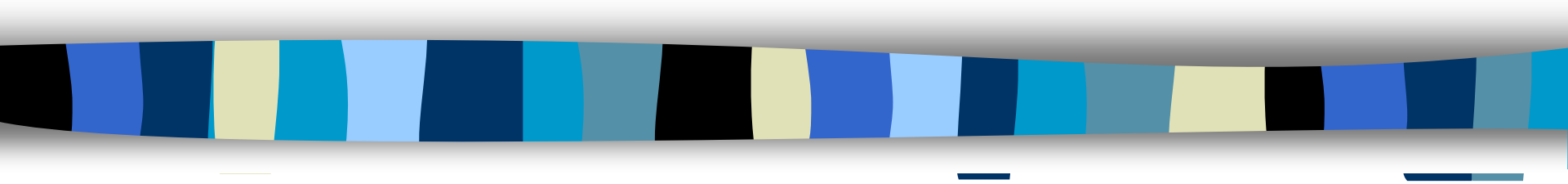
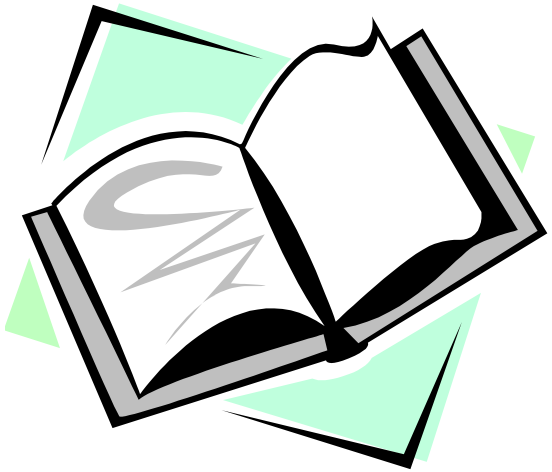
Information Security
CS 526
Topic 11



Web Security Part 1

Readings for This Lecture

- Wikipedia
  - HTTP Cookie
  - Same Origin Policy
  - Cross Site Scripting
  - Cross Site Request Forgery

