CS 88: Security and Privacy

09: Web Security: HTTP and Cookies

09-27-2022

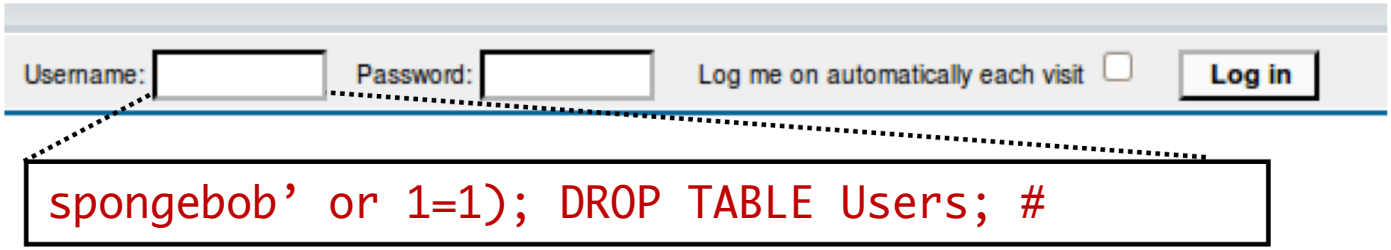
slides adapted from Dave Levine, Vitaly Shmatikov, Christo Wilson

Reading Quiz

Announcements

- Midterm Exam on October 3rd
  - 1-2.30pm and at 4 - 5.30pm @ SCI 199
  - Review in Class on Thursday
  - Dunkin Donuts + Coffee!
  - Accommodations: not informed me? do so TODAY!!!
- Thanks for your feedback last week!
  - 50%: Flipped classroom: Yay! 50%: Flipped classroom: No!
  - First upper-level G2 for majority of the class
  - Flipped on Tuesday
  - Content on Thursday + 10 minutes of ask anything!
    - Everything will be recorded
  - Solutions to worksheets: up today on Edstem
  - Feedback is important!

SQL Injection



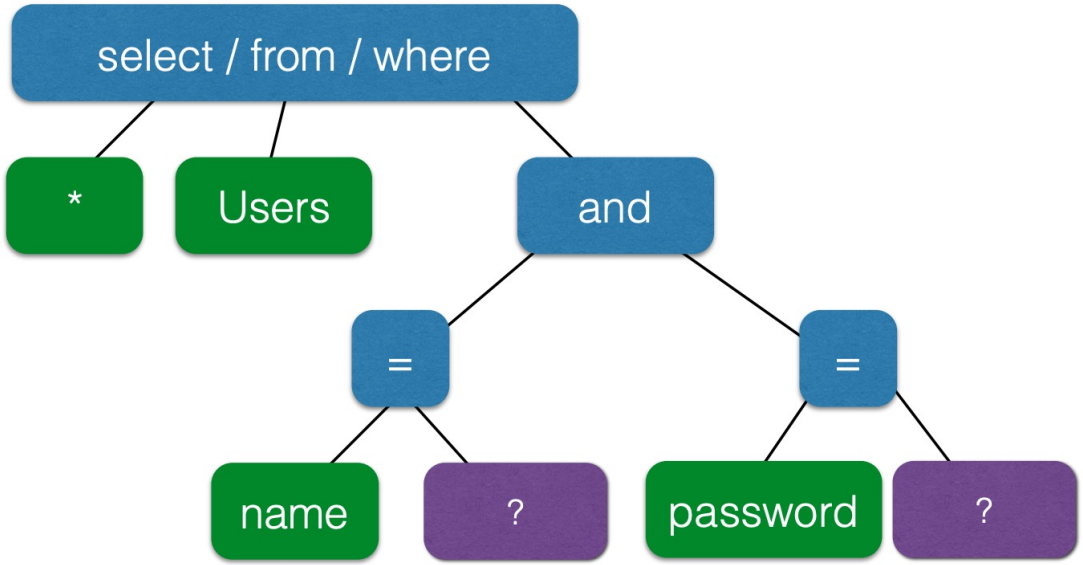

```
$result = mysql_query("select * from Users
        where(name='$user' and password='$pass');");

$result = mysql_query("select * from Users
        where(name='spongebob' or 1=1);#
        DROP TABLE Users; --
        ' and password='whocares');");
```

Can chain together statements, and can modify existing statements

The underlying issue

```
$statement = $db->prepare("select * from Users
     where(name=? and password=?);");
```



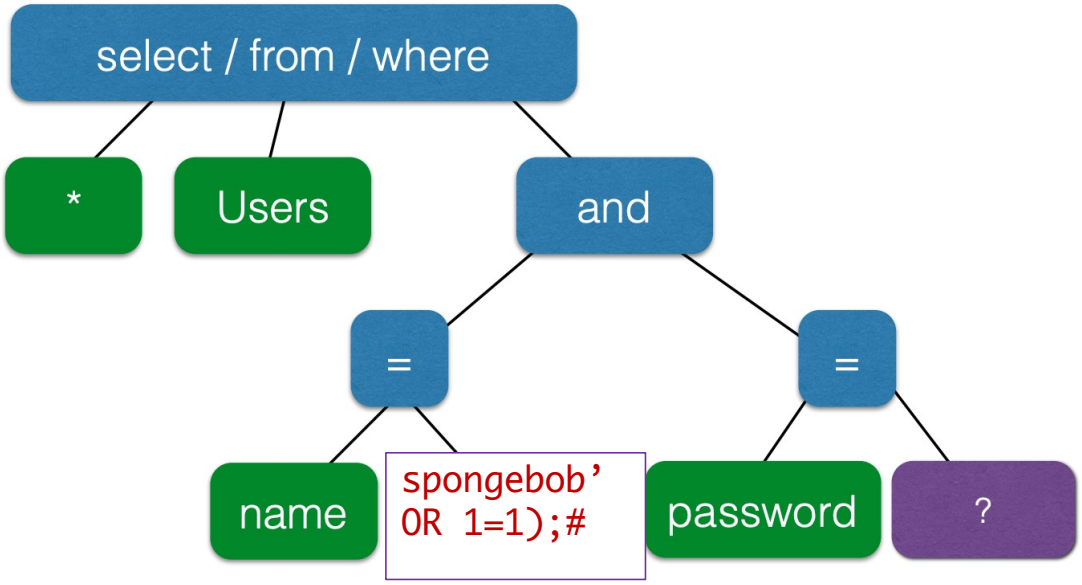
Prepare is only applied to the leaves, so the structure of the tree is fixed.

Parametrized SQL statement.

- compile the query first
- plug inputs later

The underlying issue

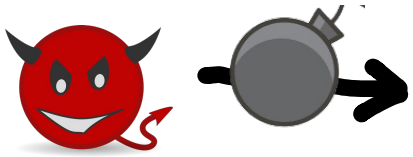
```
$statement = $db->prepare("select * from Users
     where(name=? and password=?);");
```



Prepare is only applied to the leaves, so the structure of the tree is fixed.

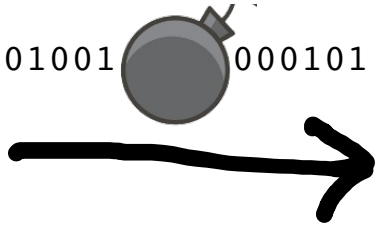
Not Just SQL!

User



Front end

Forms a string containing user input



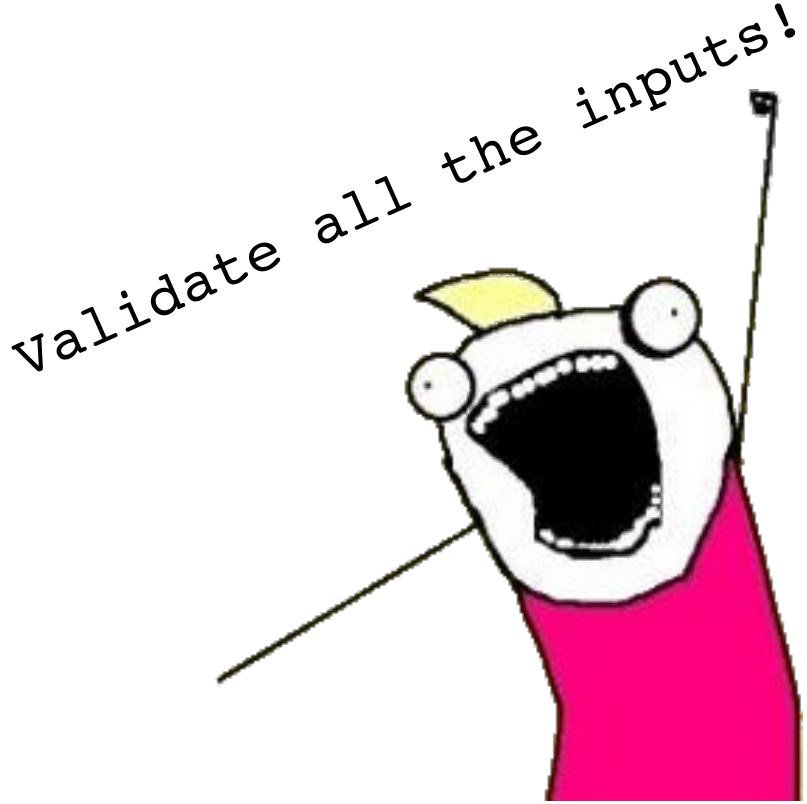
Back end

Executes this string as a command or query

Database
NoSQL storage
Javascript
eval(…)

