Web Security

Today

- Web architecture
  - Basics of web security

What is the Web?

- A platform for deploying applications, *portably* and *securely*

client

server

Web security: two sides

- Web browser: (client side)
  - Interacts with the user
  - Fetches and renders pages from the server
  - Worry about user's own data, malware, keyloggers, …
- Web application code: (server side)
  - Runs at web site: banks, e-merchants, blogs
  - Written in PHP, ASP, JSP, Python, Ruby, Node.js, …
  - Decides which page to serve to which users/requests (authorized users, dynamic content, etc)
  - Worry about all users' data, targeted attacks, …

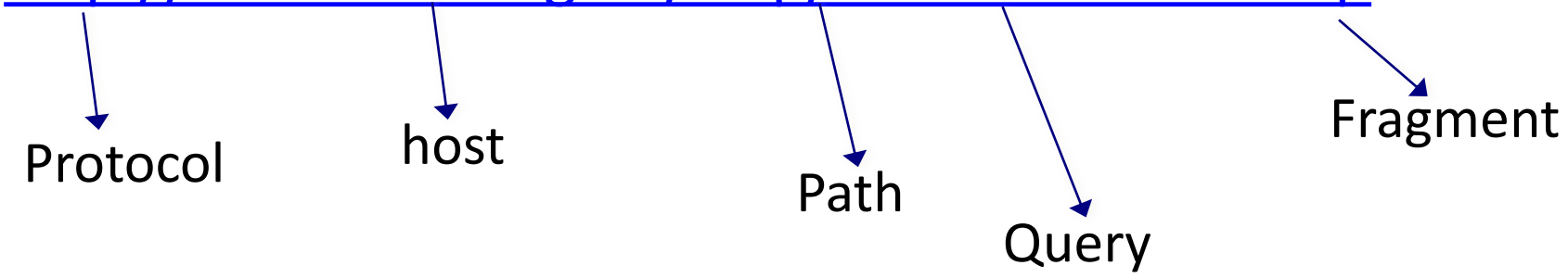
A historical perspective

- The web is an example of “bolt-on security”
- Originally, the web was invented to allow physicists to share their research papers
  - Only textual web pages + links to other pages; no security model to speak of
- Then we added embedded images
  - Crucial decision: a page can embed images loaded from another web server
- Then, Javascript, dynamic HTML, AJAX, CSS, frames, audio, video, ...
- Today, a web site is a distributed application

URLs

- Global identifiers of network-retrievable documents
- Example:

http://ecen5032.org:80/tmp/test?foo=1337#top



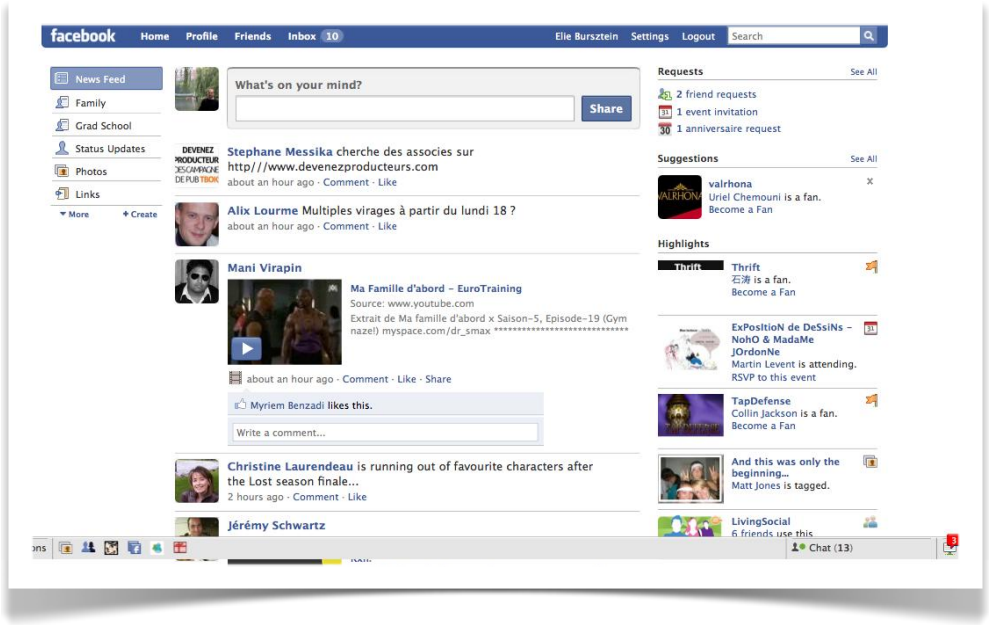
Are URLs case-sensitive?