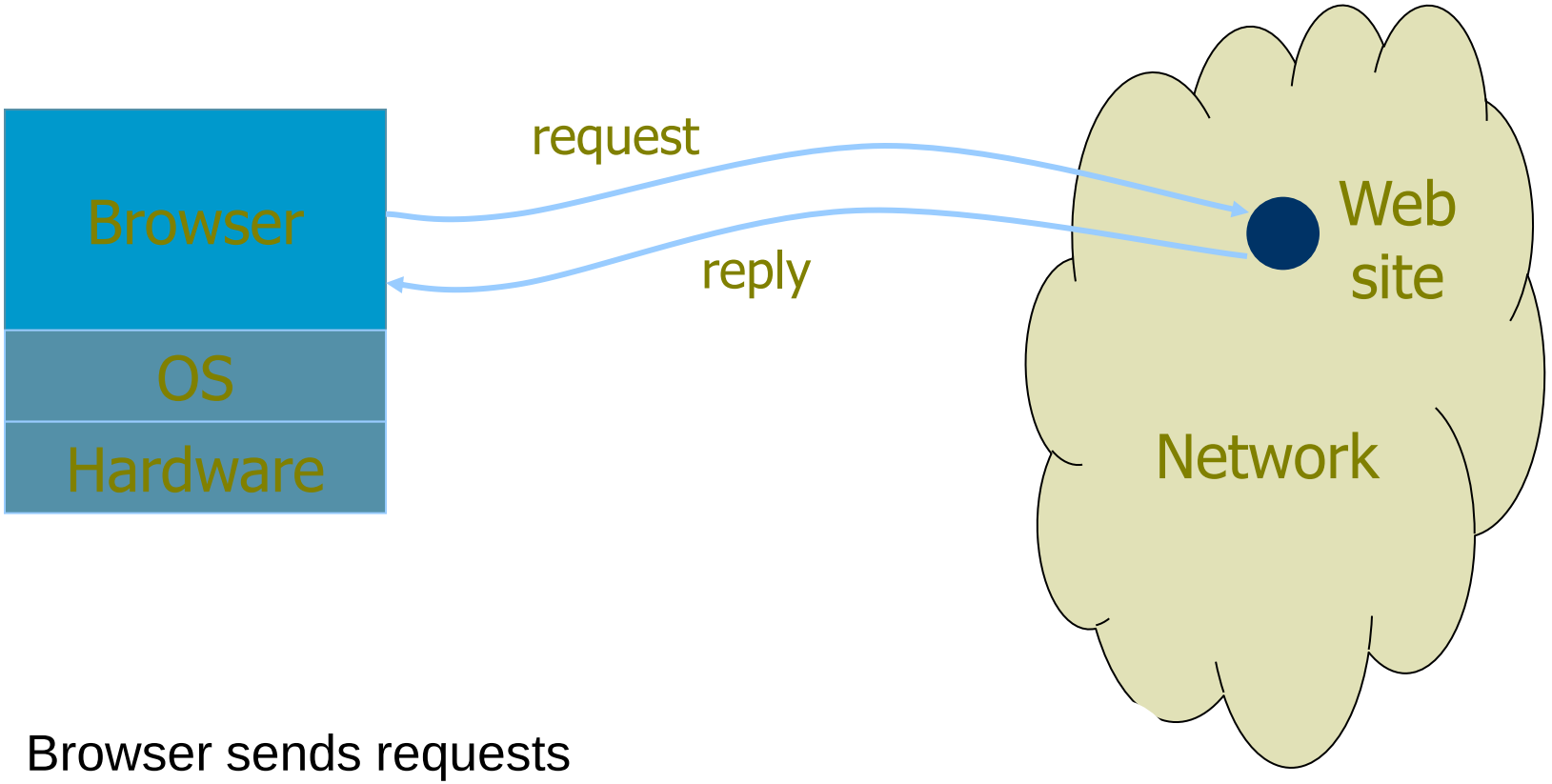


Background

- Many sensitive tasks are done through web
  - Online banking, online shopping
  - Database access
  - System administration

- Web applications and web users are targets of many attacks
  - Cross site scripting
  - SQL injection
  - Cross site request forgery
  - Information leakage
  - Session hijacking

Web Browser and Network



- Browser sends requests
- Web site sends response pages, which may include code
- Interaction susceptible to network attacks

Web Security/Privacy Issues

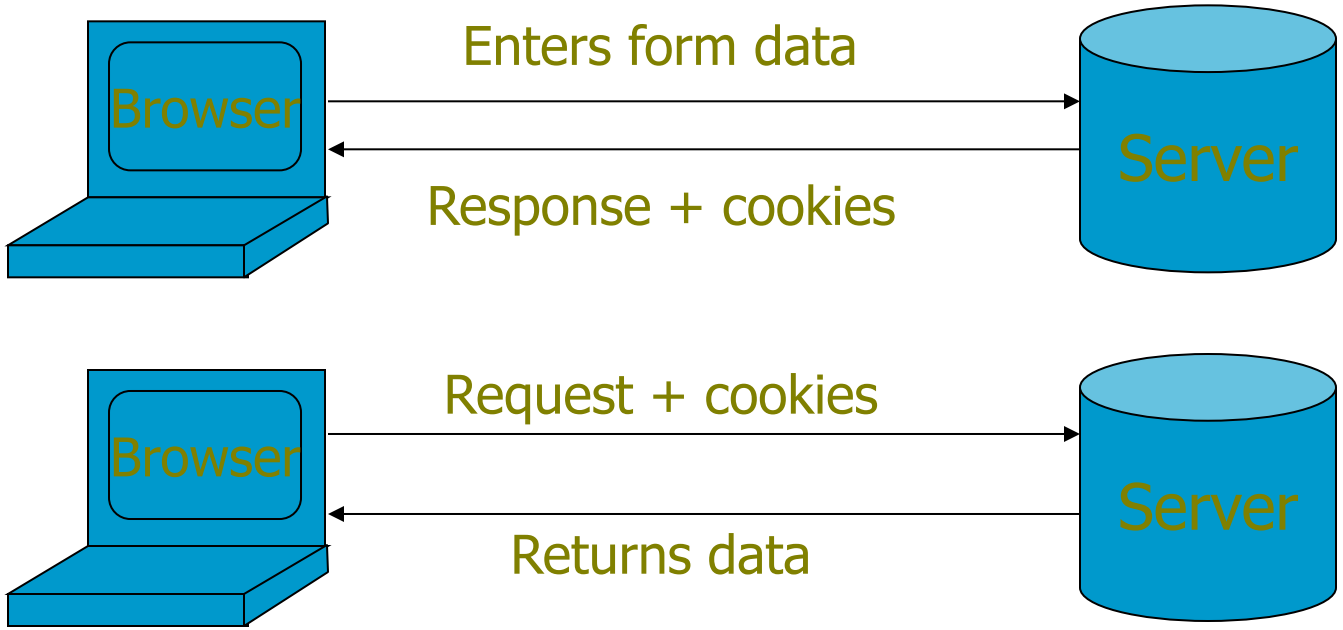
- Secure communications between client & server
  - HTTPS (HTTP over Secure Socket Layer)
- User authentication & session management
  - Cookies & other methods
- Active contents from different websites
  - Protecting resources maintained by browsers
- Web application security
- Web site authentication (e.g., anti-phishing)
- Privacy concerns