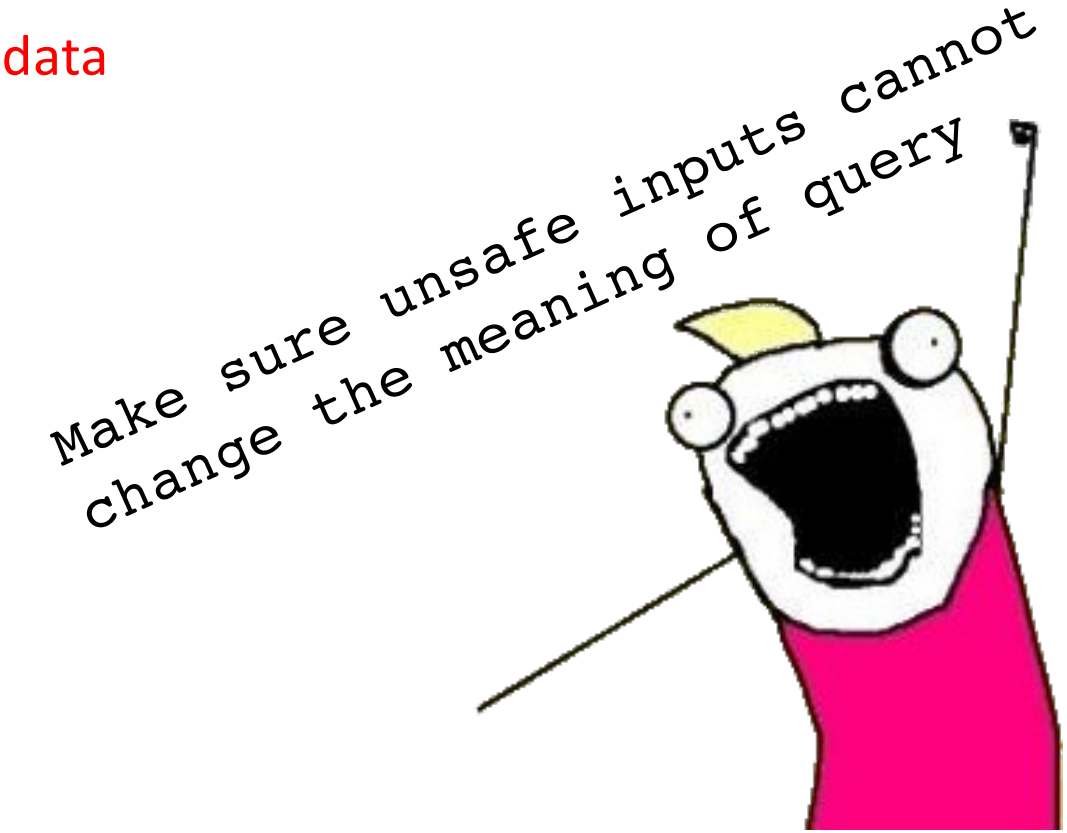
Injection vulnerabilities are a generic issue!

PREVENTING INJECTION ATTACKS

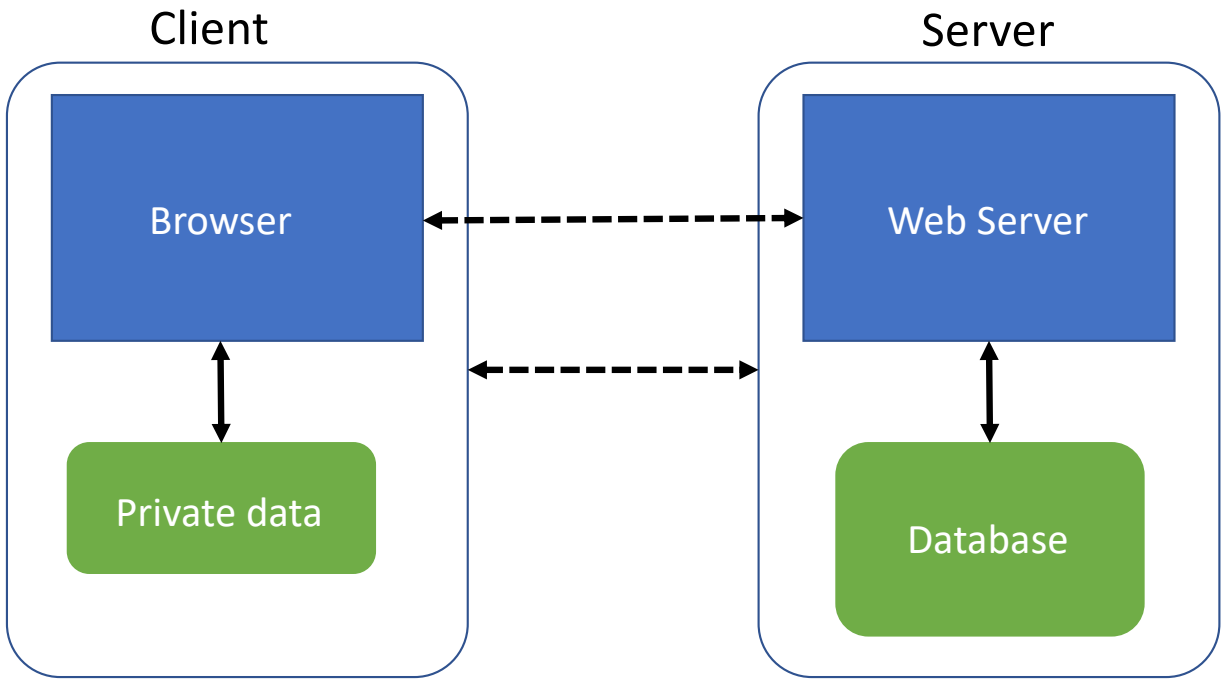


Most injection attacks trick application into interpreting data as code

This changes the semantics of a query or command generated by the application



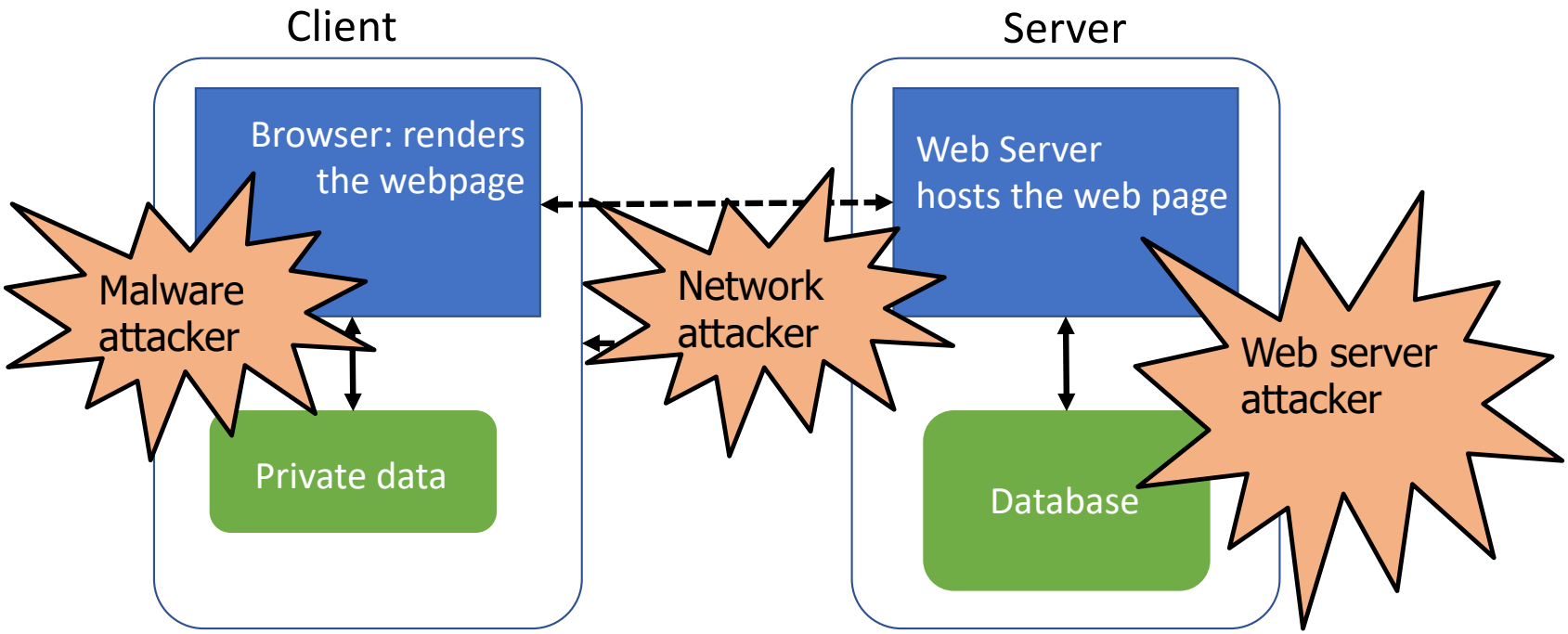
A basic web architecture



Much of the user data is part of the browser

DB is a separate entity, logically (and often physically)

Where Does the Attacker Live?



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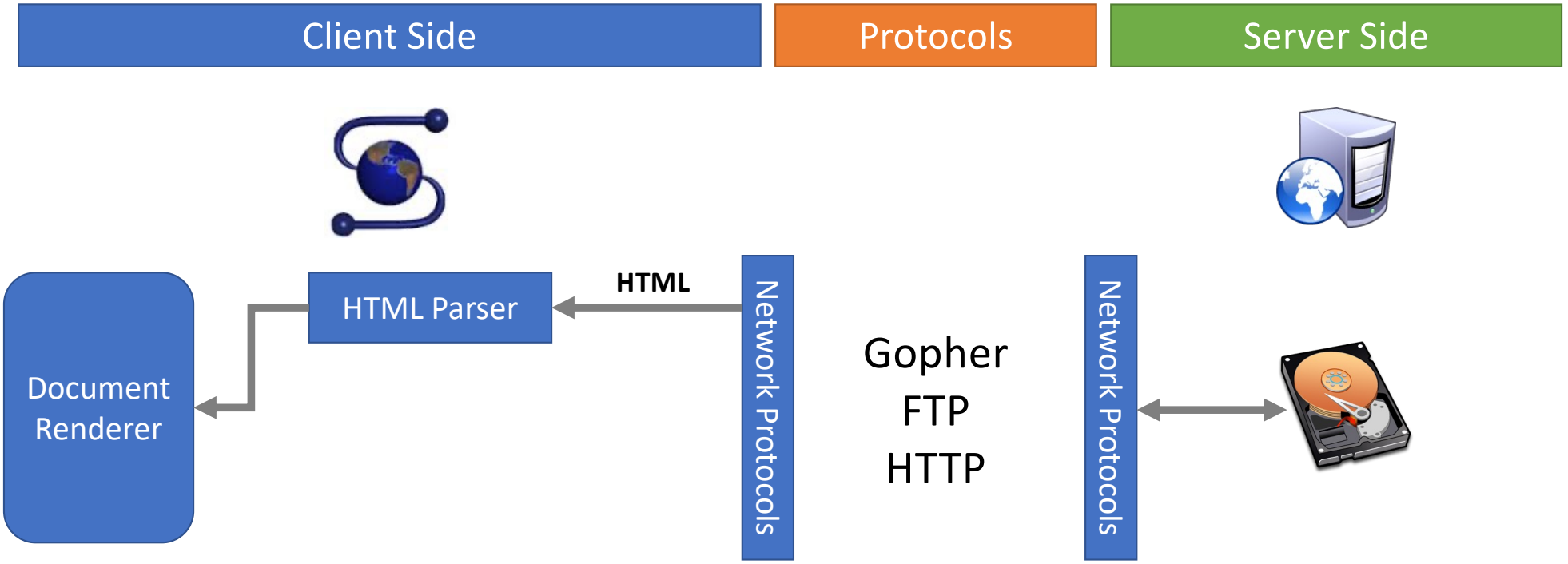
Web Architecture: Simplified View



