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Web Security

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Today

- Web architecture

- Basics of web security

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What is the Web?

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

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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

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- Example:

<https://powcoder.com/http://ecen4133.org:80/tmp/test?foo=1337#top>

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The diagram shows the URL <https://powcoder.com/http://ecen4133.org:80/tmp/test?foo=1337#top> with arrows pointing from labels to its components: Protocol points to 'http://', host points to 'ecen4133.org', Path points to '/tmp/test', Query points to '?foo=1337', and Fragment points to '#top'. The text 'Add WeChat powcoder' is overlaid in red.

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

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HTTP protocol

- HTTP is

- widely used

- Simple

- Stateless

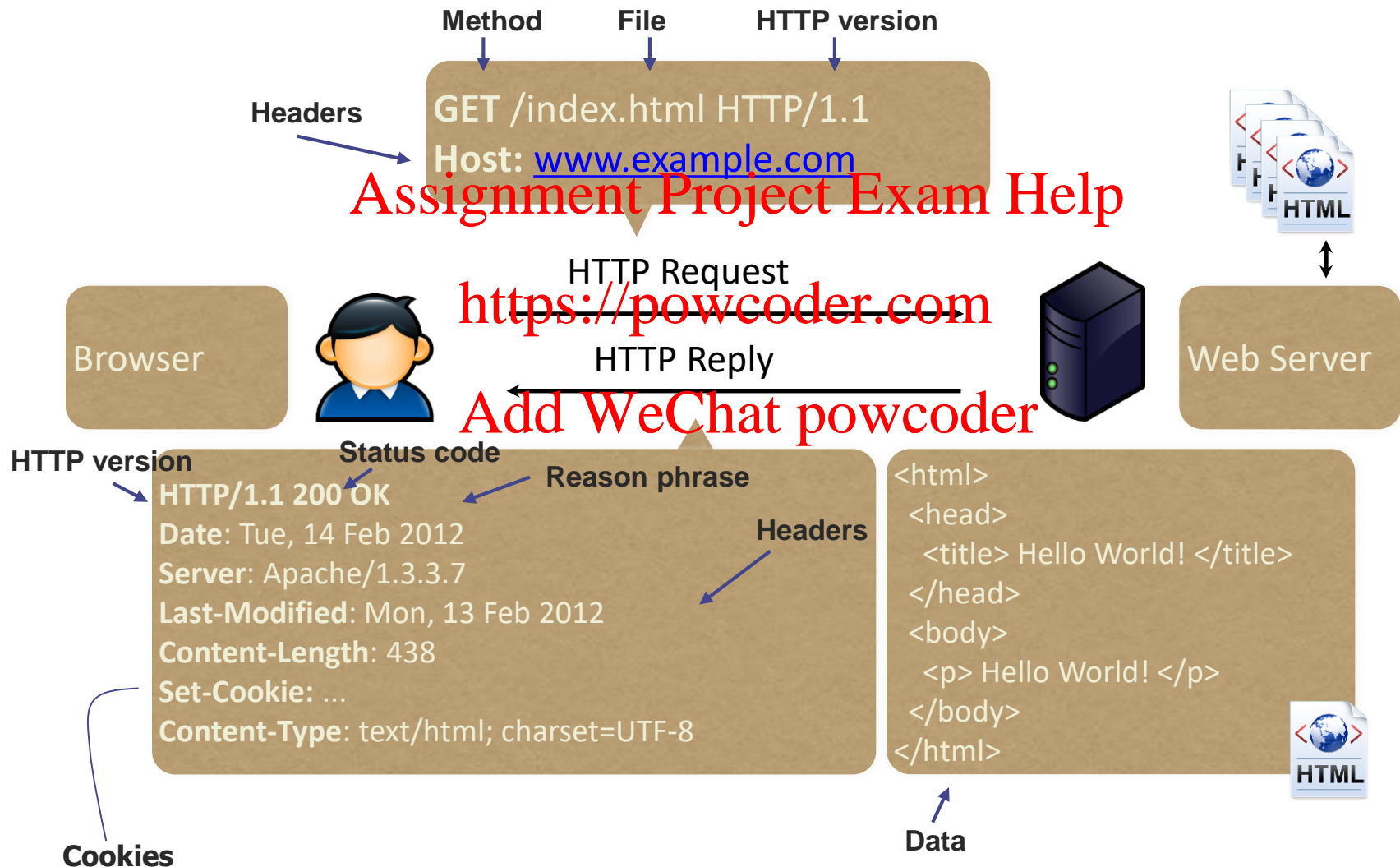
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HTTP Protocol