HTTP: HyperText 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
- 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

Use Cookies to Store State Info

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



Http is stateless protocol; cookies add state

Cookies Fields

- 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

Cookies

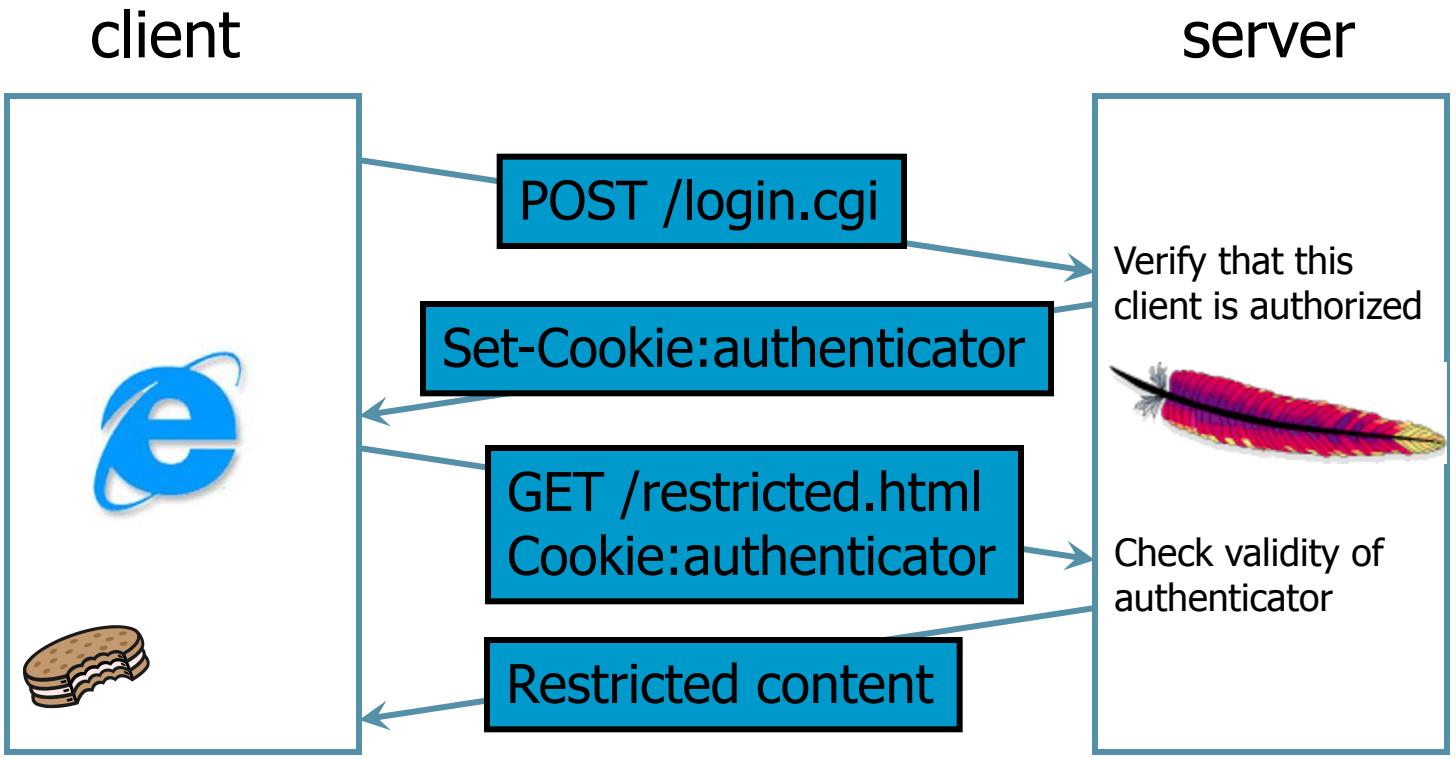
- Stored by the browser
- Used by the web applications
  - used for authenticating, tracking, and maintaining specific information about users
    - e.g., site preferences, contents of shopping carts
  - data may be sensitive
  - may be used to gather information about specific users