Web Browser
Responsible for securely confining Web content presented by visited websites

Web servers: Responsible for securely parsing input data

PHP, Ruby, ASP, JSP

Overview

- The Web Model
  - What components make up today's browsers and web servers?
  - How has this functionality evolved over time?
  - What security model governs the browser?
- Attacks Against Clients
  - Cross Site Scripting (XSS) and Response Splitting
  - Cross Site Request Forgery (CSRF)
  - Clickjacking
- Attacks Against Servers
  - SQL Injection
  - Unrestricted Uploads
  - CGI shell injection

What is the web?

- **Web (World Wide Web)**: A collection of data and services
  - Data and services are provided by **web servers**
  - Data and services are accessed using **web browsers** (e.g. Chrome, Firefox)
- The web is not the Internet
  - The Internet describes *how* data is transported between servers and browsers

Elements of the Web

- URLs: How do we uniquely identify a piece of data on the web?
- HTTP: How do web browsers communicate with web servers?
- Data on the webpage can contain:
  - HTML: A markup language for static webpages
  - CSS: A style sheet language for defining the appearance of webpages
  - Javascript: a programming language for running code in the web browser

Interacting with web servers

Protocol:
ftp
https
tor

Hostname/server
- translated to an IP address by DNS

Path to the resource

index.html is static content
i.e., a fixed file returned by the server

Interacting with web servers: dynamic content

`http://facebook.com/delete.php` Path to the resource

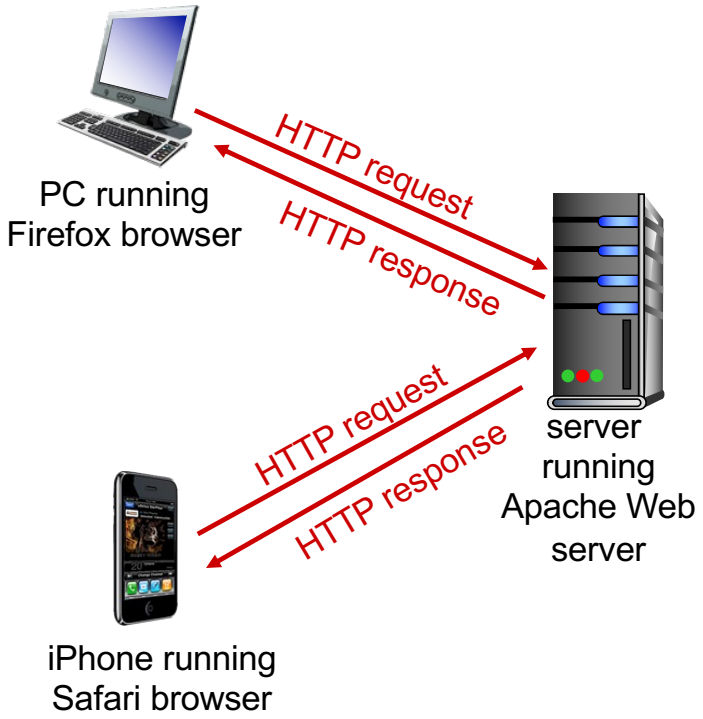
`http://facebook.com/delete.php?f=eva264&w=16`

arguments

server generates the content on the fly

HTTP: Hypertext transfer protocol

- client/server model
  - client: browser that requests, receives, (using HTTP protocol) and "displays" Web objects
  - server: Web server sends (using HTTP protocol) objects in response to requests



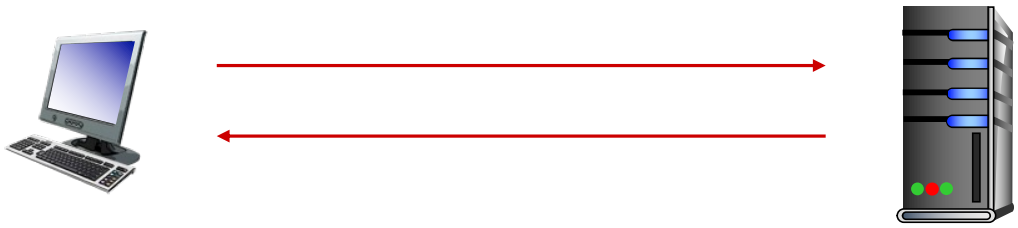
HTTP Overview

1. User types in a URL.

http://some.host.name.tld/directory/name/file.ext

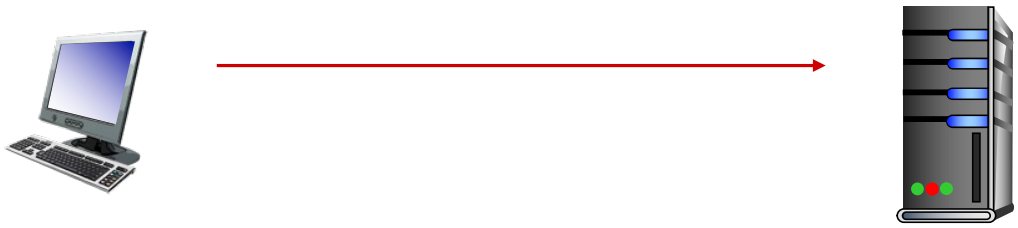
host name | path name

HTTP Overview



2. Browser establishes connection with server.
   Looks up “some.host.name.tld”
   connects //more on this later

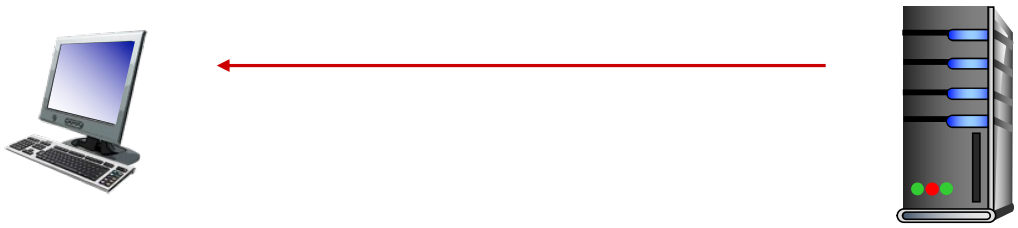
HTTP Overview



3. Browser requests the corresponding data.

GET /directory/name/file.ext HTTP/1.0
Host: some.host.name.tld
[other optional fields, for example:]
User-agent: Mozilla/5.0 (Windows NT 6.1; WOW64)
Accept-language: en

HTTP Overview



4. Server responds with the requested data.

   HTTP/1.0 200 OK

   Content-Type: text/html

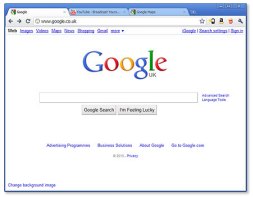
   Content-Length: 1299

   Date: Sun, 01 Sep 2013 21:26:38 GMT

   [Blank line]

   (Data data data data…)

HTTP Overview



5. Browser renders the response, fetches any additional objects, and closes the connection.

HTTP Methods

`GET:` Get the resource at the specified URL (does not accept message body)

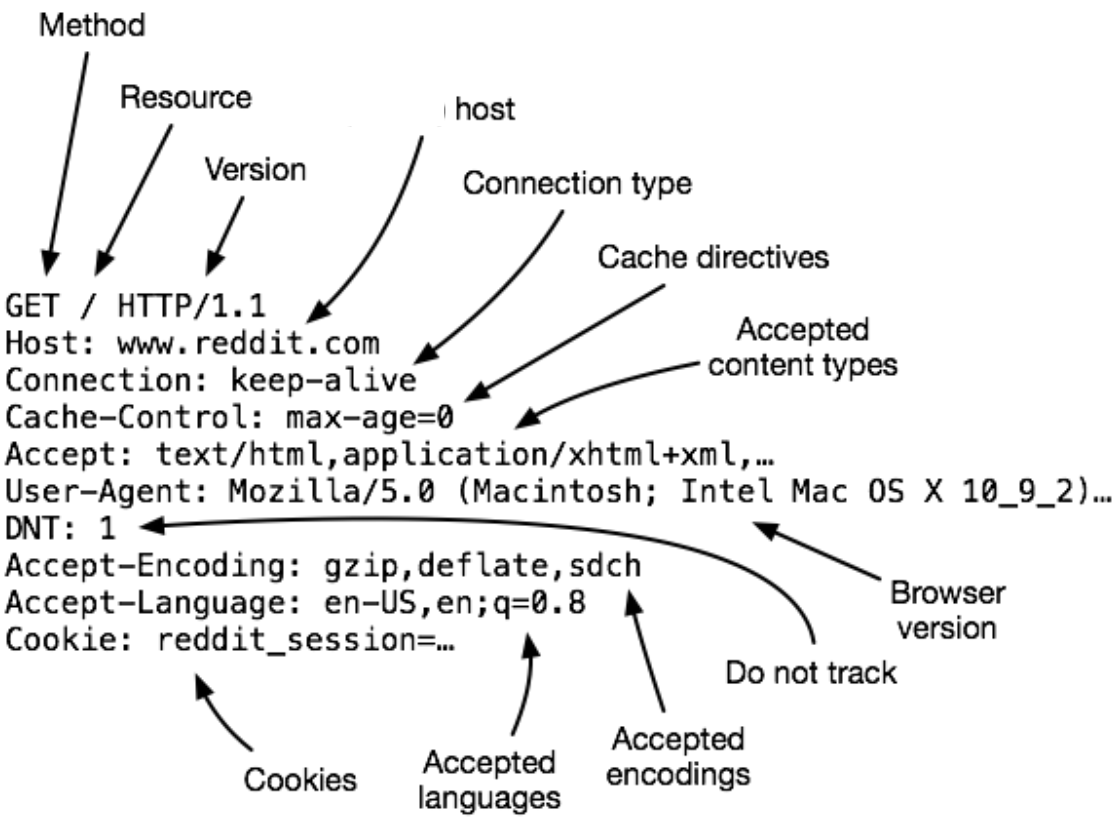
`POST:` Create new resource at URL with payload