HTTP GET request

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

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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

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HTTP POST request

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

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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

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HTML Basics

- HyperText Markup Language

- Nested “tag” structure

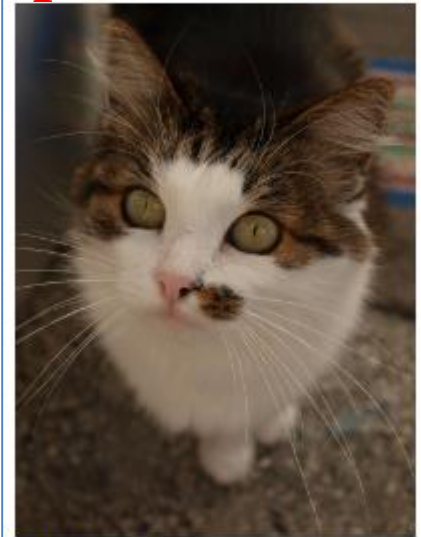
```
<html>
  <head>
    <title>Cats!</title>
  </head>
  <body>
    <h1>Look, a cat!</h1>
    <span>
      
      <br/>
      <a href="cats.html">
        Click here for more cats!
      </a>
    </span>
  </body>
</html>
```

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Look, a cat!



[Click here for more cats!](#)

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!*

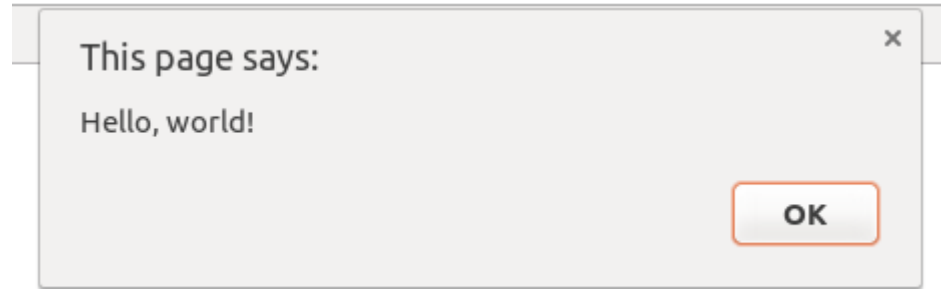
Javascript

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```
<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! 😊

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

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```
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;
};
```

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```
// 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
```

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```
// 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>
```

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JQuery

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```
<html>
  <script src="jquery-3.1.0.min.js"></script>
  <span id="foo">
    <a href="prize.html">Click here to get it!</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>
```

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Web Review | HTTP

```
GET / HTTP/1.1  
Host: gmail.com
```

http://gmail.com/
says:

Hi!



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```
HTTP/1.1 200 OK
```

```
<html>
```

```
<head>
```

```
<script>alert('Hi!')</script>
```

```
</head>
```

```

```

gmail.com



```
GET /img.png HTTP/1.1  
Host: gmail.com
```

```
HTTP/1.1 200 OK
```

```
...
```

```
<89>PNG^M ...
```

Web Review | Cookies

```
POST /login HTTP/1.1
Host: gmail.com

user=alice&pass=s3cre7
```

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```
HTTP/1.1 200 OK
Server: gws
Set-Cookie: foo="bar"
Set-Cookie: token="8kFmCe..."
<html>
...
```

gmail.com



```
GET / HTTP/1.1
Host: gmail.com
Cookie: foo="bar"; token="8k..."
```

Ah, it's
alice!



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

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“Evercookie”

- Cookies are just state servers store in your browser

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- Where else can state be stored?