HTML

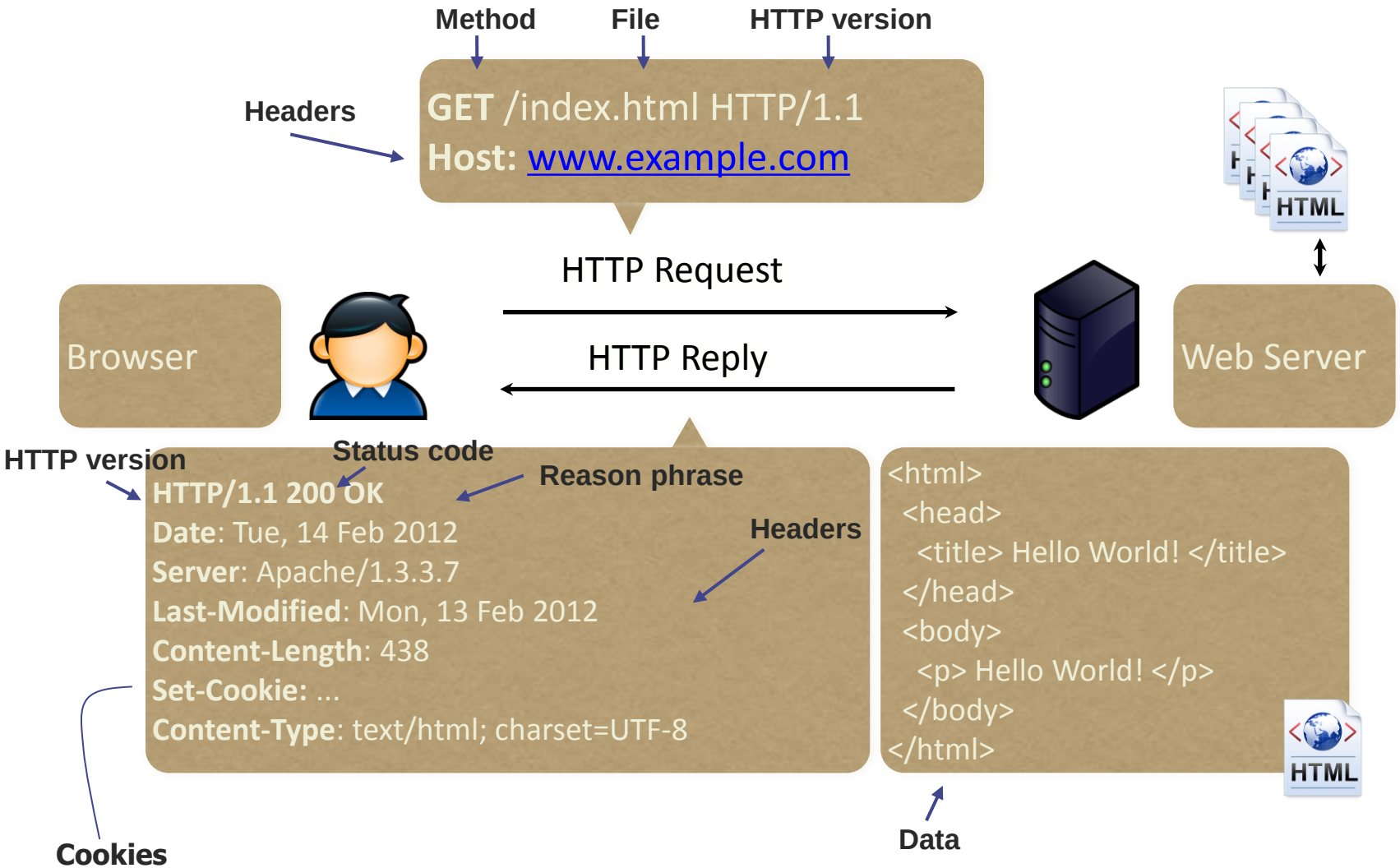
- Hypertext markup language (HTML)
  - Describes the content and formatting of Web pages
  - Rendered within browser window
- HTML features
  - Static document description language
  - Supports linking to other pages and embedding images by reference
  - User input sent to server via forms
- HTML extensions
  - Additional media content (e.g., PDF, video) supported through plugins
  - Embedding programs in supported languages (e.g., JavaScript, Java) provides dynamic content that interacts with the user, modifies the browser user interface, and can access the client computer environment

