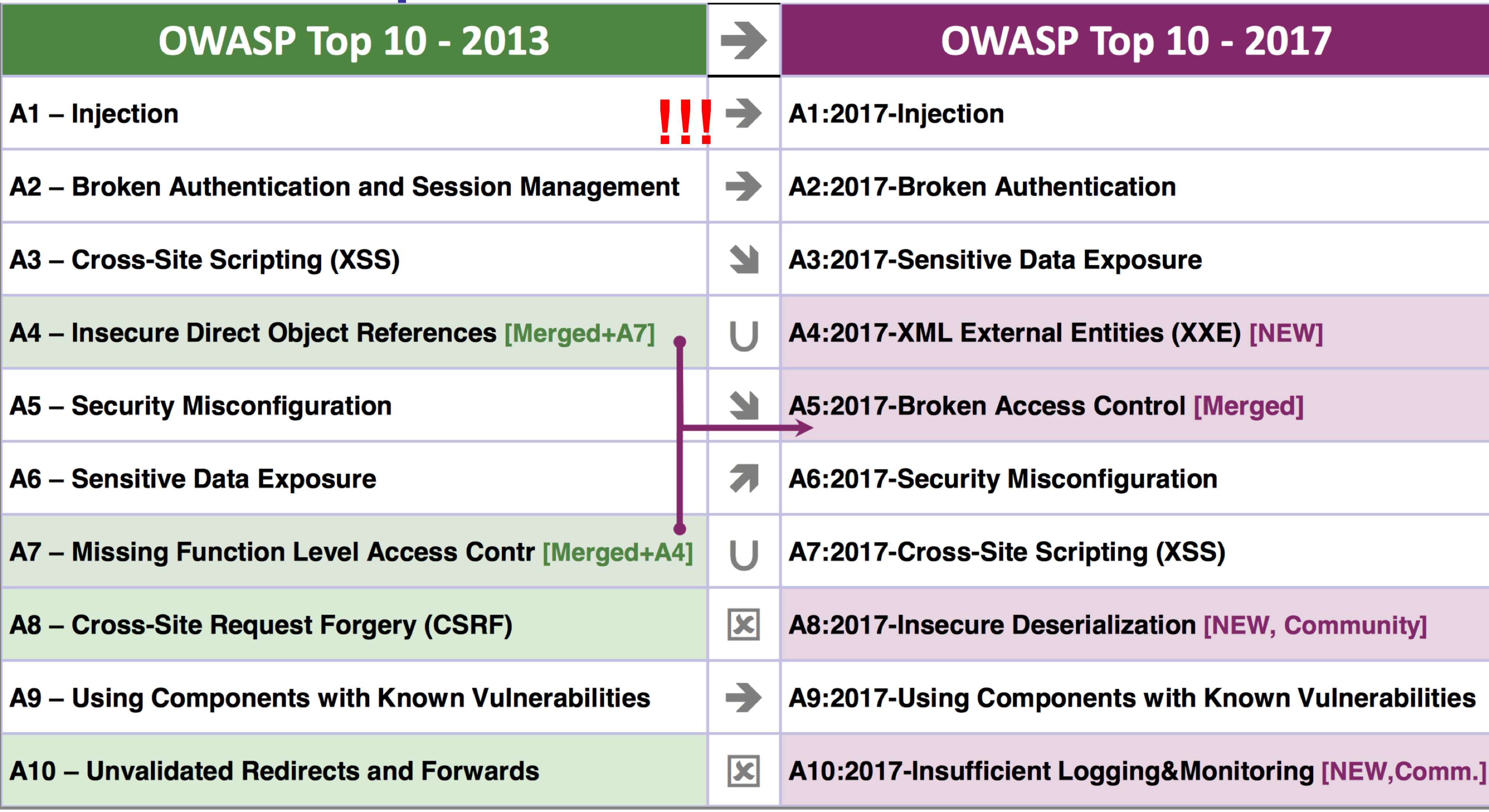
phreak + hack

In the Phrack magazine

First published in 1985

- Hundreds of proposed fixes and solutions

Top web vulnerabilities



OWASP Top 10 - 2013	→	OWASP Top 10 - 2017
A1 – Injection !!!	→	A1:2017-Injection
A2 – Broken Authentication and Session Management	→	A2:2017-Broken Authentication
A3 – Cross-Site Scripting (XSS)	↘	A3:2017-Sensitive Data Exposure
A4 – Insecure Direct Object References [Merged+A7]	∪	A4:2017-XML External Entities (XXE) [NEW]
A5 – Security Misconfiguration	↘	A5:2017-Broken Access Control [Merged]
A6 – Sensitive Data Exposure	↗	A6:2017-Security Misconfiguration
A7 – Missing Function Level Access Contr [Merged+A4]	∪	A7:2017-Cross-Site Scripting (XSS)
A8 – Cross-Site Request Forgery (CSRF)	☒	A8:2017-Insecure Deserialization [NEW, Community]
A9 – Using Components with Known Vulnerabilities	→	A9:2017-Using Components with Known Vulnerabilities
A10 – Unvalidated Redirects and Forwards	☒	A10:2017-Insufficient Logging&Monitoring [NEW,Comm.]

Please don’t repeat common mistakes!!