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- Local Storage (Javascript)

- Image/resource cache

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- Flash local shared objects

- Java storage

- Others?

Third-party cookies



The New York Times



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TheUpshot

Iowa Caucus Results Riddled With Errors and Inconsistencies

The mistakes do not appear intentional, but they raise questions about whether there will ever be a completely precise accounting.

By Nate Cohn, Josh Katz, Denise Lu, Charlie Smart, Ben Smithgall and Andrew Fischer

Feb. 6, 2020 Updated 3:14 p.m. ET



1352



DNC chairman calls for recanvass of Iowa caucuses

By Ronn Blitzer | Fox News



Third-party cookies

- External (third-parties) serve ads trackers on sites you visit
- The trackers can tell what page you are visiting, and **correlate** this with other page visits your browser makes
- Trackers then sell info to advertisers (often in real time!), who use it to show you ads relevant to you

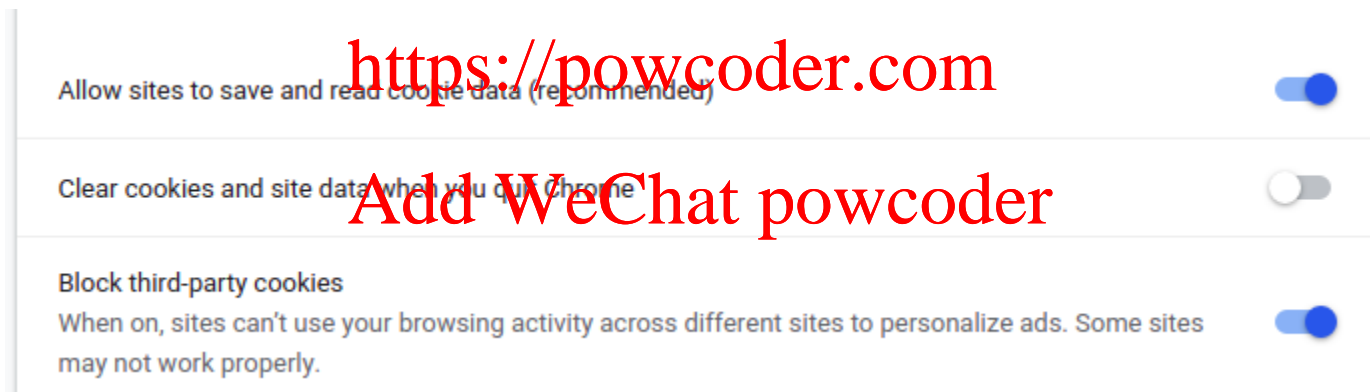
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Third-party cookies