- 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

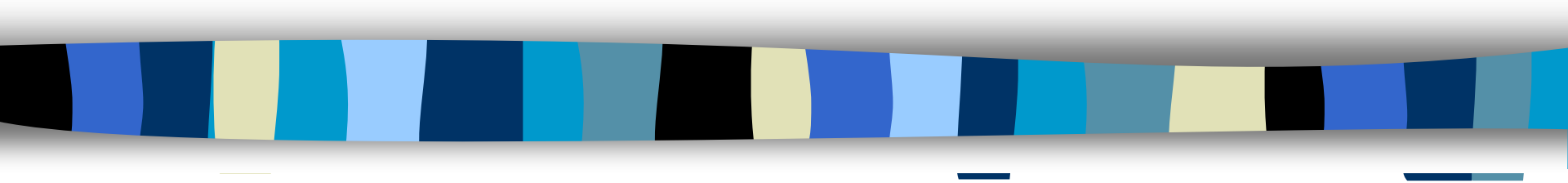


Authenticators must be unforgeable and tamper-proof

(malicious clients shouldn't be able to modify an existing authenticator)

How to design it?

Cross Site Scripting



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 that execute in browsers
- Browser extensions (plug-ins) provide further client-side programming abilities
  - E.g., Flash

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>
```

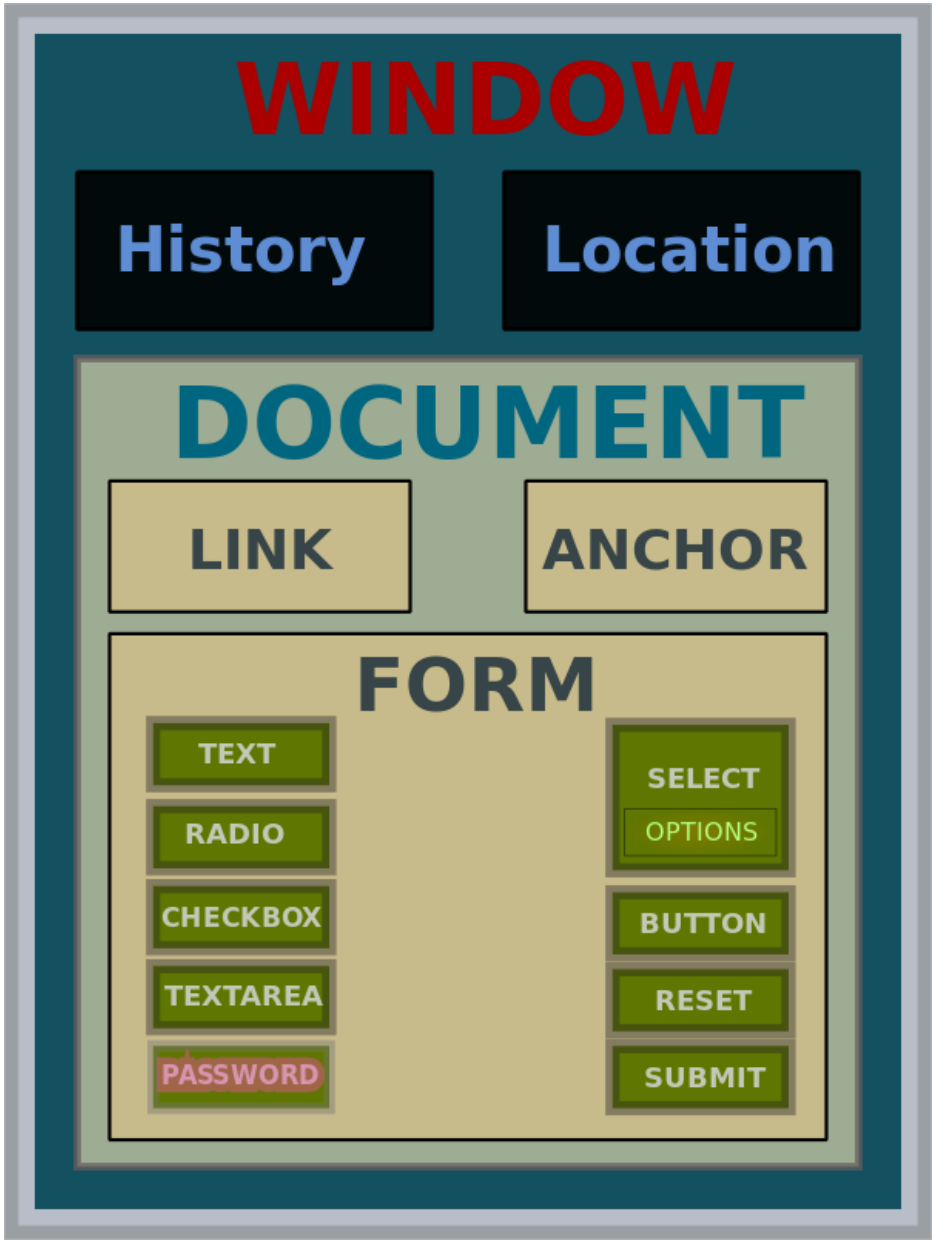
Browser receives content, displays HTML and executes scripts

Scripts are Powerful

- Client-side scripting is powerful and flexible, and can access the following resources
  - Local files on the client-side host
    - read / write local files
  - Webpage resources maintained by the browser
    - Cookies
    - Domain Object Model (DOM) objects
      - steal private information
      - control what users see
      - impersonate the user
  - Communicating with websites (via XMLHttpRequest)

Domain Object Model (DOM)

- Object-oriented model to represent webpages that allow programming access in Javascript



Browser as an Operating System

- 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

Sandbox

- A security mechanism for separating/limiting running programs
  - Running untrusted programs.
    - E.g., javascripts in webpages, mobile apps
  - Running programs that are likely to be exploited.
    - E.g., network daemon programs
- Implementation: Clearly identify what resources a program needs and cut off the rest
  - Examples include operating system–level virtualization (such as Unix chroot), virtual machine monitors (VMMs), Java applets,