General code injection attacks

- Attacker user provides bad input
- Web server does not check input format
- Enables attacker to execute arbitrary code on the server

Example:
code injection based on eval (PHP)

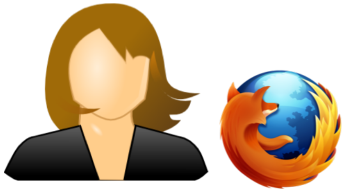
- $_GET['A']: gets the input with name A from a GET HTTP request
- $_POST['B']: gets the input with name B from a POST HTTP request

1. User visits calculator web app in user browser and writes 3+5 ENTER
2. User's browser sends HTTP GET request http://site.com/calc.php?exp=" 3+5"
3. Script at server receives http request and runs $_GET("exp") =" 3+5"

Example:
code injection based on eval (PHP)

- the web server uses eval to evaluate a string as code
  - e.g. eval(‘$result = 3+5’) produces 8

calculator:
http://site.com/calc.php



http://site.com/calc.php?exp =“ 3+5”

```
$exp = $_GET[‘exp'];
eval('$result = ' . $exp . ';');
```

Attack: http://site.com/calc.php?exp=“ 3+5 ; system(‘rm *.*’)”

Code injection using system()

- Example: PHP server-side code for sending email

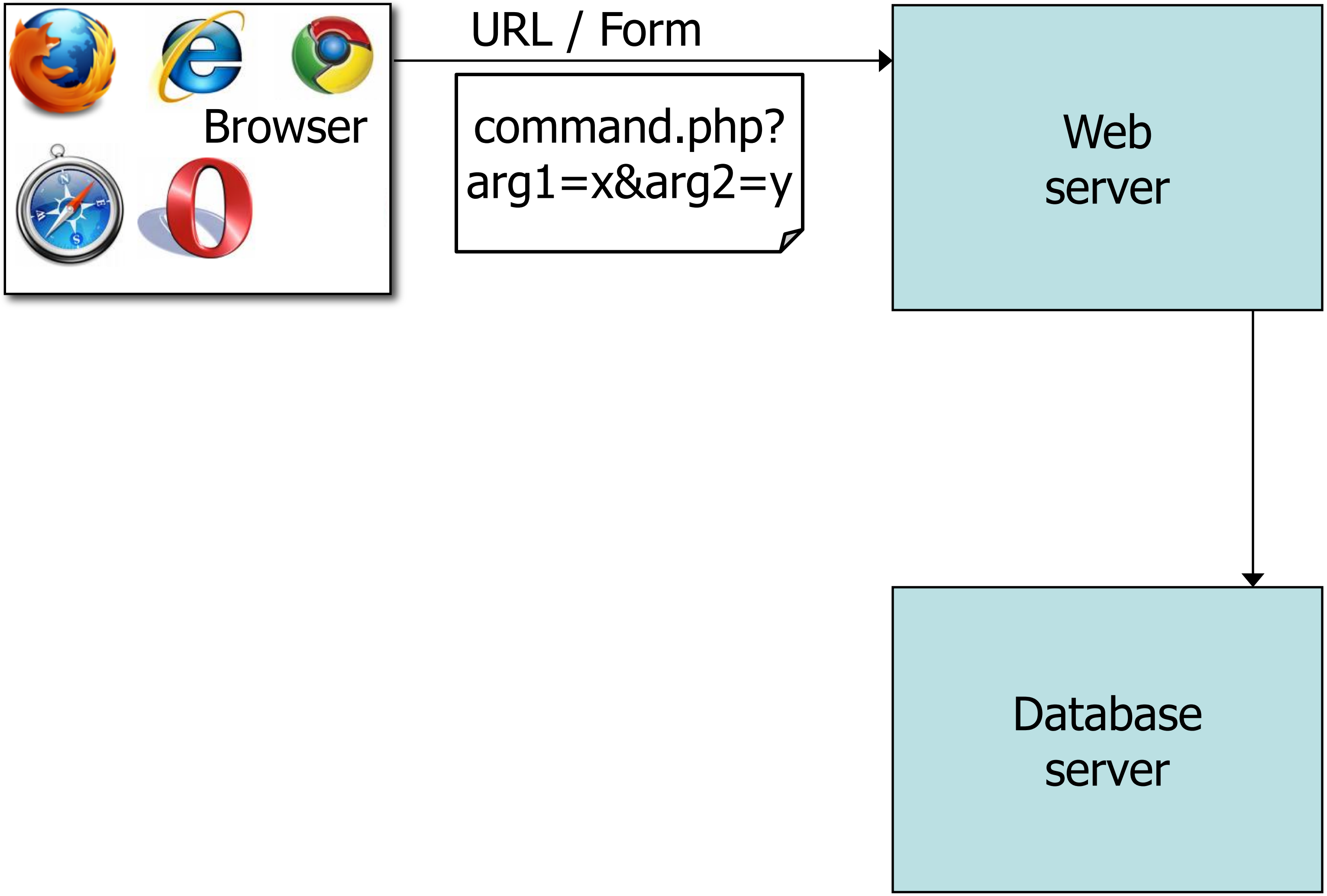
```
$email = $_POST[“email”]
$subject = $_POST[“subject”]
system(“mail  $email –s  $subject < /tmp/joinmynetwork”)
```

- Attacker can post

```
http://yourdomain.com/mail.php?
   email=hacker@hackerhome.net &
   subject=“foo < /usr/passwd; ls”
```