HTTP protocol

- HTTP is
  - widely used
  - Simple
  - Stateless



HTTP Protocol



HTTP GET request

- Used to fetch resources
- Shouldn’t change state on the server

```
GET /cat.jpg HTTP/1.1
Host: catpictures.net
Connection: keep-alive
Upgrade-Insecure-Requests: 1
User-Agent: Mozilla/5.0 (X11; Linux x86_64) AppleWebKit/537.36
    (KHTML, like Gecko) Chrome/56.0.2924.76 Safari/537.36
Accept: text/html,application/xhtml+xml;q=0.9,image/webp,*/*;q=0.8
Accept-Encoding: gzip, deflate, sdch, br
Accept-Language: en-US,en;q=0.8
```

HTTP POST request

- Used to update state on the server
- Clients can send/upload files/data

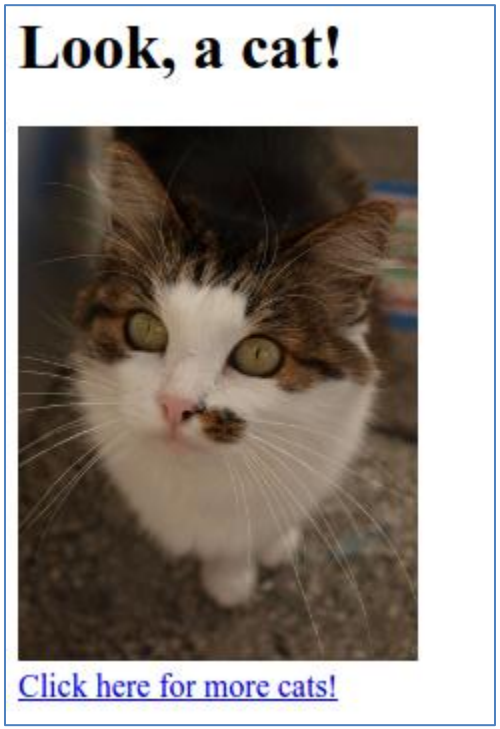
```
POST /register HTTP/1.1
Host: catpictures.net
Connection: keep-alive
Upgrade-Insecure-Requests: 1
User-Agent: Mozilla/5.0 (X11; Linux x86_64) AppleWebKit/537.36
    (KHTML, like Gecko) Chrome/56.0.2924.76 Safari/537.36
Accept: text/html,application/xhtml+xml;q=0.9,image/webp,*/*;q=0.8
Accept-Encoding: gzip, deflate, sdch, br
Accept-Language: en-US,en;q=0.8
Content-Length: 20

User=bob&Pass=abc123
```

HTML Basics

- HyperText Markup Language
  - Nested “tag” structure

```
<html>
  <head>
    <title>Cats!</title>
  </head>
  <body>
    <h1>Look, a cat!</h1>
    <span>
      <img src="cat.jpg" width="200px"/>
      <br/>
      <a href="cats.html">
       Click here for more cats!
      </a>
    </span>
  </body>
</html>
```