`PUT:` Replace target resource with request payload

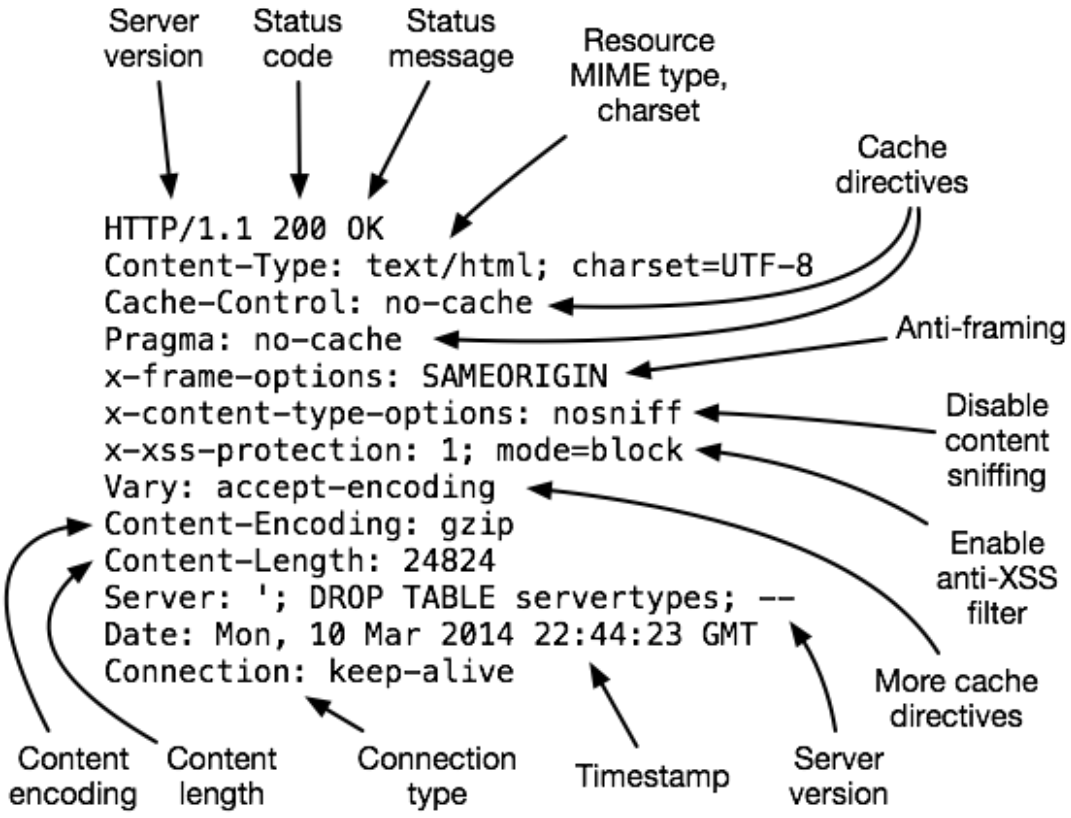
`PATCH:` Update part of the resource

`DELETE:` Delete the specified URL

HTTP Request Header



HTTP Response Header



Example

```
GET / HTTP/1.1
Host: demo.cs.swarthmore.edu

HTTP/1.1 200 OK
Vary: Accept-Encoding
Content-Type: text/html
Accept-Ranges: bytes
ETag: "316912886"
Last-Modified: Wed, 04 Jan 2017 17:47:31 GMT
Content-Length: 1062
Date: Wed, 05 Sep 2018 17:27:34 GMT
Server: lighttpd/1.4.35
```

Response headers

Response Body

Example

GET / HTTP/1.1
Host: demo.cs.swarthmore.edu

Response Headers

<html><head><title>Demo Server</title></head>
<body>
.....
</body>
</html>

Response Body

Discussion Question: HTTP Extensible Headers

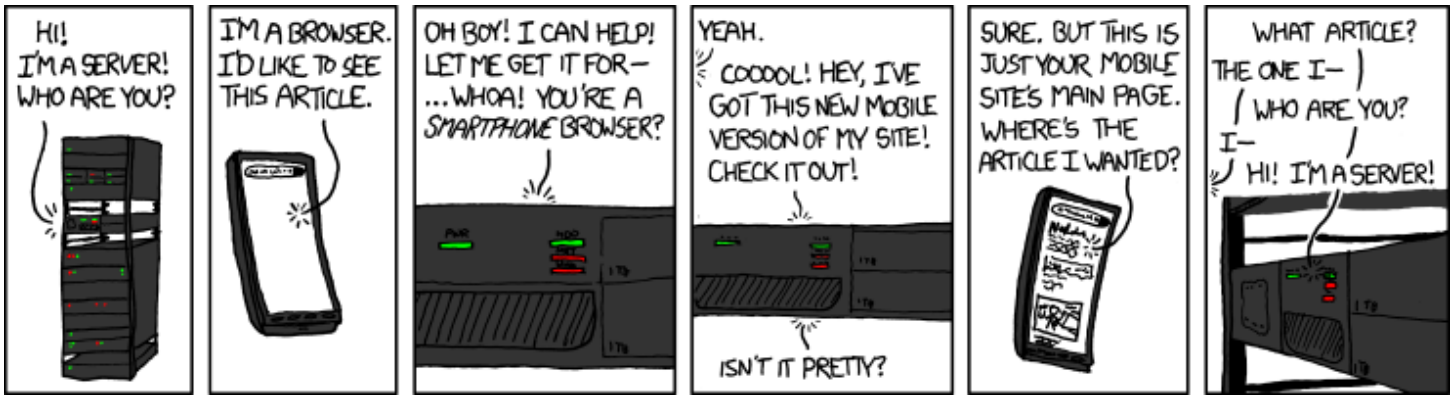
The Swarthmore IT department decides to come up with a new header field Trusted_Source in HTTP response fields. This field is used to tag all websites that have swarthmore as the origin, as trusted. How can swarthmore ensure deployability? Can this scheme be subverted by a malicious user?

```
GET /directory/name/file.ext HTTP/1.0
Host: some.host.name.tld
[other optional fields, for example:]
User-agent: Mozilla/5.0 (Windows NT 6.1; WOW64)
Accept-language: en
Referer: http://google.com?q=swarthmore.edu
```

```
HTTP/1.0 200 OK
Content-Type: text/html
Content-Length: 1299
Date: Sun, 01 Sep 2013 21:26:38 GMT
Trusted_Source = Yes
[Blank line]
(Data data data data…)
```

A. Cannot be deployed, hence cannot be subverted.
B. Can be deployed, cannot be subverted
C. Can be deployed, can be subverted
D. Hard to deploy, can be subverted.

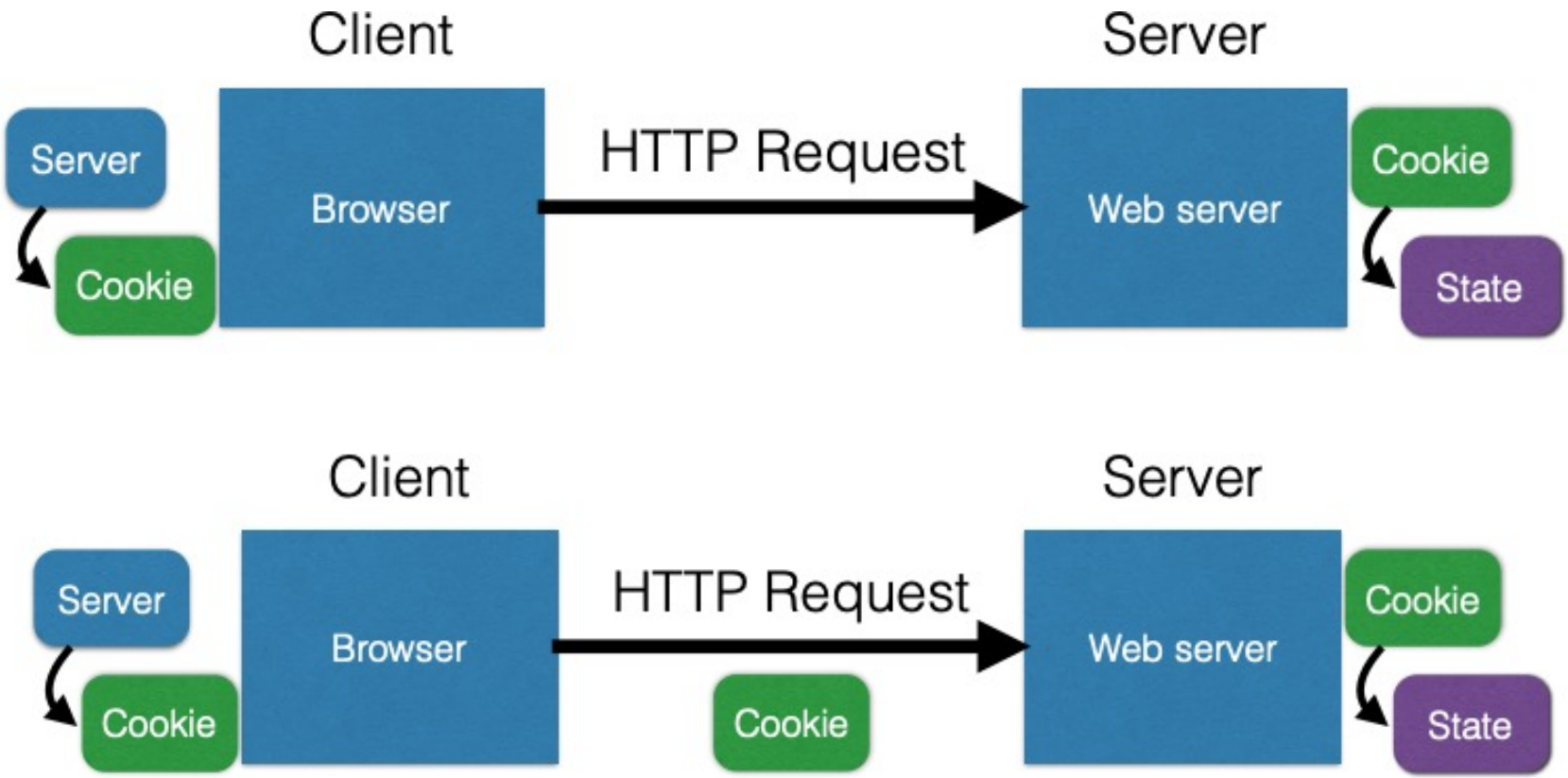
State(less)