SQL injection

Structure of Modern Web Services



Browser

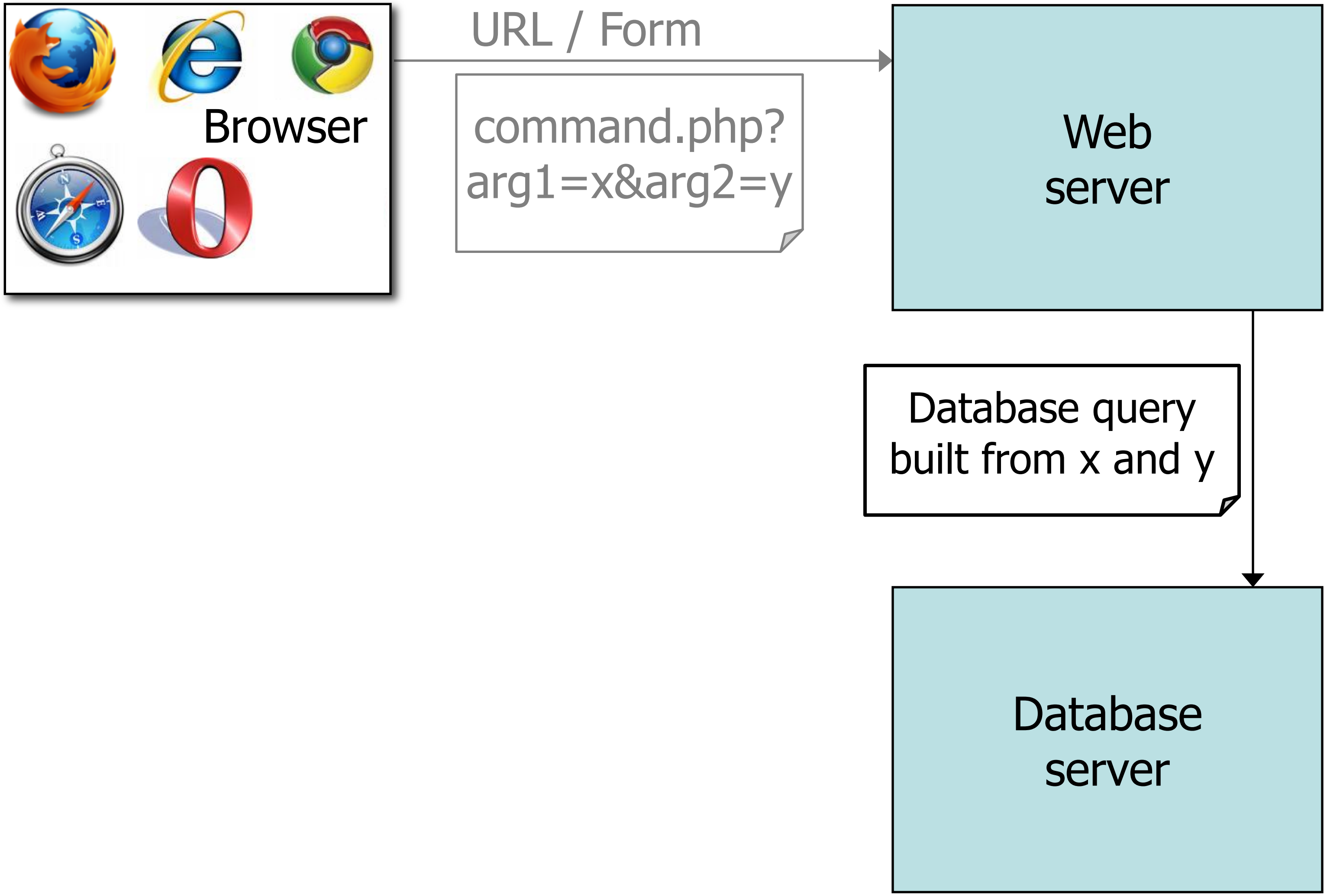
URL / Form

command.php?
arg1=x&arg2=y

Web
server

Database
server

Structure of Modern Web Services



Browser

URL / Form

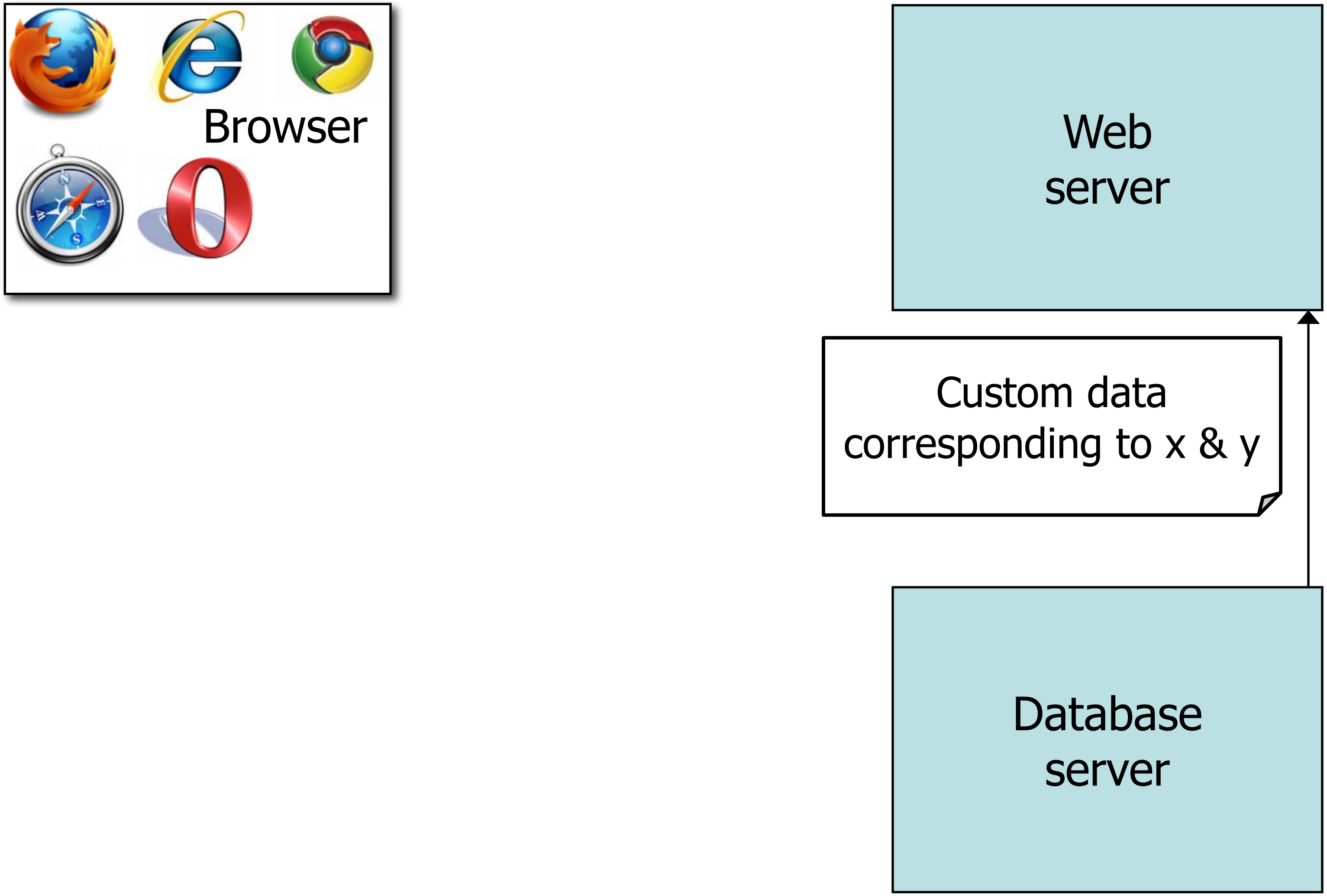
command.php?
arg1=x&arg2=y

Web
server

Database query
built from x and y

Database
server

Structure of Modern Web Services



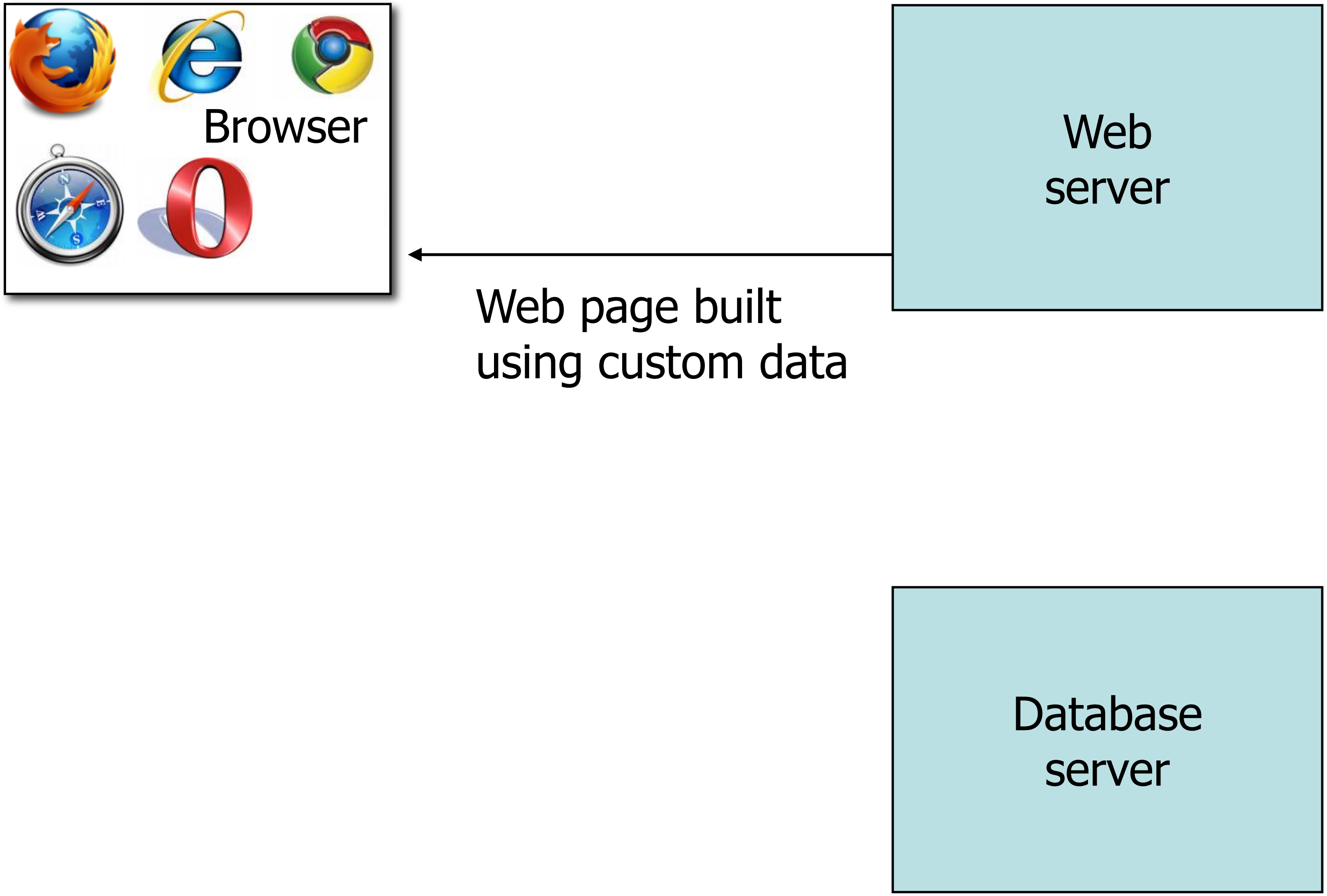
Browser

Web server

Custom data corresponding to x & y

Database server

Structure of Modern Web Services



Browser

Web server

Web page built using custom data

Database server

Databases

MySQL PostgreSQL mongoDB ORACLE

- **Structured** collection of data
  - Often storing tuples/rows of related values
  - Organized in tables

Customer		
AcctNum	Username	Balance
1199	zuckerberg	35.7
0501	bgates	79.2
…	…	…

Databases

- Widely used by web services to store server and user information
- Database runs as separate process to which web server connects
  - Web server sends queries or commands derived from incoming HTTP request
  - Database server returns associated values or modifies/updates values

SQL

- Widely used database query language
  – (Pronounced “ess-cue-ell” or “sequel”)
- Fetch a set of rows:

  SELECT *column* FROM *table* WHERE *condition*

  returns the value(s) of the given column in the specified table, for all records where *condition* is true.
- e.g:

  SELECT Balance FROM Customer WHERE Username='bgates'

  will return the value 79.2

Customer

AcctNum	Username	Balance
1199	zuckerberg	35.71
0501	bgates	79.2
…	…	…
…	…	…

SQL (cont.)