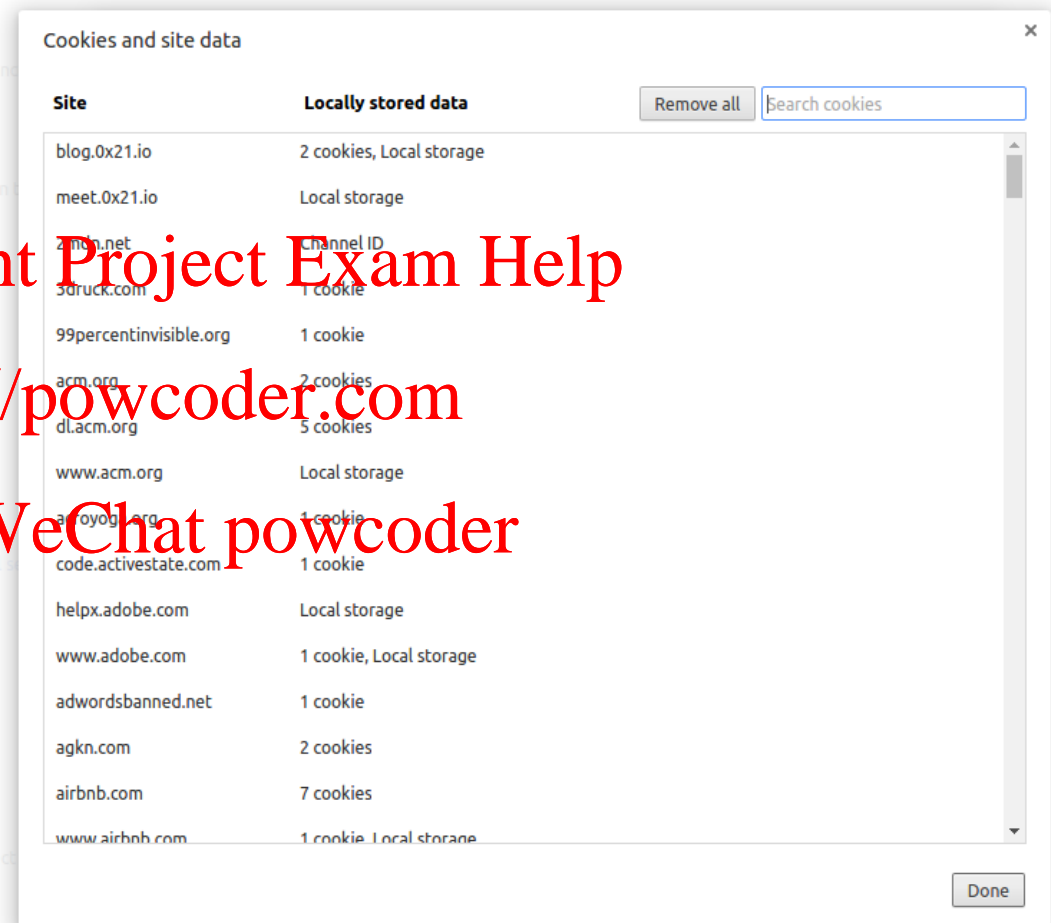
- Most browsers let you disable third-party cookies
 - Only send cookies to first-party sites, never to external/third-party sites



- Privacy extensions: Adblock, Ghostery, PrivacyBadger, etc block trackers

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



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

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Security on the web

- Risk #1: we don't want a malicious site to be able to trash my files/programs on my computer
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 - Browsing to <https://powcoder.com> (or evil.com) should not infect my computer with malware, read or write files on my computer, etc.
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- 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 web sites
 - 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