Same Origin Policy

- The basic security model enforced in the browser
- SoP isolates the scripts and resources downloaded from different origins
  - E.g., evil.org scripts cannot access bank.com resources
- Use origin as the security principal
  - Note that the concept of user accounts does not apply here as security principals
- Origin = domain name + protocol + port
  - all three must be equal for origin to be considered the same

Same Original Policy: What it Controls

- Same-origin policy applies to the following accesses:
  - manipulating browser windows
  - URLs requested via the XmlHttpRequest
  - manipulating frames (including inline frames)
  - manipulating documents (included using the object tag)
  - manipulating cookies

Problems with S-O Policy

- Poorly enforced on some browsers
  - Particularly older browsers
- 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 properties of document from another
- Can be bypassed in Cross-Site-Scripting attacks

- Usability: Sometimes prevents desirable cross-origin resource sharing

Browser Architecture: One Process versus Multiple Processes

- Most processes (e.g., Firefox, Internet Explorer) use one process for a web browser
  - Multiple threads are used for rendering different webpages
- Chrome uses multiple processes
  - Use OS protection mechanism to ensure that webpages from different sites cannot easily interact
    - Because they run in different processes
  - Reliability advantage: crashing in rendering one website doesn't affect another
  - Security advantage: vulnerability in rendering does not compromise other sites; isolate plug-ins
  - Uses 3 types of processes: browser, renderers, plug-ins

What will the following program output?