(XKCD #869, “Server Attention Span”)

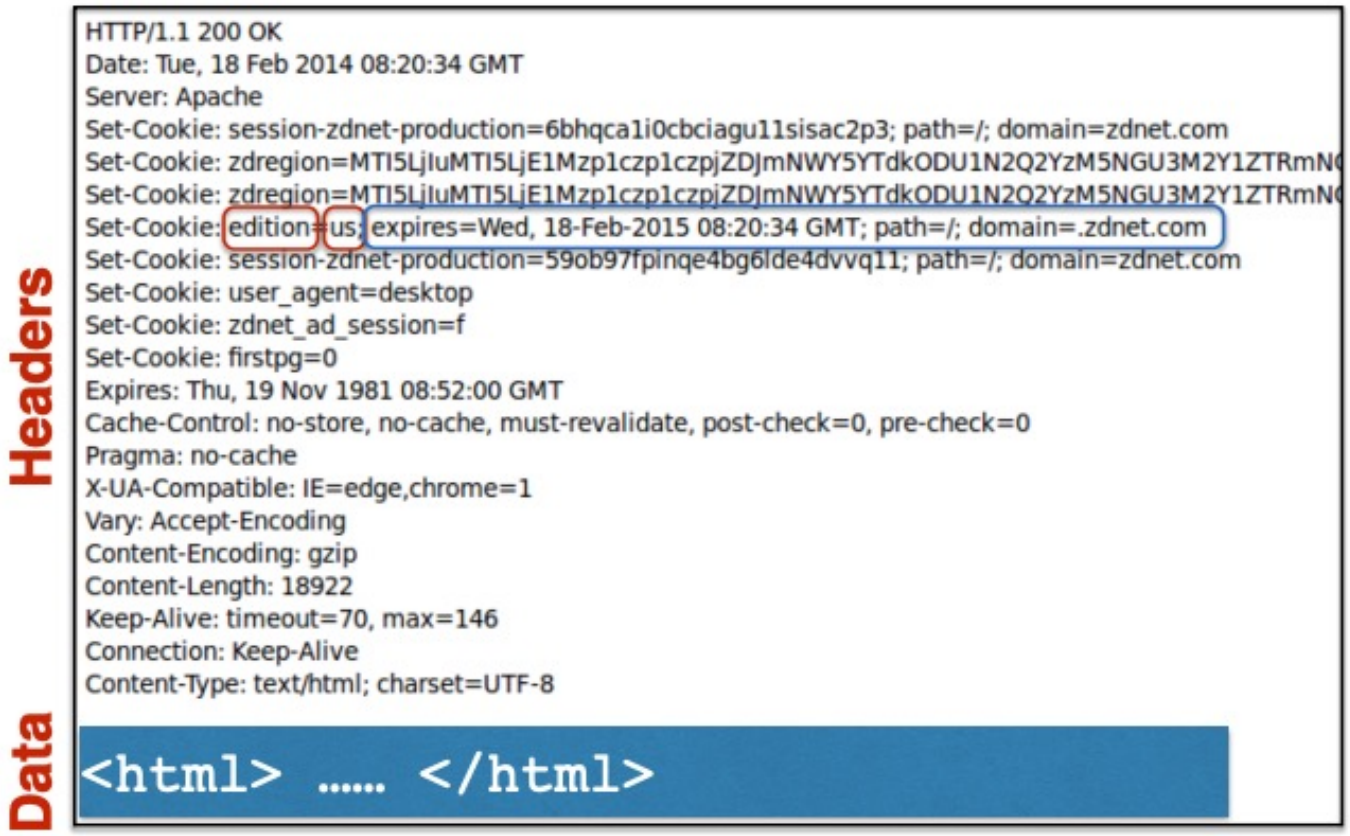
What Are Cookies Used For?

- Authentication
  - The cookie proves to the website that the client previously authenticated correctly
- Personalization
  - Helps the website recognize the user from a previous visit
- Tracking
  - Follow the user from site to site;
  - Read about iPads on CNN and see ads on Amazon 😱
  - How can an advertiser (A) know what you did on another site (S)?


Client
Server
Server
Browser
HTTP Request
Web server
Cookie
Cookie
State
Client
Server
Server
Browser
HTTP Request
Web server
Cookie
Cookie
Cookie
State

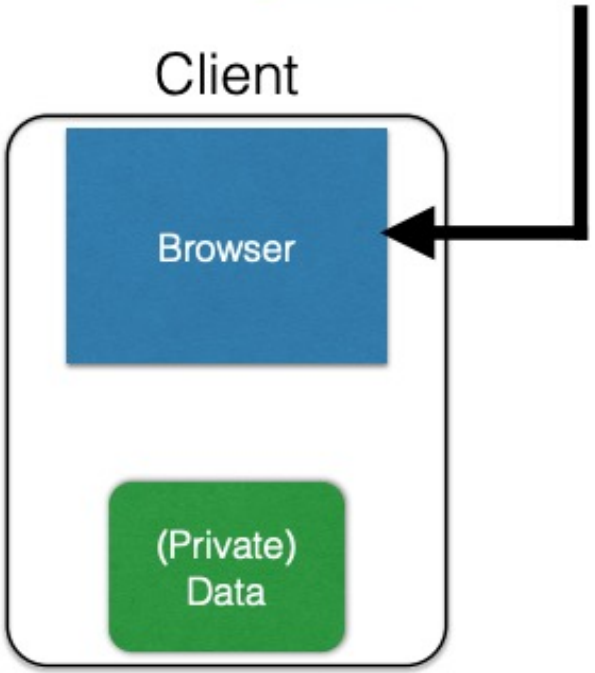
Cookies are key-value pairs

Set-Cookie:key=value; options; ….



Cookies

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

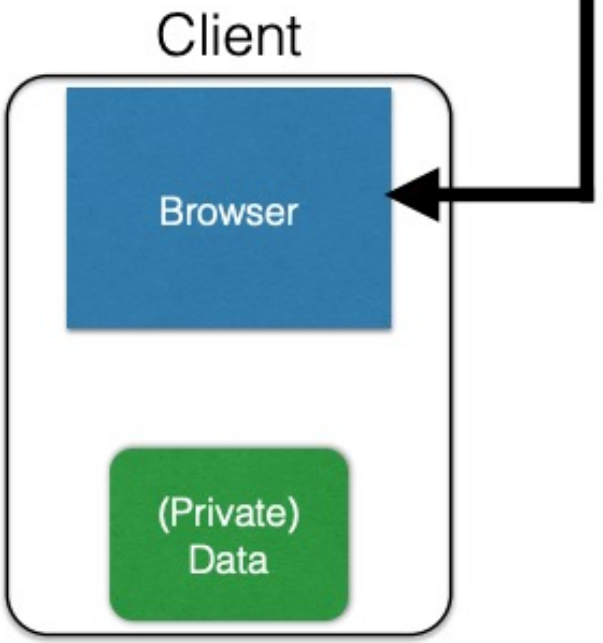


Semantics

- Store “us” under the key “edition” (think of it like one big hash table)