- Can add data to the table (or modify):

```
INSERT INTO Customer VALUES (8477, 'oski', 10.00);
```

Customer		
AcctNum	Username	Balance
1199	zuckerberg	35.7
0501	bgates	79.2
8477	oski	10.00
…	…	…

SQL (cont.)

- Can delete entire tables:

```
DROP TABLE Customer
```

- Issue multiple commands, separated by semicolon:

```
INSERT INTO Customer VALUES (4433, 'vladimir',
70.0); SELECT AcctNum FROM Customer
WHERE Username='vladimir'
```

returns 4433.

SQL Injection Scenario

- Suppose web server runs the following code:

```
$recipient = $_POST[‘recipient’];
$sql = "SELECT AcctNum  FROM Customer
WHERE                    Username='$recipient'  ";
$rs = $db->executeQuery($sql);
```

- Server stores URL parameter “recipient” in variable $recipient and then builds up a SQL query
- Query returns recipient’s account number
- Server will send value of $sql variable to database server to get account #s from database

SQL Injection Scenario

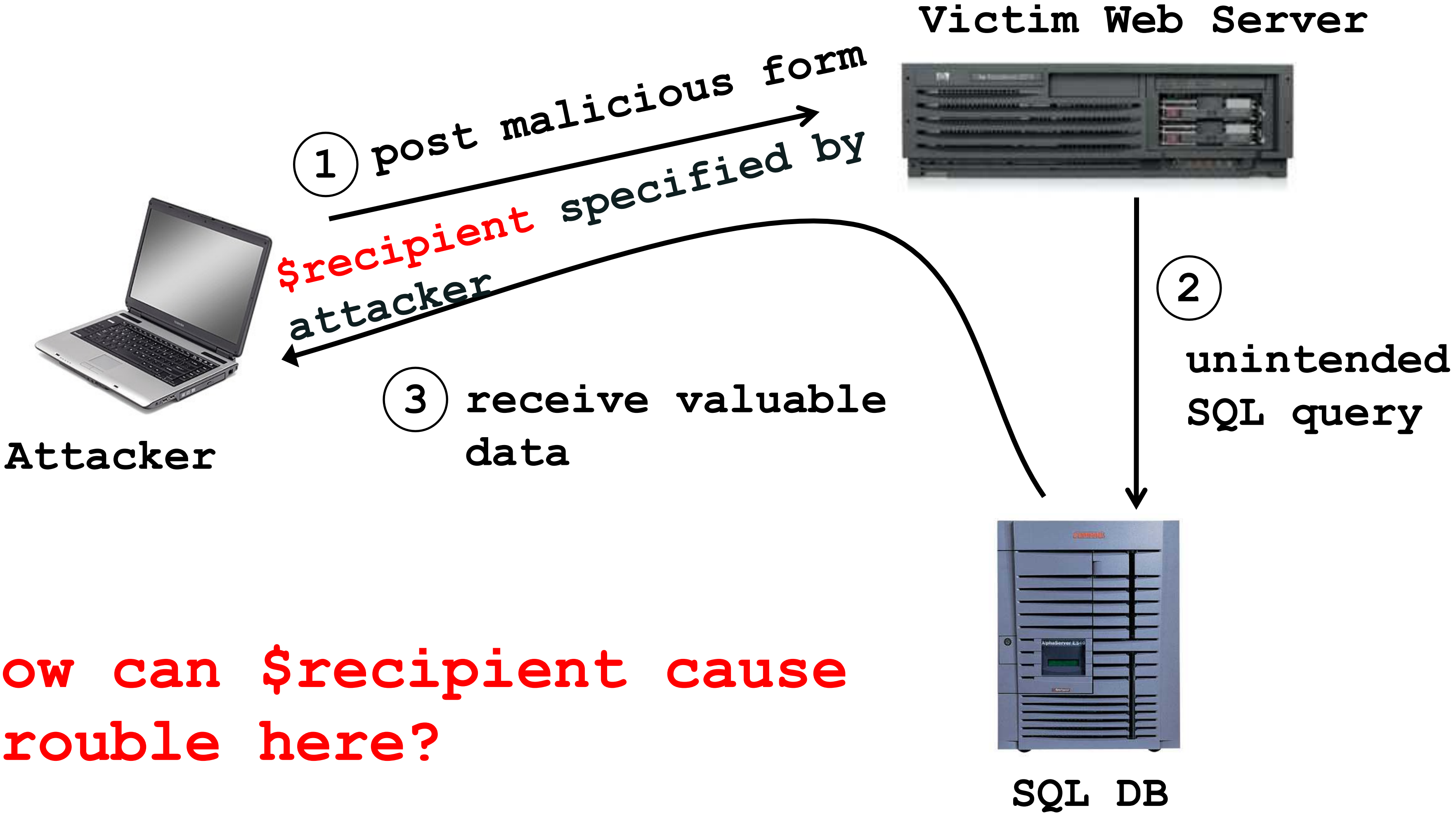
- Suppose web server runs the following code:

```
$recipient = $_POST[‘recipient’];

$sql = "SELECT AcctNum  FROM Customer
WHERE                    Username='$recipient'  ";

$rs = $db->executeQuery($sql);
```

- So for HTTP request “?recipient=Bob” the SQL query is:

```
"SELECT AcctNum FROM Customer WHERE
        Username='Bob' "
```

Basic picture: SQL Injection



Victim Web Server

1 post malicious form

$recipient specified by attacker

2 unintended SQL query

3 receive valuable data

Attacker

SQL DB

How can $recipient cause trouble here?

