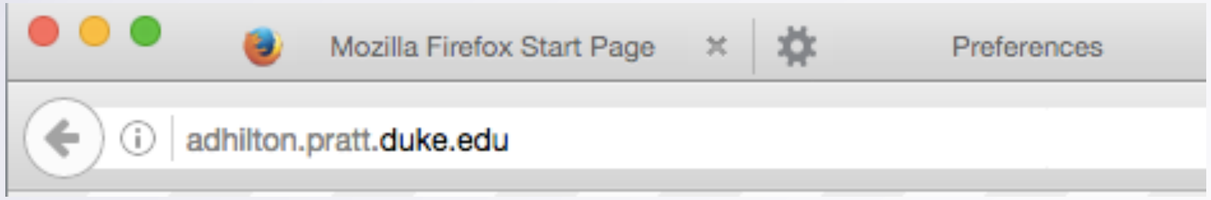
Engineering Robust Server Software

Web Protocols and Technologies

Today: Web Protocols/Technologies

- "The Web" is full of
  - Many browsers (Chrome, Firefox,…)
  - Different server "stacks"
- Yet they all work together..
  - Everything speaks the same language
- Let's delve into that

The Life of a Web Request



- I enter a URL in my browser…

The Life of a Web Request

```
GET / HTTP/1.1
User-Agent: Wget/1.17.1 (linux-gnu)
Accept: */*
Accept-Encoding: identity
Host: adhilton.pratt.duke.edu
Connection: Keep-Alive
```

- Browser sends an HTTP "GET" request to the server
  - Which is running a web server daemon, listening on port 80

HTTP Request Basics

- HTTP Requests have a "verb" and a URI (and then a version number)

```
GET / HTTP/1.1
POST /home/drew HTTP/1.1
PUT /foo/bar/xyz  HTTP/1.1
DELETE /blah/blah/blah HTTP/1.1
```

- Read about HTTP "verbs" (aka methods):
  - https://tools.ietf.org/html/rfc7231#section-4.3
- Most common for web browsers: GET + POST
  - Others useful for web-based APIs

The Life of a Web Request

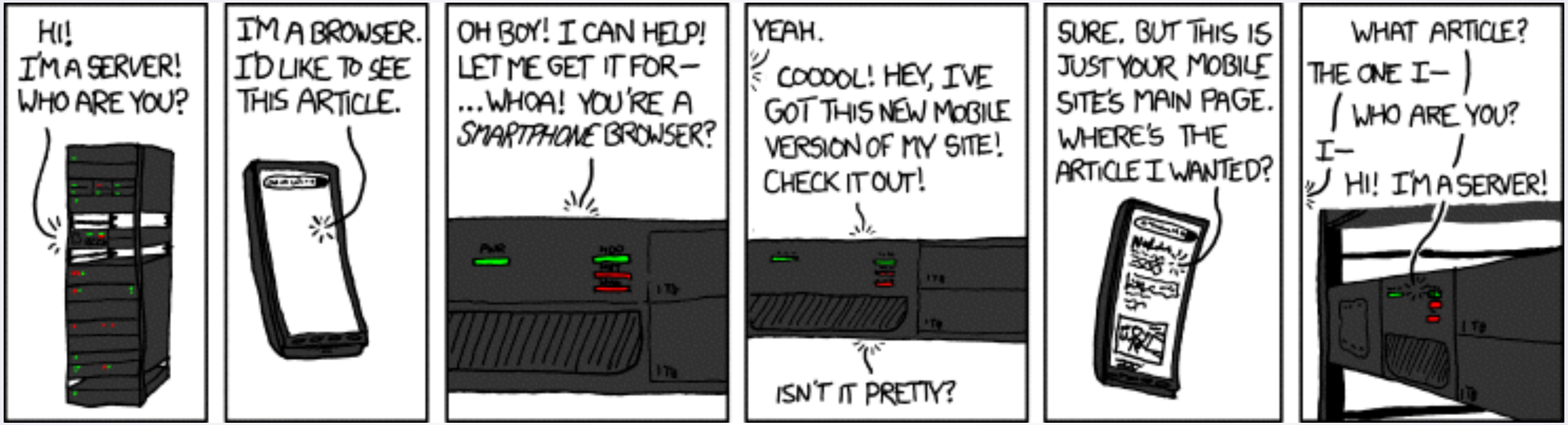
```
HTTP/1.1 200 OK
Date: Tue, 17 Jan 2017 02:08:36 GMT
Server: Apache/2.2.15 (Scientific Linux)
Etag: "1484618676-0"
Content-Language: en
Cache-Control: public, max-age=3600
Last-Modified: Tue, 17 Jan 2017 02:04:36 GMT
Expires: Sun, 19 Nov 1978 05:00:00 GMT
Content-Type: text/html; charset=utf-8
….
```