Cookies

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



Semantics

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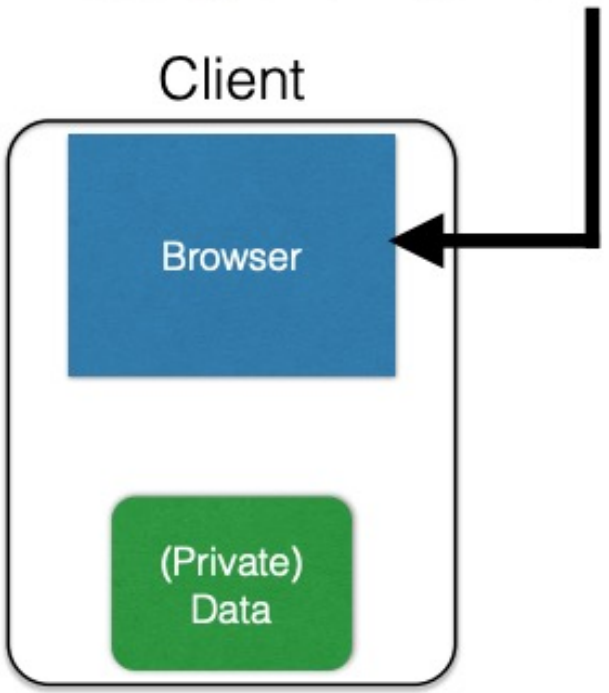
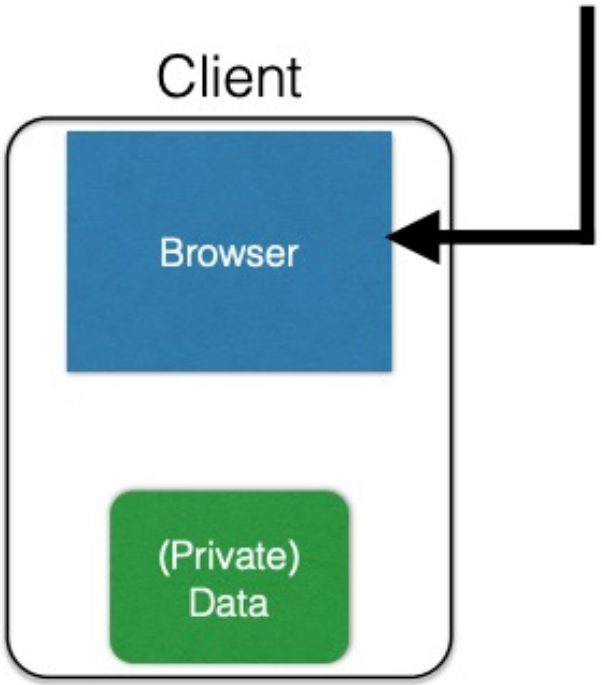


Semantics

- Store “us” under the key “edition” (think of it like one big hash table)
- This value is no good as of Wed Feb 18…
- This value should only be readable by any domain ending in `.zdnet.com`

Cookies

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



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- This value is no good as of Wed Feb 18…
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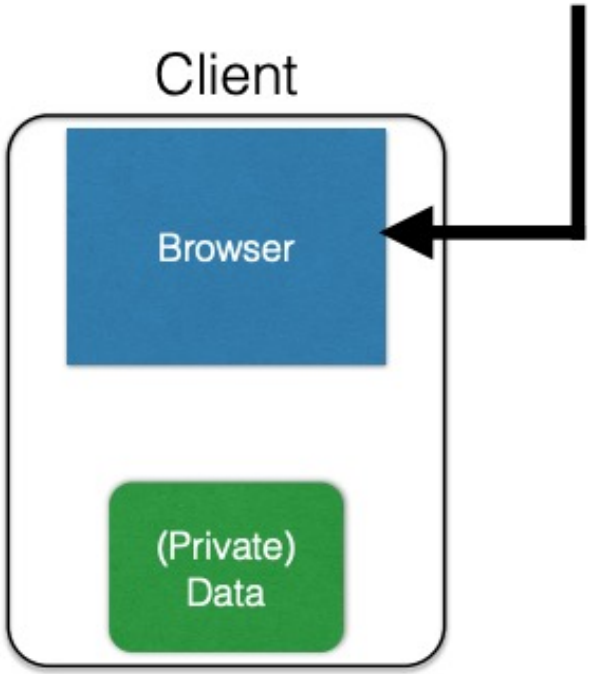
- This should be available to any resource within a subdirectory of `/`

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” (think of it like one big hash table)
- This value is no good as of Wed Feb 18…
- 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 to any future requests to `<domain>/<path>`

Discussion Question: Let's say the web-page at http://cute-puppies.com looks like the following:

```
<html>
        <body>
            <p>Here is a GIF of puppies</p>
            <img src="https://cute-puppies.com/labrador.gif">
            <script type="text/javascript"
                    src="http://yahoo.com/analytics.js"></script>
 </body>
</html>
```

Alice uses Mozilla Firefox. In her first browser tab, she has https://swarthmore.edu open. In a second tab, she opens http://cute-puppies.com. In a third tab, she opens http://cute-puppies.com once again. Which entities know that the same person visited cute-puppies.com twice?

A. cute-puppies.com operators B. yahoo.com operators C. Mozilla D. Swarthmore

Browser: Basic Execution Model

Each browser window or frame:

- Loads content
- Renders
  - Processes HTML and executes scripts to display the page
  - May involve images, subframes, etc.
- Responds to events

Events

- User actions: OnClick, OnMouseover
- Rendering: OnLoad, OnUnload
- Timing: setTimeout(), clearTimeout()

HTML and Scripts

```
<html>
    …
<p> The script on this page adds two numbers
<script>
    var num1, num2, sum
    num1 = prompt("Enter first number")
    num2 = prompt("Enter second number")
    sum = parseInt(num1) + parseInt(num2)
    alert("Sum = " + sum)
</script>
    …
</html>
```

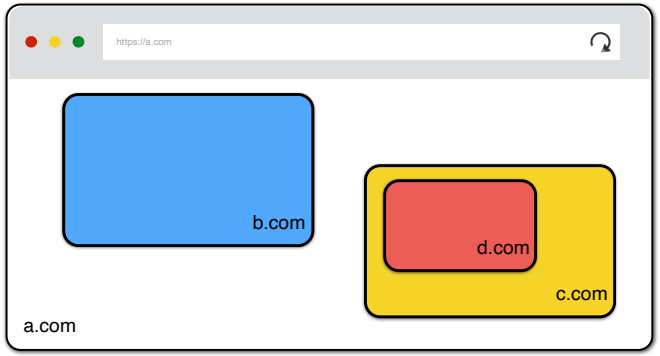
Browser receives content, displays HTML and executes scripts

(i)Frames

Beyond loading individual resources, websites can also load other *websites* within their window

- Frame: rigid visible division
- iFrame: floating inline frame

Allows delegating screen area to content from another source (e.g., ad)



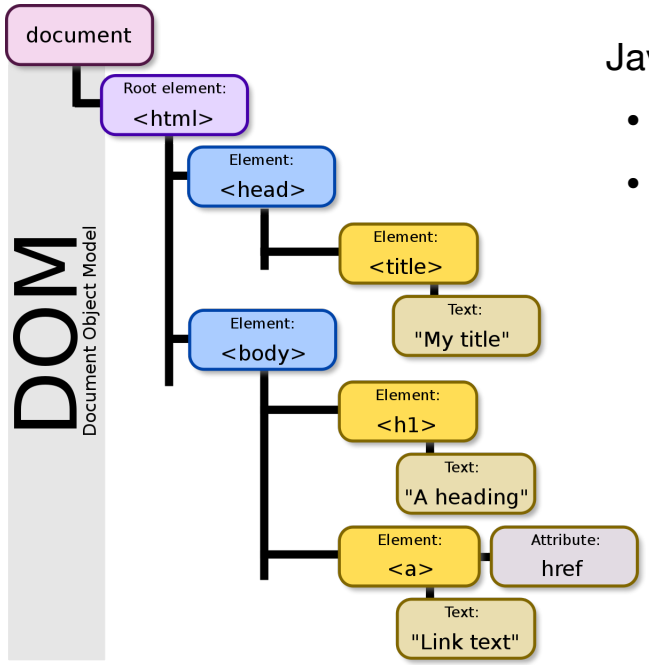
Event-Driven Script Execution

```
<script type="text/javascript">
    function whichButton(event) {
     if (event.button==1) {
              alert("You clicked the left mouse button!") }
     else {
              alert("You clicked the right mouse button!")
     }}
</script>
…
<body onmousedown="whichButton(event)">
…
</body>
```

Script defines a page-specific function

Function gets executed when some event happens

Document Object Model (DOM)

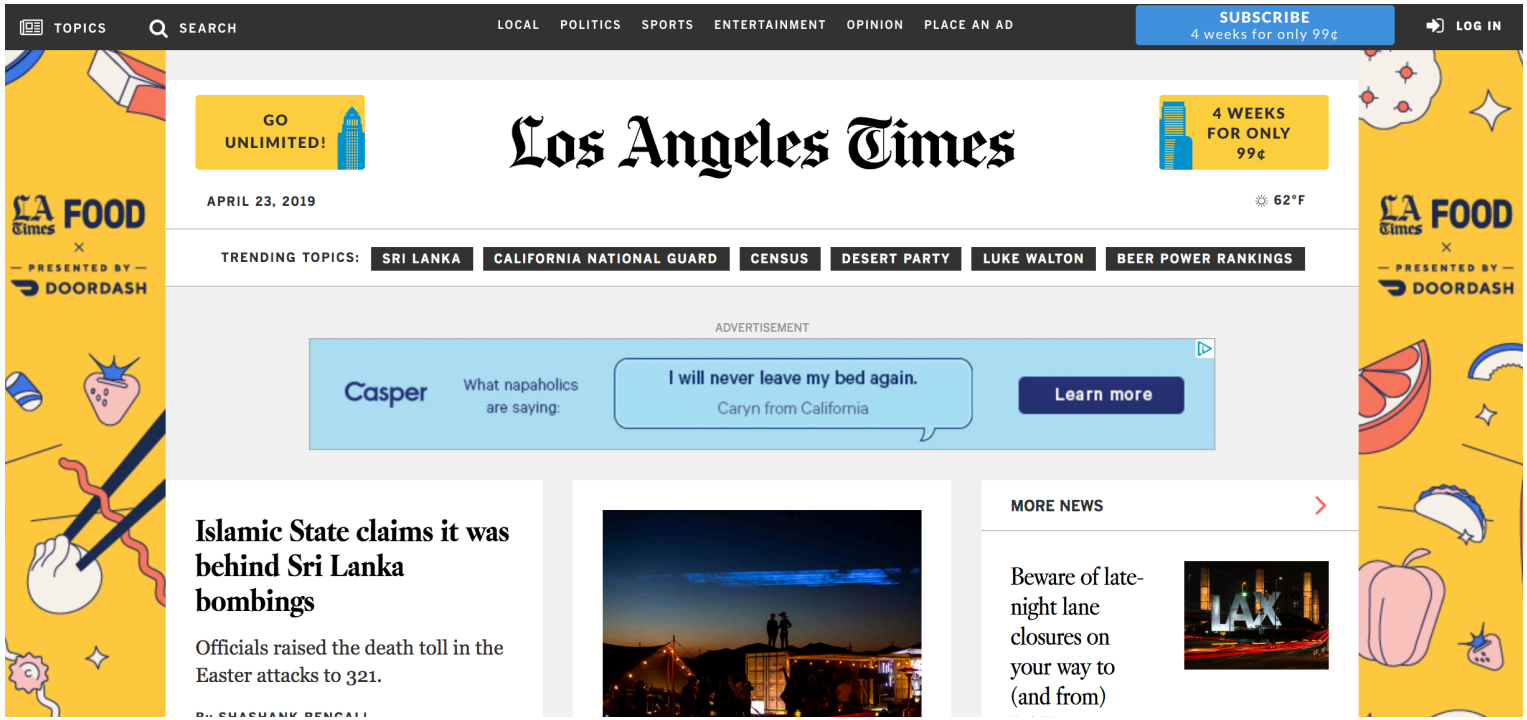


Javascript can read and modify page by interacting with DOM

- Object Oriented interface for reading/writing page content
- Browser takes HTML -> structured data (DOM)