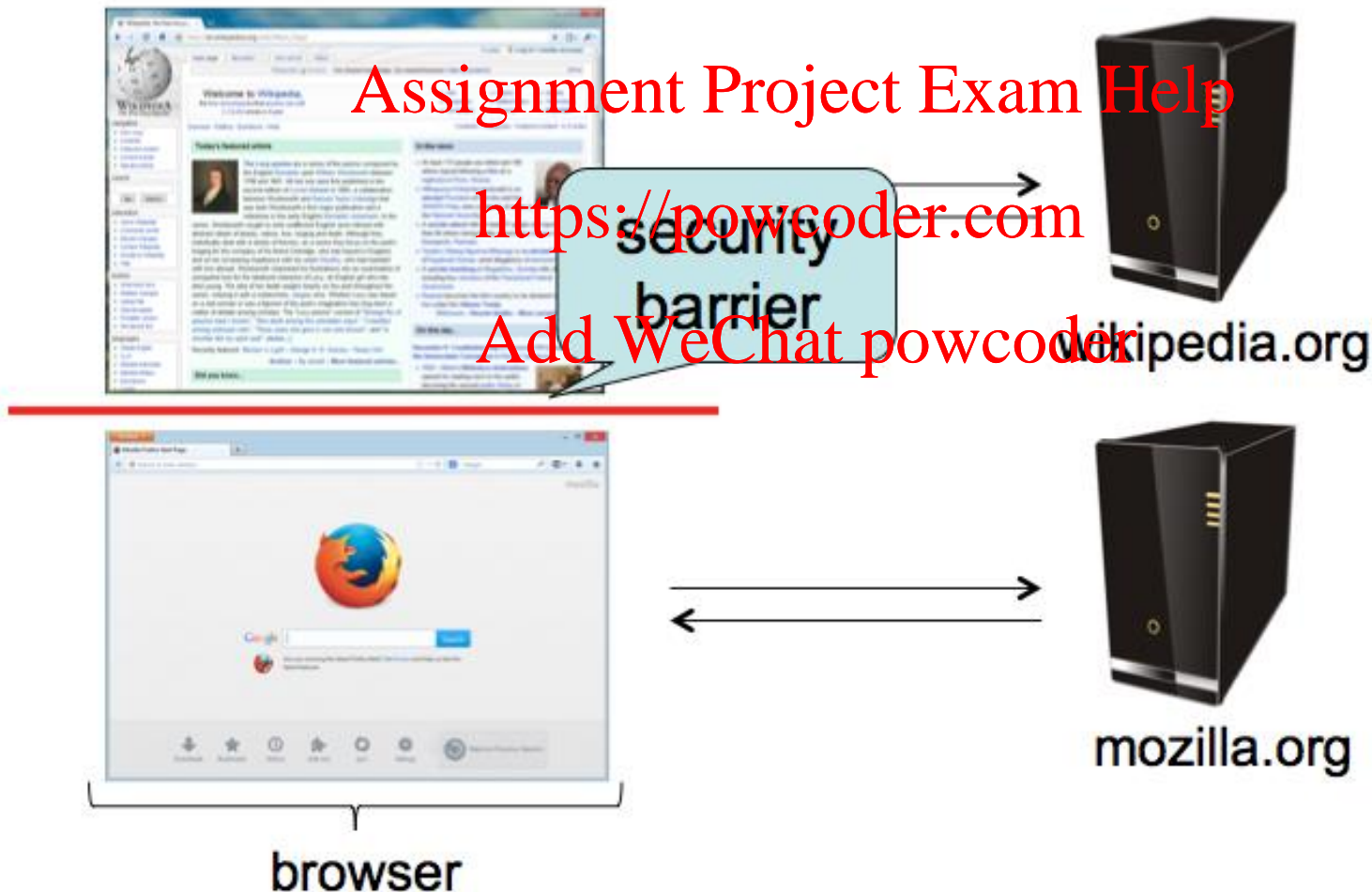
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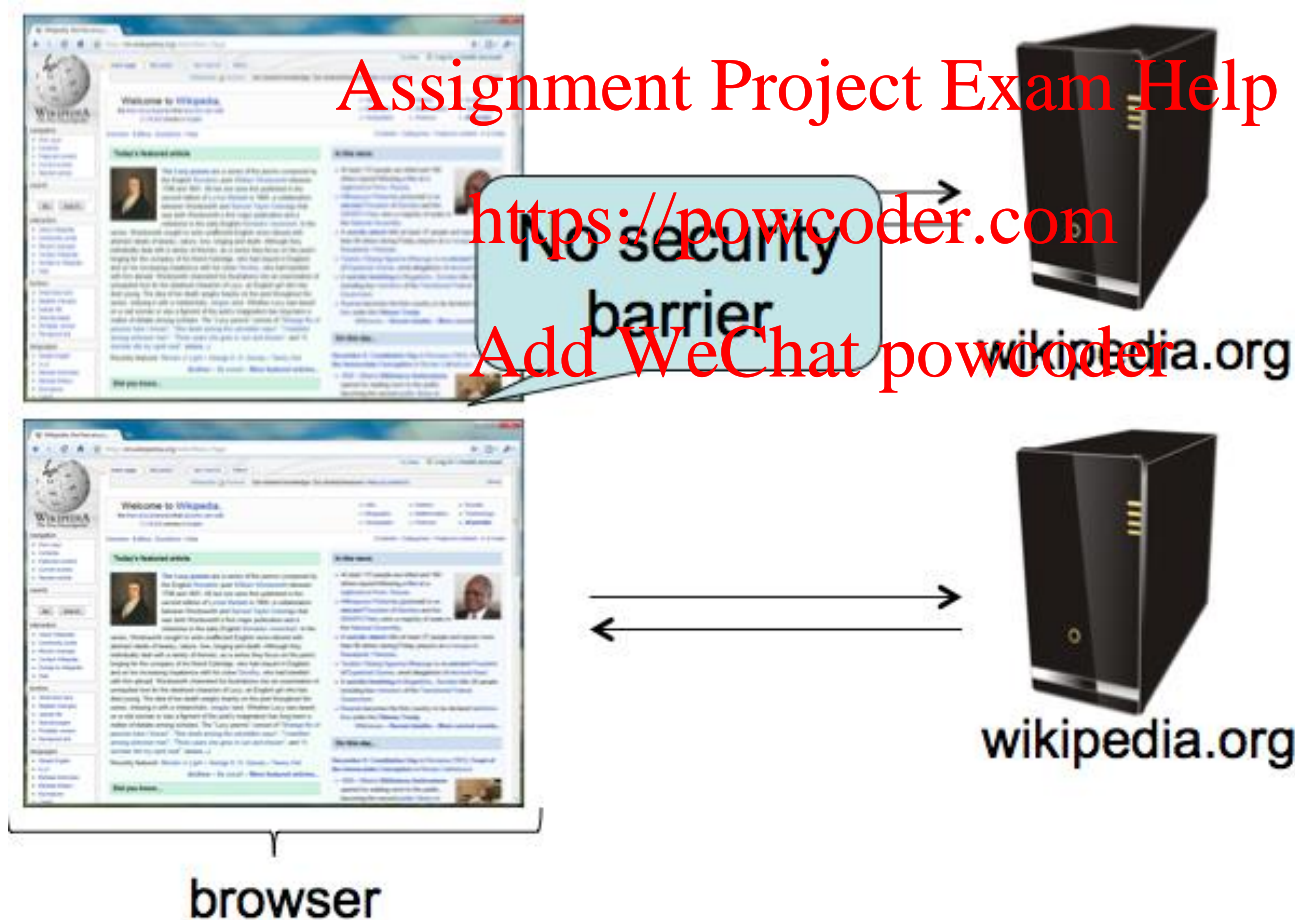
Same-origin policy