- Server responds (in this case: 200 OK)
- With headers and data
  - The data (in this case) is HTML—could be anything (JSON, XML, image,…)

HTTP Responses

- Responses come with response code
  - 1xx = informational
  - 2xx = successful
  - 3xx = redirection
  - 4xx = error
  - …
  - https://tools.ietf.org/html/rfc7231#section-6
- Headers, give meta-data about response
  - E.g, content length, encoding,…
- Also, (if appropriate), the data

HTTP: Stateless Protocol

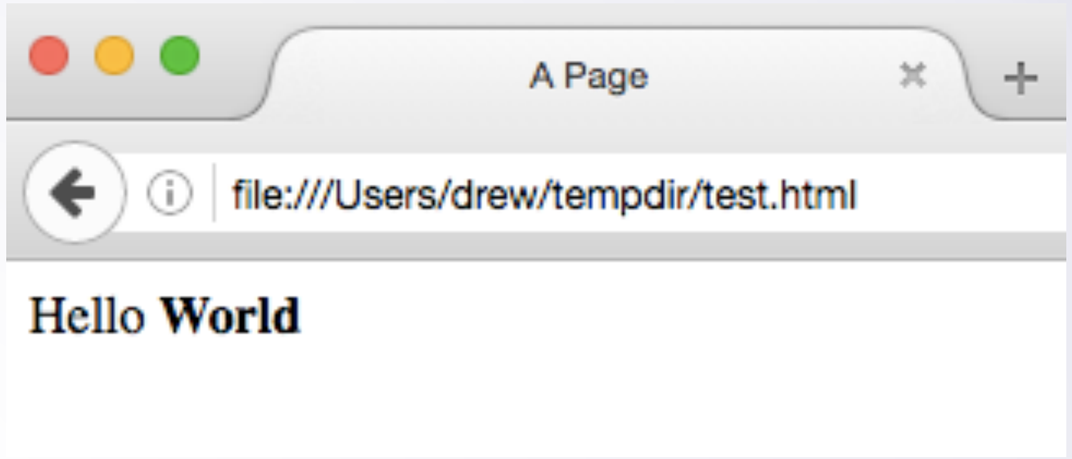


https://xkcd.com/869/

- Http is Stateless:
  - Each request is separate from all the others
  - Want session information? Include in request/responses

HTML

```
<!DOCTYPE html>
<html>
  <head>
    <title>A Page</title>
  </head>
  <body>
    Hello <b>World</b>
  </body>
</html>
```



- Hypertext Markup Language:
  - Not a programming language (does not execute things)
  - Marks up content (describes how to format it)

Fancier Page?

- Most common fancier things:
  - link text
  - …
  - …
  - <h1>…</h1> <h2>…</h2> etc
  -   thing1   thing 2 …
  -   thing1   thing 2 …
  - <img src="cats.png">
- https://developer.mozilla.org/en-US/docs/Web/HTML/Element

Elements can have Attributes

- <a **href="http://foo.bar.com/xyz/blah.html"**>link text
- <img **src="cats.png"**>
- A few interesting ones:
  - **class**: for use with CSS
  - **name**: for use with forms
  - **id**: for use with JavaScript (also CSS)