Problem

```
$recipient = $_POST[‘recipient’];
$sql = "SELECT AcctNum  FROM Customer
WHERE                   Username='$recipient'  ";
$rs = $db->executeQuery($sql);
```

Untrusted user input ‘recipient’ is embedded directly into SQL command

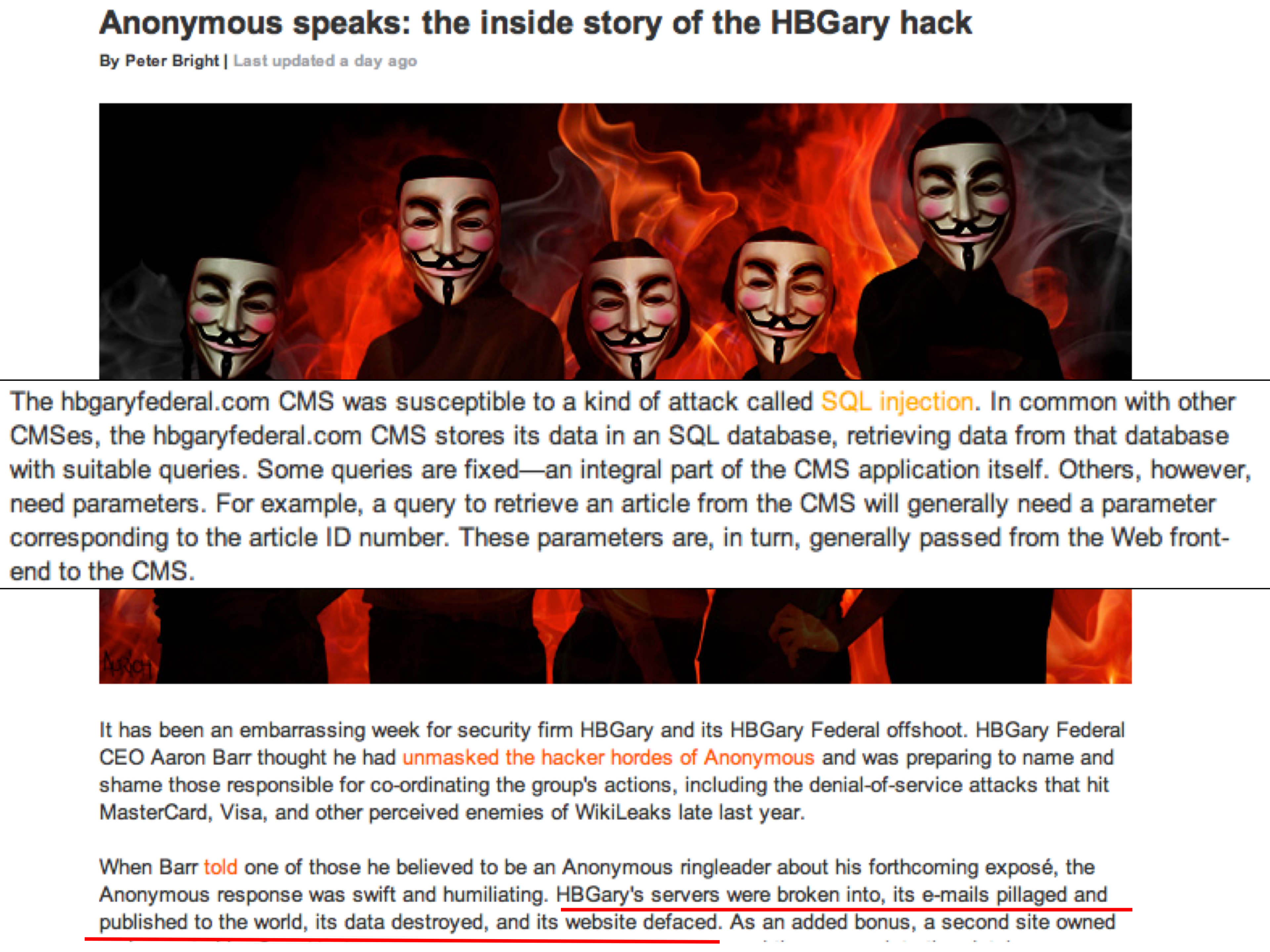
Attack:

$recipient = alice’; SELECT * FROM Customer;’

Returns the entire contents of the Customer!

CardSystems Attack

- CardSystems
  - credit card payment processing company
  - SQL injection attack in June 2005
  - put out of business
- The Attack
  - 263,000 credit card #s stolen from database
  - credit card #s stored unencrypted
  - 43 million credit card #s exposed