```
#include <stdio.h>
void main() {
    int x;
    int y;
    y = (x = 3) + (x = 4);
    printf("%d %d\n", x, y);
}
```

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 (these inputs can have scripts)

How XSS Works on Online Blog

- Everyone can post comments, which will be displayed to everyone who view the post
- Attacker posts a malicious comment that includes scripts (which reads local authentication credentials and send of to the attacker)
- Anyone who view the post can have local authentication cookies stolen
- Web apps will check that posts do not include scripts, but the check sometimes fail.
- Bug in the web application. Attack happens in browser.

Effect of the Attack

- Attacker can execute arbitrary scripts in browser
- 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.

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

Avoiding XSS bugs (PHP)

- Main problem:
  - Input checking is difficult --- many ways to inject scripts into HTML.
- Preprocess input from user before echoing it
- PHP: **htmlspecialchars**(string)

  & → & " → " ' → '

  < → < > → >

  - **htmlspecialchars**(
    "Test", ENT_QUOTES);

    Outputs:

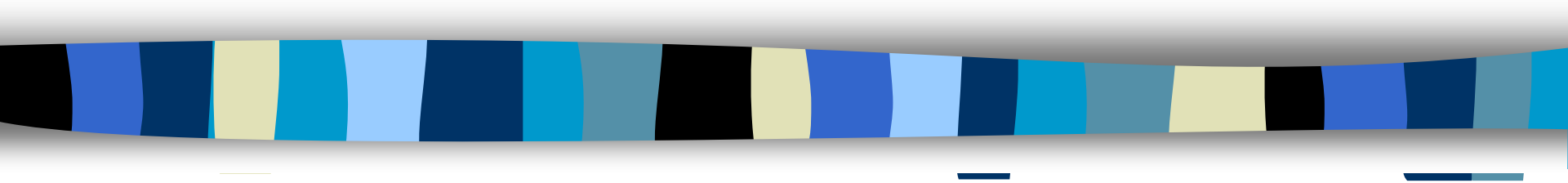
    Test

Avoiding XSS bugs (ASP.NET)

- ASP.NET 1.1:
  - **Server.HtmlEncode(string)**
    - Similar to PHP htmlspecialchars
  - validateRequest: (on by default)
    - Crashes page if finds <script> in POST data.
    - Looks for hardcoded list of patterns.
    - Can be disabled:

      <%@ Page validateRequest="false" %>

Cross site request forgery



Cross site request forgery (abbrev. CSRF or XSRF)

- Also known as **one click attack** or **session riding**
- Effect: Transmits unauthorized commands from a user who has logged in to a website to the website.
- Recall that a browser attaches cookies set by domain X to a request sent to domain X; the request may be from another domain
  - Site Y redirects you to facebook; if you already logged in, the cookie is attached by the browser

CSRF Explained

- 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

Real World CSRF Vulnerabilities

- Gmail
- NY Times
- ING Direct (4th largest saving bank in US)
- YouTube
- Various DSL Routers
- Purdue WebMail
- PEFCU
- Purdue CS Portal
- …

Prevention

- Server side:
  - use cookie + hidden fields to authenticate a web form
    - hidden fields values need to be unpredictable and user-specific; thus someone forging the request need to guess the hidden field values
  - requires the body of the POST request to contain cookies
    - Since browser does not add the cookies automatically, malicious script needs to add the cookies, but they do not have access because of Same Origin Policy
- User side:
  - logging off one site before using others
  - selective sending of authentication tokens with requests (may cause some disruption in using websites)

Coming Attractions …

- More Web Security Issues
  - SQL injection
  - Side channel information leakage
  - Cookie privacy issues