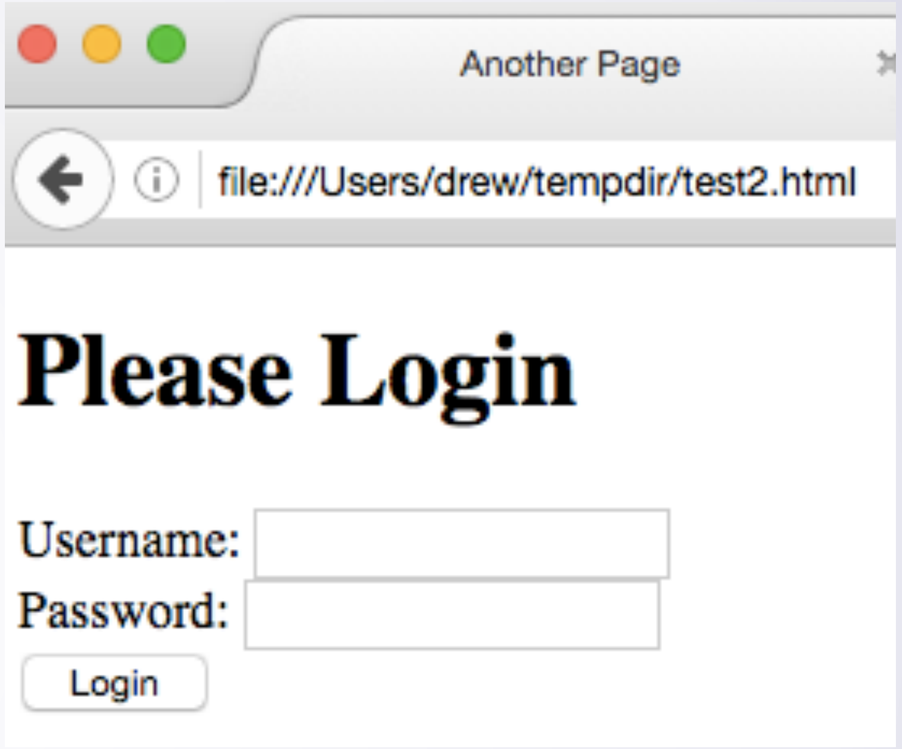
- https://developer.mozilla.org/en-US/docs/Web/HTML/Attributes

HTML Forms

- Often we want to submit data to the server
  - E.g., when the user presses a "submit" button
- Use HTML "forms"
  - Use <form> tag to enclose the inputs for the form
    - Has attributes of where to send data, whether to GET or POST
  - Put input elements (and others) inside:
    - <textarea>, <select>, <button>, <input>, …
  - Give each input a **name** attribute
    - Will be how you identify which data is which on the server

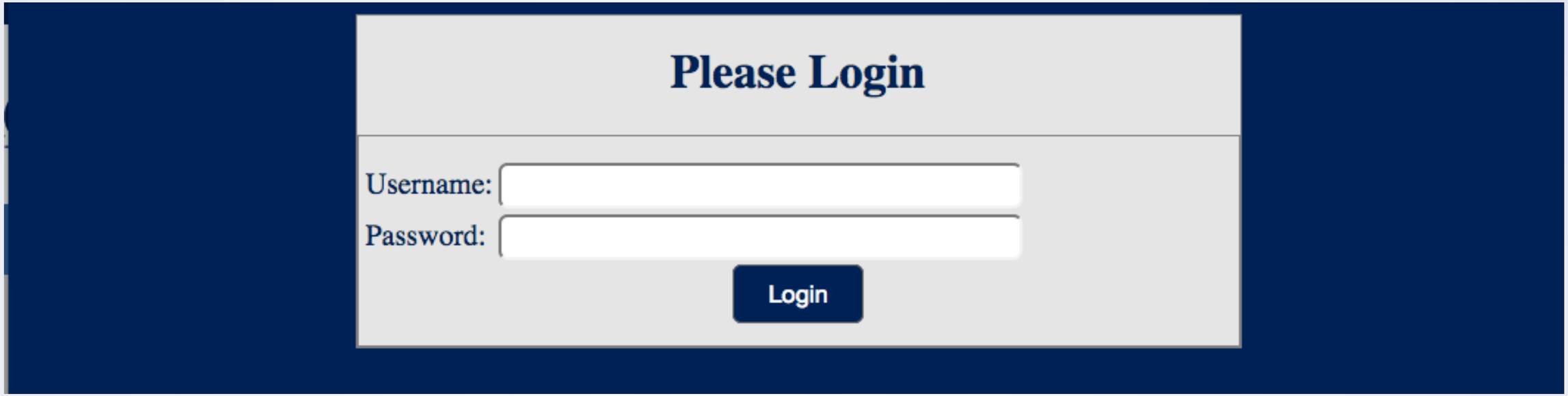
Cascading Style Sheets

```
<!DOCTYPE html>
<html>
  <head>
    <title>Another Page</title>
  </head>
  <body>
    <h1>Please Login</h1>
    <form>
      Username: <input> </input><br/>
      Password: <input> </input><br/>
      <button>Login</button>
    </form>
  </body>
</html>
```