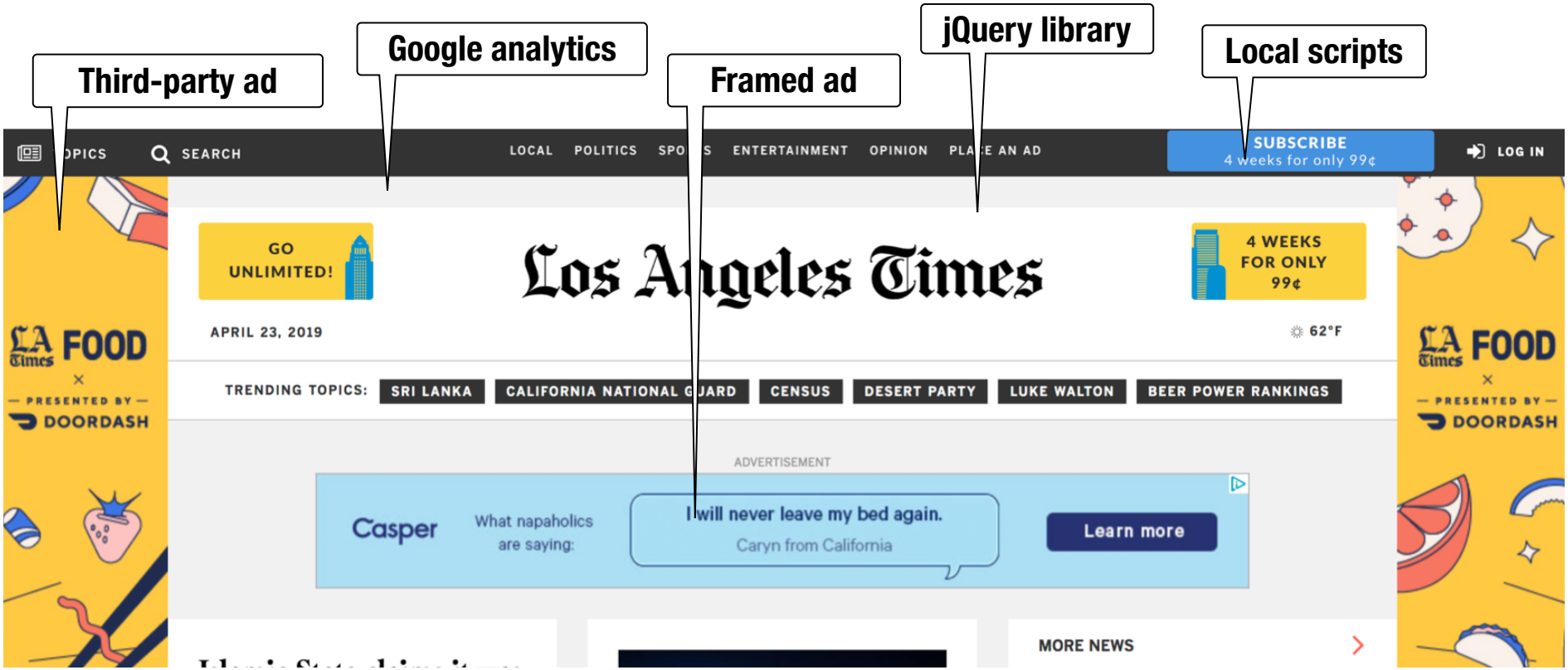
```
<p id="demo"></p>

<script>
  document.getElementById('demo').innerHTML = Date()
</script>
```

Modern Website

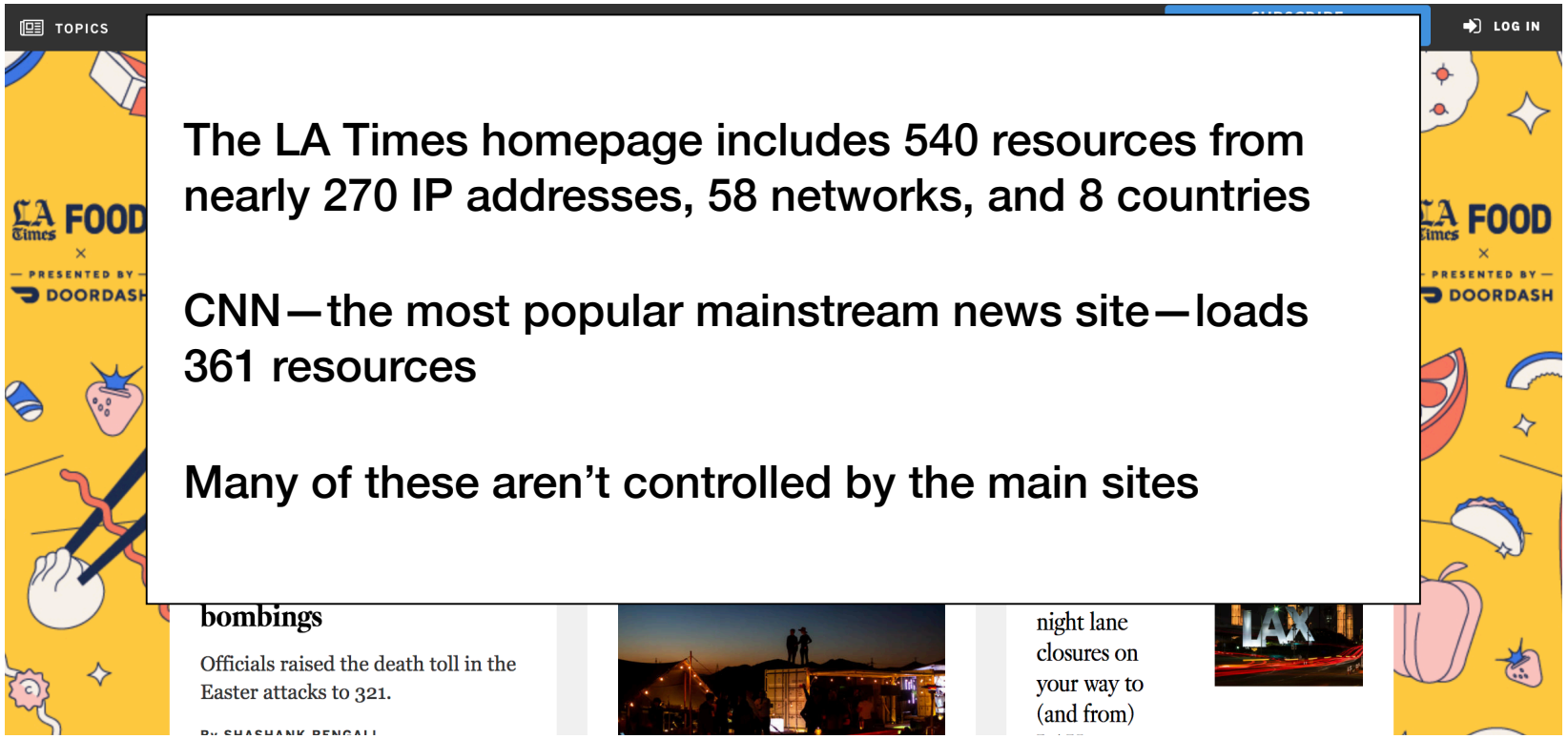


Which sections of this page generate cookies? How many third-party cookies?

Modern Website



Modern Website



Cookies and web authentication

- An extremely common use of cookies is to track users who have already authenticated
- If the user already visited http://website.com/login.html?user=alice&pass=secret with the correct password, then the server associates a “session cookie” with the logged-in user’s info
- Subsequent requests (GET and POST) include the cookie in the request headers and/or as one of the fields: http://website.com/doStuff.html?sid=81asf98as8eak
- The idea is for the server to be able to say “I am talking to the same browser that authenticated Alice earlier.”

Web Isolation

Safely browse the web

Visit a web sites (including malicious ones!) without incurring harm

Site A cannot steal data from your device, install malware, access camera, etc.