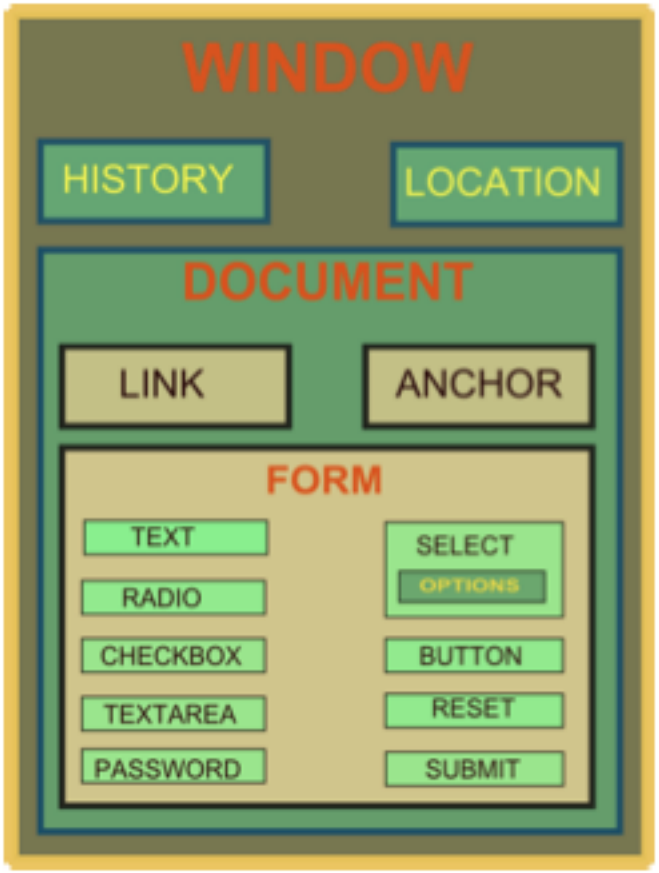
HTML, CSS, Javascript

- HTML for **structure**
  - What elements of a page are related?
  - What resources should be included?
- CSS (Cascading Style Sheet) for **style**
  - What fonts/colors/sizes/positions should elements be?
- Javascript for **dynamic content**
  - When a user clicks this, do that
  - *Here be dragons!*

Javascript

```
<html>
  <head>
    <script type="text/javascript">
       alert('Hello, World!');
    </script>
  </head>
  <body>
  </body>
</html>
```

DOM Tree: Document Object Model



- "The Document Object Model is a platform- and language-neutral interface that will allow programs and scripts to dynamically access and update the content, structure and style of documents."

Javascript

- Functional, imperative, and object-oriented
- Oh, and untyped. Good luck! ☺

```
function factorial(x) {
    var r = x;
    for (var i=1; i<x; i++) {
        r *= (x-i);
    }
    return r;
}

alert(factorial(10));

setTimeout(function () {
               alert(factorial(10));
           }, 1000);
```

Functional!

```
// Assign unnamed (anonymous) functions to variables
var factorial = function (x) {
    var r = x;
    for (var i=1; i<x; i++) {
        r *= (x-i);
    }
    return r;
};

// Anonymous functions can be passed like a function pointer
setTimeout(function () {
                alert(factorial(10));
            }, 1000);

// You can even call anonymous functions!
(function (name) { alert('Hello, ' + name))('Alice');
```

Untyped weirdness!

```
var x = ‘dog’ + 5; // ‘dog5’


x = ‘5’ + 3;       // ‘53’
x = ‘5’ – 3;       // 2
x = ‘dog’ – 3;     // NaN

// No need to memorize this, but just know JS is weird...
x = [];            // An (empty) array
x = ![];           // false
x = 0 + [];        // “0”
x = +[];           // 0
x = +!+[];         // 1  (because !0 == true and +true == 1)
// Can write any Javascript program using only 6 characters:
// JSFuck:     ()+[]!
```