- Each site is isolated from all others



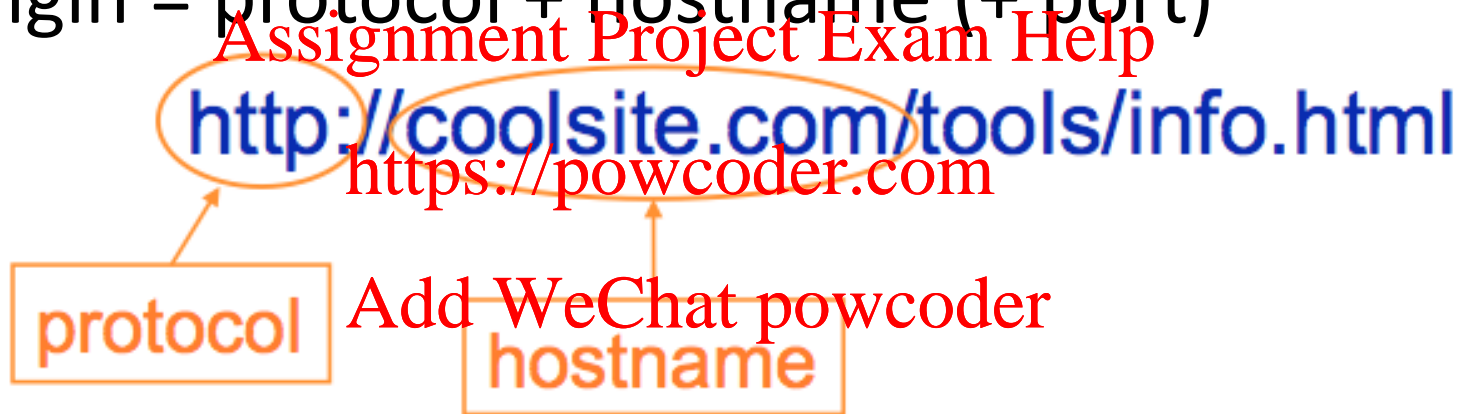
Same-origin policy

- 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

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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 <https://powcoder.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** \approx 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**