Anonymous speaks: the inside story of the HBGary hack

By Peter Bright | Last updated a day ago

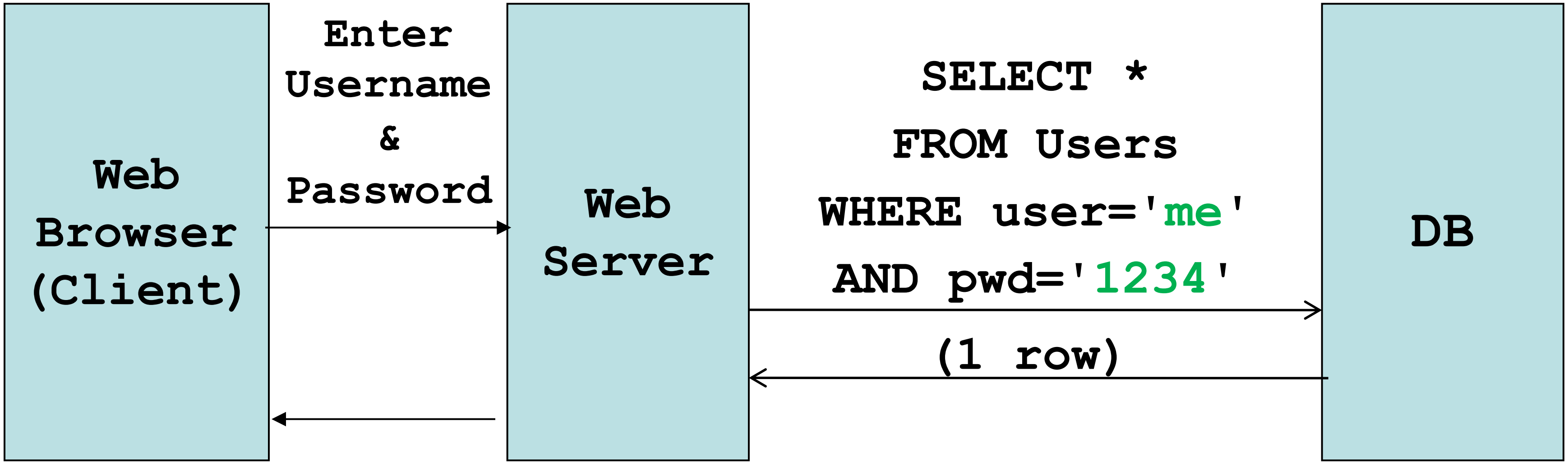
The hbgaryfederal.com CMS was susceptible to a kind of attack called SQL injection. In common with other CMSes, the hbgaryfederal.com CMS stores its data in an SQL database, retrieving data from that database with suitable queries. Some queries are fixed—an integral part of the CMS application itself. Others, however, need parameters. For example, a query to retrieve an article from the CMS will generally need a parameter corresponding to the article ID number. These parameters are, in turn, generally passed from the Web front-end to the CMS.

It has been an embarrassing week for security firm HBGary and its HBGary Federal offshoot. HBGary Federal CEO Aaron Barr thought he had unmasked the hacker hordes of Anonymous and was preparing to name and shame those responsible for co-ordinating the group's actions, including the denial-of-service attacks that hit MasterCard, Visa, and other perceived enemies of WikiLeaks late last year.

When Barr told one of those he believed to be an Anonymous ringleader about his forthcoming exposé, the Anonymous response was swift and humiliating. HBGary's servers were broken into, its e-mails pillaged and published to the world, its data destroyed, and its website defaced. As an added bonus, a second site owned

Another example: buggy login page (ASP)

```
set ok = execute( "SELECT * FROM Users
     WHERE user=' "  &  form(“user”)  &
  " '
     AND   pwd=' " & form(“pwd”) & “ '”
  );

if not ok.EOF
     login success
else  fail;
```



Web Browser (Client)

Enter Username & Password

Web Server

```
SELECT *
FROM Users
WHERE user='me'
AND pwd='1234'
```

(1 row)

DB

Normal Query

Another example: buggy login page (ASP)

```
set ok = execute( "SELECT * FROM Users
      WHERE user=' "  &  form(“user”)  &
  " '
      AND   pwd=' " & form(“pwd”) & “ '”
  );

if not ok.EOF
      login success
else  fail;
```

Is this exploitable?

Bad input

- Suppose user = “ `'or 1=1 --` ” (URL encoded)

- Then scripts does:

```
ok = execute( SELECT …
          WHERE user= ' ' or 1=1  -- … )
```

  - The “`--`” causes rest of line to be ignored.
  - Now ok.EOF is always false and login succeeds.

- The bad news: easy login to many sites this way.

`Besides logging in, what else can attacker do?`

Even worse: delete all data!

- Suppose user =

  “ ' ; DROP TABLE Users -- ”

- Then script does:

```
ok = execute( SELECT …
   WHERE user= ' ' ; DROP TABLE Users
  …   )
```

What else can an attacker do?

- Add query to create another account with password, or reset a password

- **Suppose user =**

  “ ’ ; INSERT INTO TABLE Users (‘attacker’, ‘attacker secret’); -- ”

- **And pretty much everything that can be done by running a query on the DB!**

How to prevent SQL injection?

- Ideas?