Javascript accessing the DOM

```
<html>
  <span id="foo">
    <a href="prize.html">Click here, quick!</a>
  </span>
  <script>
    function too_late() {
        document.getElementById('foo').innerText = "TOO SLOW!";
    }
    setTimeout(too_late, 100);
  </script>
</html>
```

JQuery

```
<html>
  <script src="jquery-3.1.0.min.js"></script>
  <span id="foo">
    <a href="prize.html">Click here, quick!</a>
  </span>
  <script>
    function too_late() {
        $('#foo').innerText = "TOO SLOW!";
    }
    setTimeout(too_late, 100);
  </script>
</html>
```

AJAX (w/ JQuery)

```
<html>
  <script src="jquery-3.1.0.min.js"></script>
  <span id="foo">Loading the weather...</span>
  <script>
    $(function() {
        // This function will be called on DOM load

        // $.get(url, cb) makes an asynchronous retrieval of
        // the provided URL, and calls the second argument
        $.get("https://site.com/weather", function (data) {
                // This function is called with the result of
                // loading the URL
                $('#foo').html(data);
            });
    });
  </script>
</html>
```

Security on the web

- Web sites should not be able to read or change files on my computer
- Web sites should not be able to learn what other websites I visit, or how I interact with them
- Web sites should not be able to cause me to interact with other unrelated websites

Security on the web

- Risk #1: we don't want a malicious site to be able to trash my files/programs on my computer
  - Browsing to awesomevids.com (or evil.com) should not infect my computer with malware, read or write files on my computer, etc.
- Defense: Javascript is sandboxed;
  try to avoid security bugs in browser code;
  privilege separation; automatic updates; etc.

Security on the web

- Risk #2: we don't want a malicious site to be able to spy on or tamper with my information or interactions with other websites
  - Browsing to evil.com should not let evil.com spy on my emails in Gmail or buy stuff with my Amazon account, even if I am logged in
- Defense: the **same-origin policy**
  - A security policy grafted on after-the-fact, and enforced by web browsers
  - Intuition: each web site is isolated from all others

Security on the web

- Risk #3: we want data stored on a web server to be protected from unauthorized access
  - More on this in the web project!
  - Next week: XSS, CSRF, SQL injection…
- Defense: server-side security

Cookies

- Cookies are a small bit of information stored on a computer associated with a specific server
  - When you access a specific website, it might store information as a cookie
  - Every time you revisit that server, the cookie is re-sent to the server
  - Effectively used to hold state information over sessions
- Cookies can hold any type of information
  - Can also hold sensitive information
    - This includes passwords, credit card information, social security number, etc.
    - Session cookies, non-persistent cookies, persistent cookies
  - Almost every large website uses cookies