Site A cannot affect session on **Site B** or eavesdrop on **Site B**

Support secure high-performance web apps

Web-based applications (e.g., Google Meet) should have the same or better security properties as native desktop applications

Web Security Model

Subjects

"Origins" — a unique **scheme://domain:port**

Objects

DOM tree, DOM storage, cookies, javascript namespace, HW permission

Same Origin Policy (SOP)

Goal: Isolate content of different origins

- **Confidentiality**: script on evil.com should not be able to *read* bank.ch
- **Integrity**: evil.com should not be able to *modify* the content of bank.ch

Origins Examples

Origin defined as scheme://domain:port

All of these are different origins — *cannot* access one another

- http://swarthmore.edu
- http://**www.**swarthmore.edu
- http://swarthmore.edu**:8080**
- **https**://swarthmore.edu

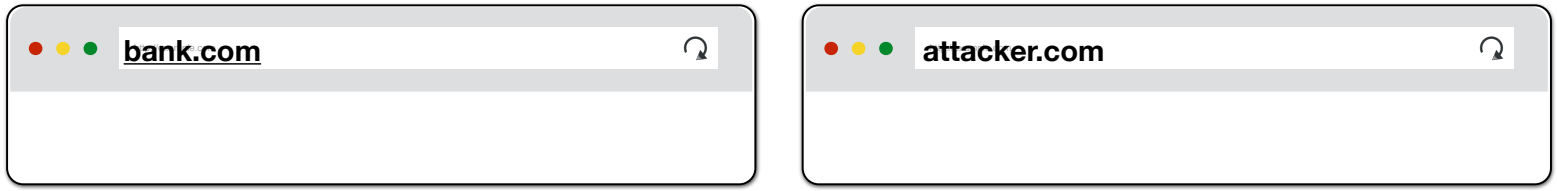
These origins are the same — *can* access one another

- http://swarthmore.edu
- http://swarthmore.edu:80
- http://swarthmore.edu.cs

Bounding Origins — Windows

Every Window and Frame has an origin

Origins are blocked from accessing other origin's objects



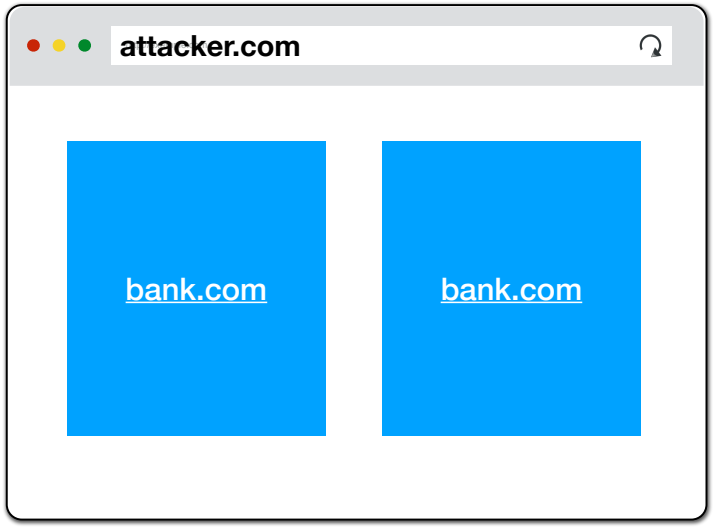
`attacker.com` cannot…

- *read or write* content from **`bank.com`** tab
- *read or write* **`bank.com`**'s *cookies*
- *detect* that the other tab has **`bank.com`** loaded

Bounding Origins — Frames

Every Window and Frame has an origin

Origins are blocked from accessing other origin's objects



`attacker.com` cannot…

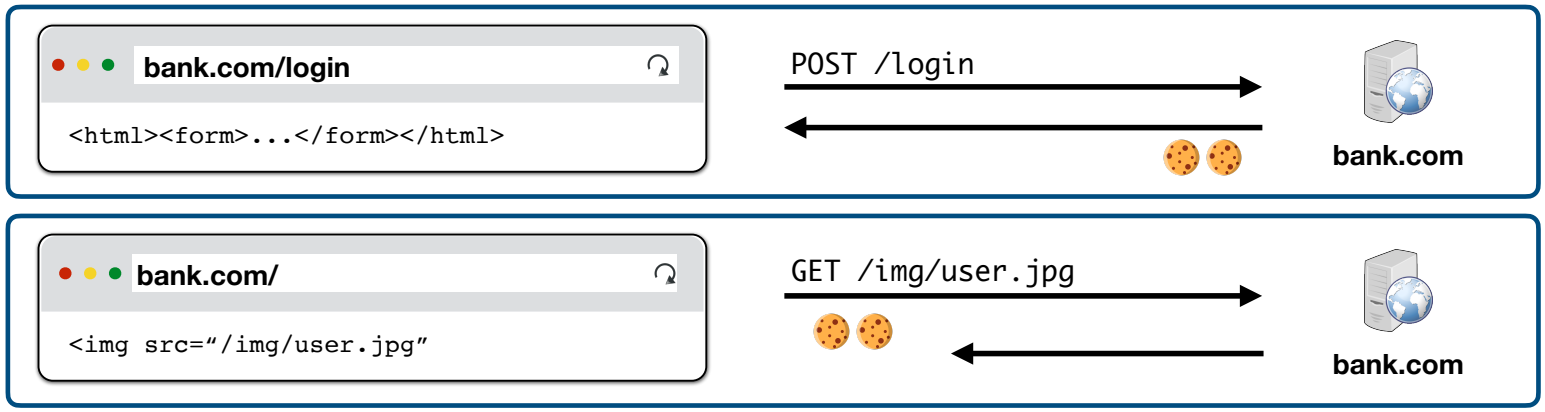
- *read* content from **`bank.com`** frame
- *access* **`bank.com`**'s *cookies*
- *detect* that has **`bank.com`** loaded

HTTP Cookies

Set-Cookie: <cookie-name>=<cookie-value>

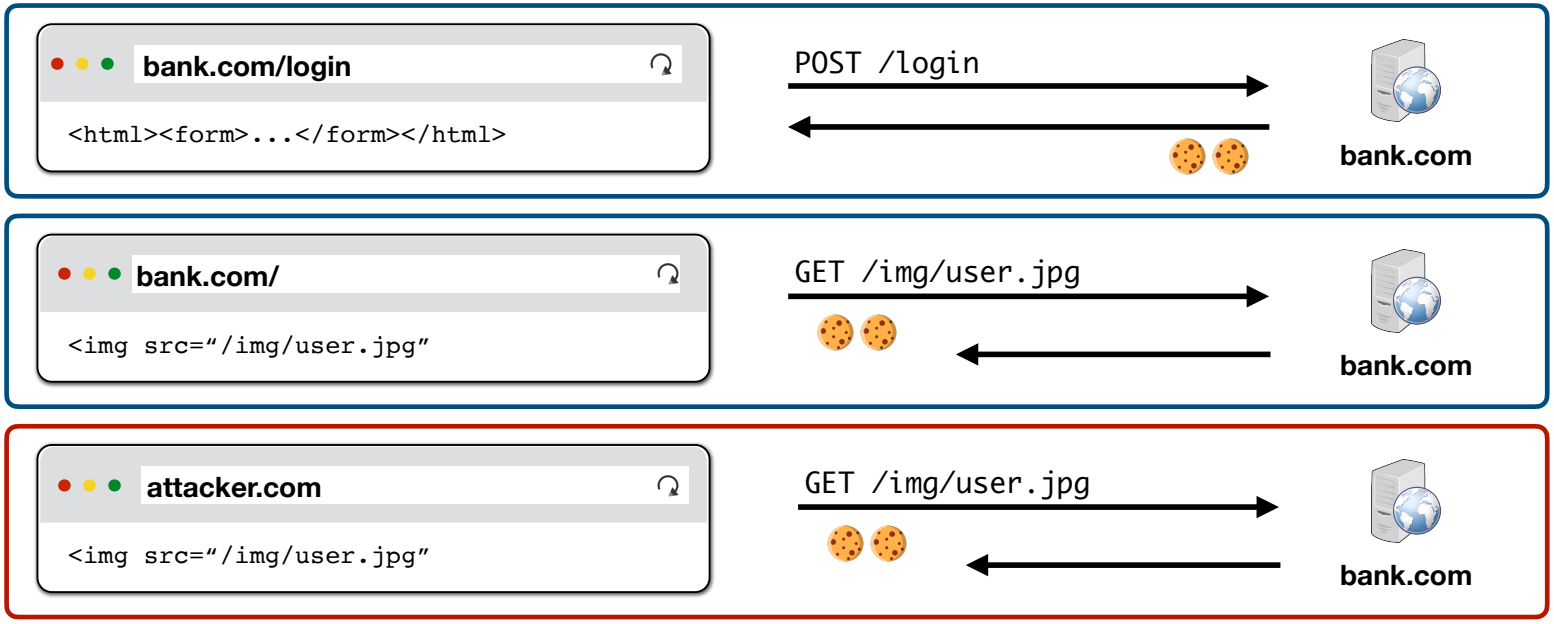
Cookies

“In scope” cookies are sent based on origin regardless of requester



Cookies

“In scope” cookies are sent based on origin regardless of requester



Cookie Same Origin Policy

Cookies use a different definition of origin than the DOM:

(domain, path): (cs88.swarthmore.edu, /foo/bar)

A page can set a cookie for its domain or any parent domain (as long as the parent domain is not a public suffix).

Can set a cookie for its path or any parent path.

Browser sends cookies that are in a URL's scope. Cookies that…

belong to domain or parent domain

AND

are located at the same path or parent path

DOM definition of an origin:
(scheme, domain, port)

Setting Cookie Scope

Websites can set a scope to be any parent of domain and URL path

- ✔ cs88.swarthmore.edu *can* set cookie for cs88.swarthmore.edu
- ✔ cs88.swarthmore.edu *can* set cookie for swarthmore.edu
- ❌ swarthmore.edu *cannot* set cookie for cs88.swarthmore.edu

- ✔ website.com/ *can* set cookie for website.com/
- ✔ website.com/login *can* set cookie for website.com/
- ❌ website.com *cannot* set cookie for website.com/login

Scoping Example

name = cookie1 value = a domain = login.site.com path = /	name = cookie2 value = b domain = site.com path = /	name = cookie3 value = c domain = site.com path = /my/home

cookie domain is suffix of URL domain ∧ cookie path is a prefix of URL path

	Cookie 1	Cookie 2	Cookie 3
checkout.site.com			
login.site.com			
login.site.com/my/home			
site.com/account			

Scoping Example

name = cookie1 value = a domain = login.site.com path = /	name = cookie2 value = b domain = site.com path = /	name = cookie3 value = c domain = site.com path = /my/home

cookie domain is suffix of URL domain ∧ cookie path is a prefix of URL path

	Cookie 1	Cookie 2	Cookie 3
checkout.site.com	No	Yes	No
login.site.com	Yes	Yes	No
login.site.com/my/home	Yes	Yes	Yes
site.com/account	No	Yes	No