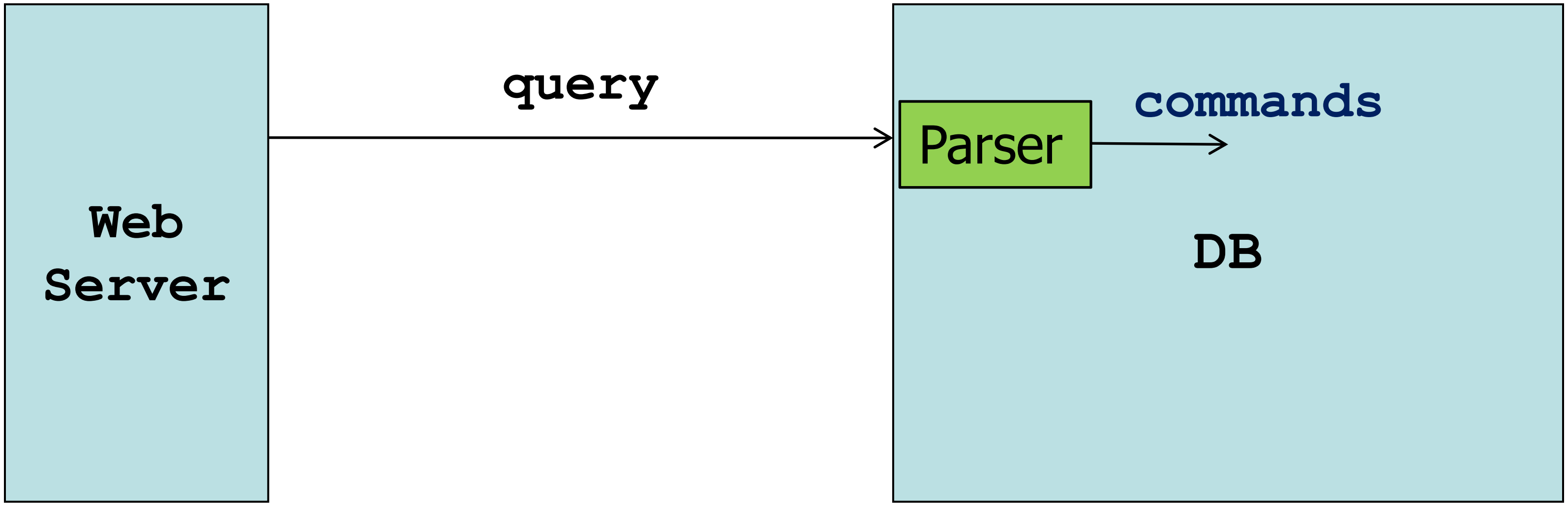
SQL Injection Prevention

- Sanitizate user input: check or enforce that value/string that does not have commands of any sort
  - Disallow special characters, or
  - Escape input string

```
SELECT PersonID  FROM People WHERE
    Username=’ alice\’; SELECT * FROM People;’
```

How to escape input

You “escape” the SQL parser



How to escape input

- The input string should be interpreted as a string and not as a special character
- To escape the SQL parser, use backslash in front of special characters, such as quotes or backslashes

The SQL Parser does…

- If it sees ’ it considers a string is starting or ending
- If it sees \’ it considers it just as a character part of a string and converts it to ‘

For

SELECT PersonID FROM People WHERE
    Username=’ alice\’; SELECT * FROM People;\’

The username will be matched against alice’; SELECT * FROM People;’ and no match will be found

- Different parsers have different escape sequences or API for escaping

Examples

- What is the string username compared to (after SQL parsing), and when does it flag a syntax error? (syntax error appears at least when quotes are not closed)

[..] WHERE Username=’alice’;	alice
[..] WHERE Username=’alice\’;	Syntax error, quote not closed
[..] WHERE Username=’alice\’’;	alice’
[..] WHERE Username=’alice\\’;	alice\

because \\ gets converted to \ by the parser

SQL Injection Prevention

- Avoid building a SQL command based on raw user input, use existing tools or frameworks
- E.g. (1): the Django web framework has built in sanitization and protection for other common vulnerabilities
  - Django defines a query abstraction layer which sits atop SQL and allows applications to avoid writing raw SQL
  - The execute function takes a sql query and replaces inputs with escaped values
- E.g. (2): Or use parameterized/prepared SQL

Parameterized/prepared SQL

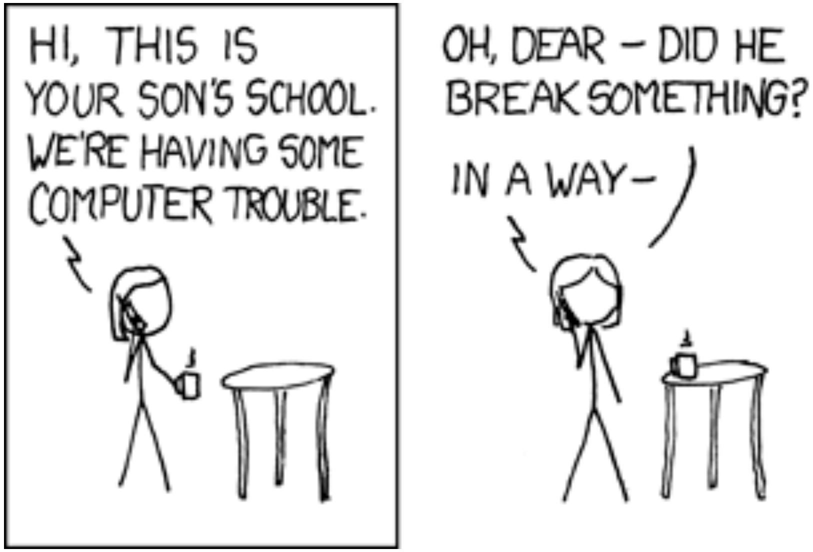
- Builds SQL queries by properly escaping args: ′ → \′
- Example: Parameterized SQL: (ASP.NET 1.1)
  - Ensures SQL arguments are properly escaped.

```
SqlCommand cmd = new SqlCommand(
    "SELECT * FROM UserTable WHERE
    username = @User AND
    password = @Pwd", dbConnection);

cmd.Parameters.Add("@User", Request[“user”] );

cmd.Parameters.Add("@Pwd", Request[“pwd”] );

cmd.ExecuteReader();
```

How to prevent general injections

Similarly to SQL injections:

- Sanitize input from the user!
- Use frameworks/tools that already check user input


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–

Summary

- Injection attacks were and are the most common web vulnerability
- It is typically due to malicious input supplied by an attacker that is passed without checking into a command; the input contains commands or alters the command
- Can be prevented by sanitizing user input

Random fact 2 about …Scott Shenker

Recall random fact 1: "I have never taken a CS course in my life, and I don't program."

What is Scott's key to success?

"About 30% of my diet is chocolate. No other food matters to me."

Scott Shenker