More on Cookies

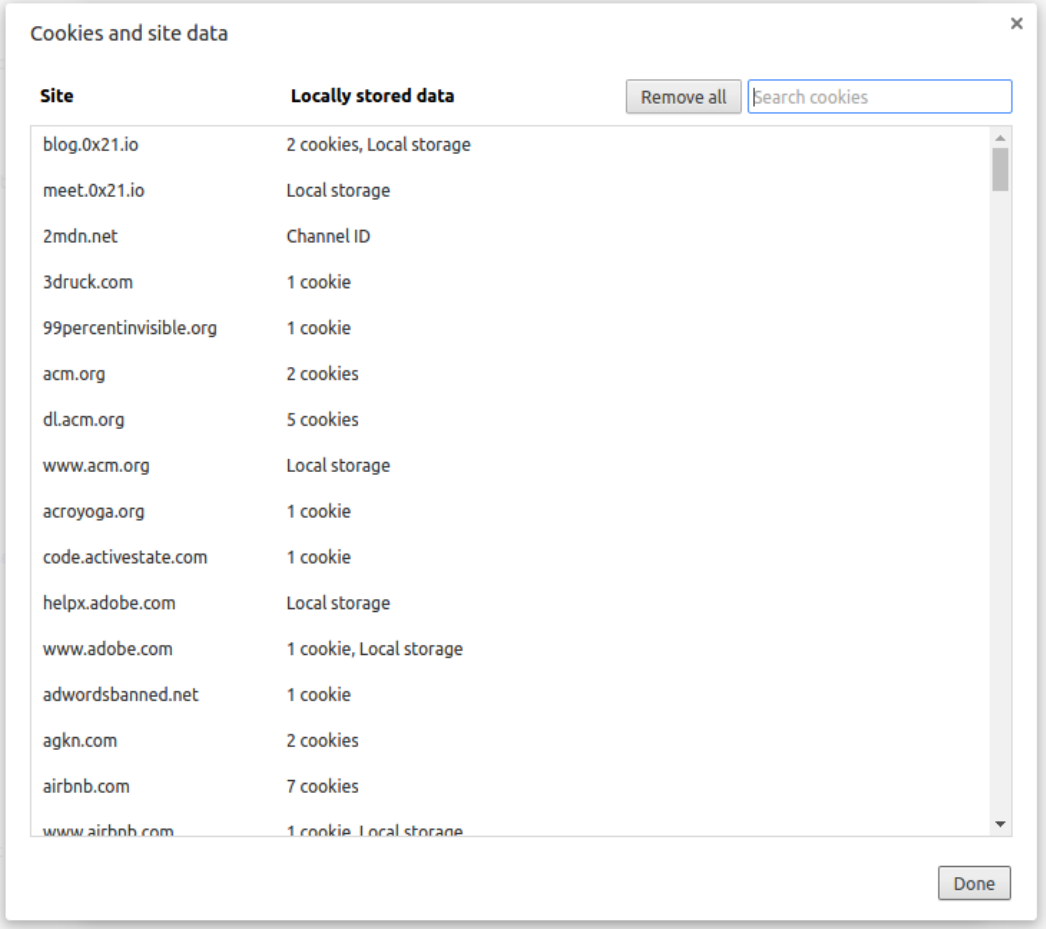
- Cookies are stored on your computer and can be controlled
  - However, many sites require that you enable cookies in order to use the site
  - Their storage on your computer naturally lends itself to exploits (Think about how ActiveX could exploit cookies...)
  - You can (and probably should) clear your cookies on a regular basis
  - Most browsers will also have ways to turn off cookies, exclude certain sites from adding cookies, and accept only certain sites' cookies
- Cookies expire
  - The expiration is set by the sites' session by default, which is chosen by the server
  - This means that cookies will probably stick around for a while

Evercookie

- Cookies are just state servers store in your browser
- Other places where state can be stored?
  - Local Storage (Javascript)
  - Image/resource cache
  - Flash local shared objects
  - Java storage
  - Others?

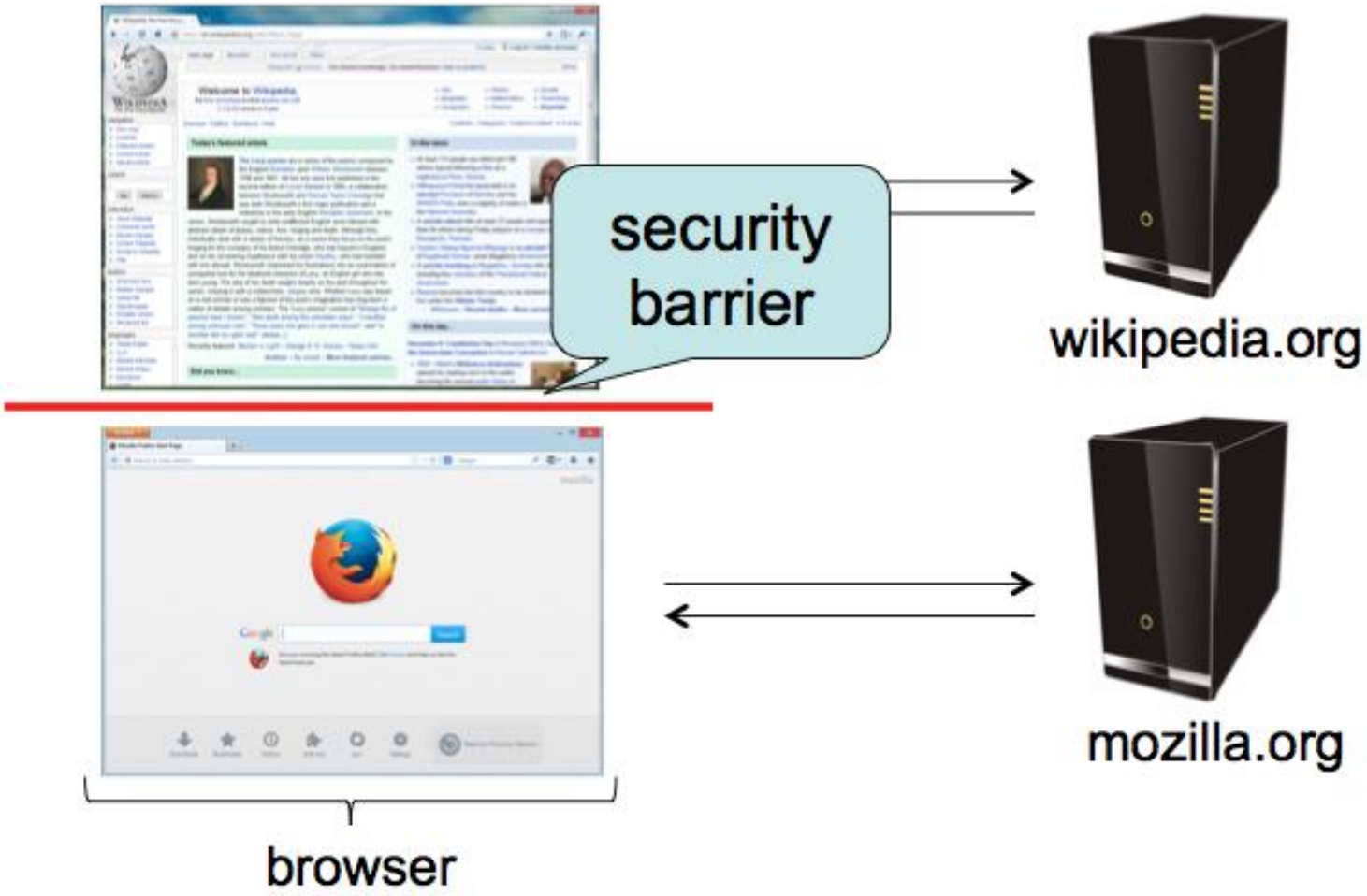
Taking Care of Your Cookies

- Managing your cookies in Chrome:
  - Remove Cookie
  - Remove All Cookies
  - Displays information of individual cookies
  - Also tells names of cookies, which probably gives a good idea of what the cookie stores
    - i.e. amazon.com: session-id



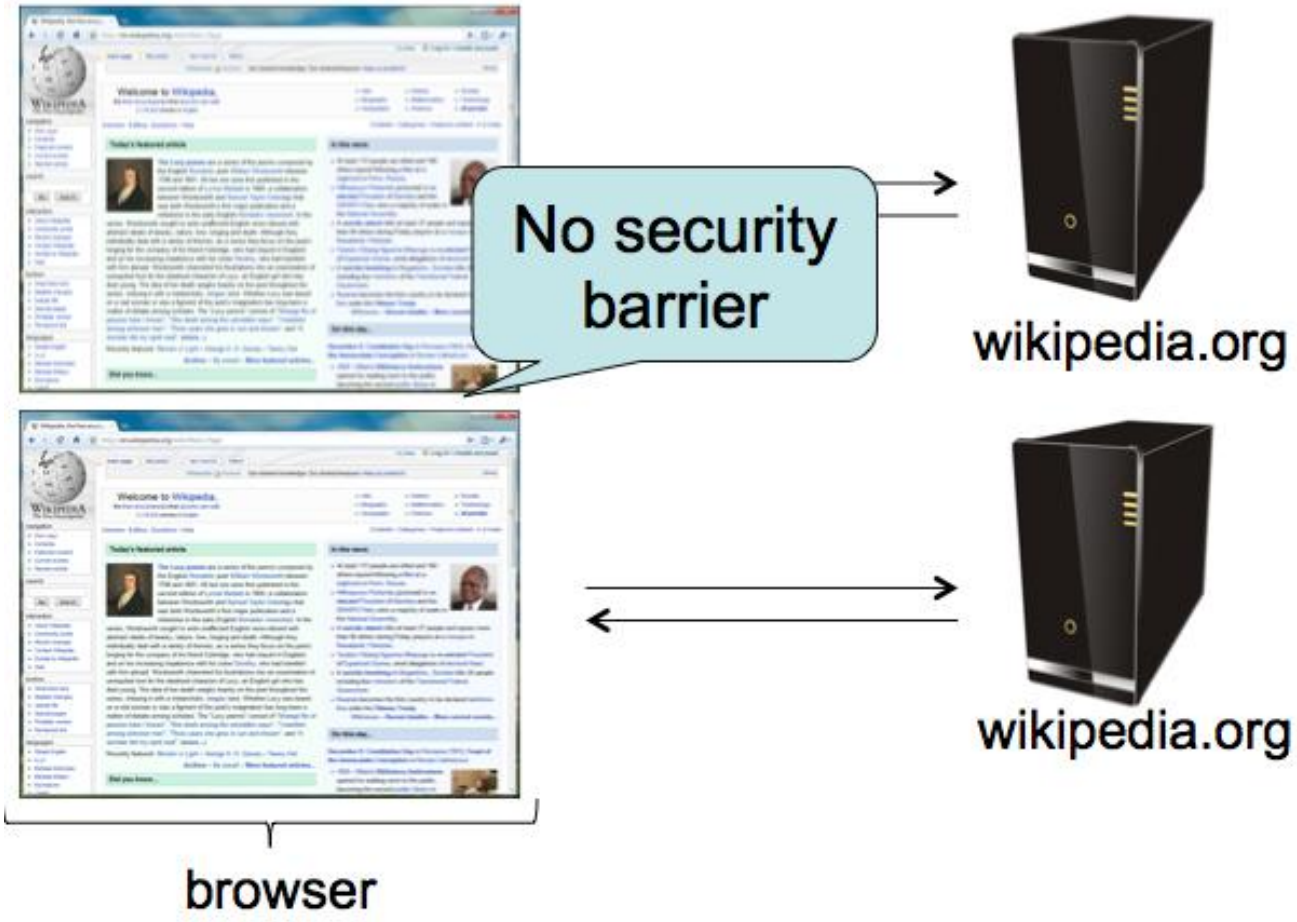
Same-origin policy

- Each site is isolated from all others



Same-origin policy

- Multiple pages from same site aren't isolated



Same-origin policy

- Granularity of protection: the *origin*
- Origin = protocol + hostname (+ port)

- Javascript on one page can read, change, and interact freely with all other pages from the same origin

Same-origin policy

- The origin of a page (frame, image, ...) is derived from the URL it was loaded from
- Special case: Javascript runs with the origin of the page that loaded it

Confining the Power of JavaScript Scripts

- Given all that power, browsers need to make sure JS scripts don't abuse it
- For example, don't want a script sent from hackerz.com web server to read cookies belonging to bank.com ...
- ... or alter layout of a bank.com web page
- ... or read keystrokes typed by user while focus is on a bank.com page!

Same-origin policy

- Browsers provide isolation for JS scripts via the Same Origin Policy (**SOP**)
- Simple version:
  - Browser associates web page elements (layout, cookies, events) with a given **origin** ≈ web server that provided the page/cookies in the first place
    - Identity of web server is in terms of its hostname, e.g., bank.com
- SOP = *only scripts received from a web page's origin have access to page's elements*
- **XSS: Subverting the Same Origin Policy**

Exercise

- Ad servers are increasingly being used to display essential content for web sites. Suppose that the same host is used to serve images for two different web sites.
  1. Explain why this is a threat to user privacy.
  2. Is this threat eliminated if the browser is configured to reject third-party cookies?