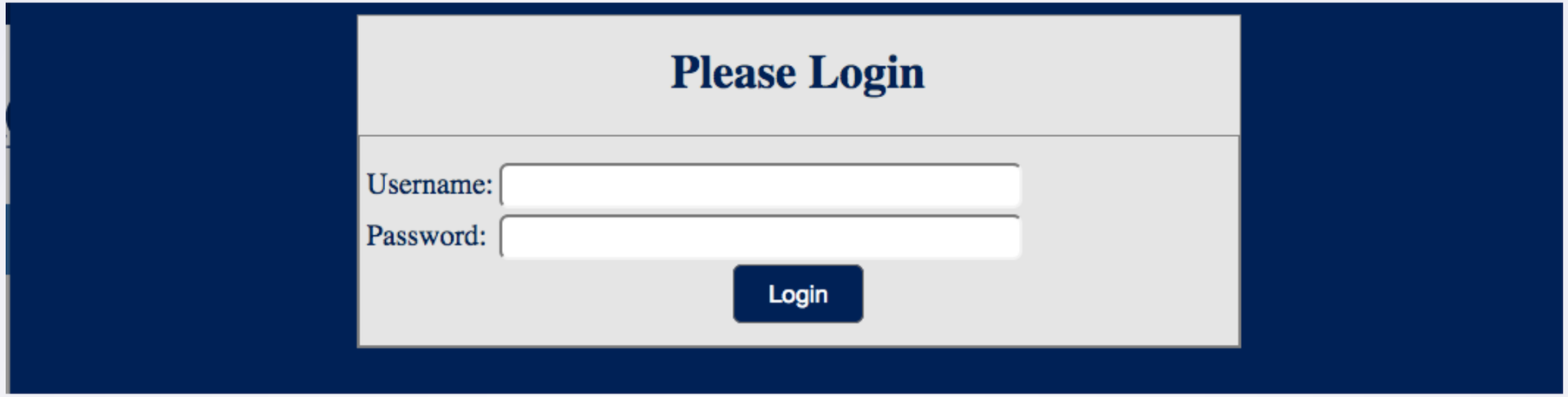
- Even if we put more stuff on our page, it doesn't look nice

With CSS…



- CSS lets us change how the browser **styles** the HTML
  - Positioning, colors, shapes, font sizes,…

CSS Basics




```
body {
    background: #001A57;
}
```

```
h1 {
    text-align: center;
    color: #001A57;
}
```

- Can re-style any occurrence of a tag (e.g., body, h1…)

CSS Basics

```
div.container {
    border: 1px solid gray;
    background: #E5E5E5;
    margin: auto;
    min-width: 350px;
    max-width: 600px;
}
div.box {
    border: 1px solid gray;
    margin: auto;
    padding: 15px 2px;
}
```

```
<div class="container">
  <h1>Please Login</h1>
  <div class="box">
```

- Can re-style a tag by class

CSS Basics

```
.label {
    font-size: 20px;
    color: #001A57;
}
```

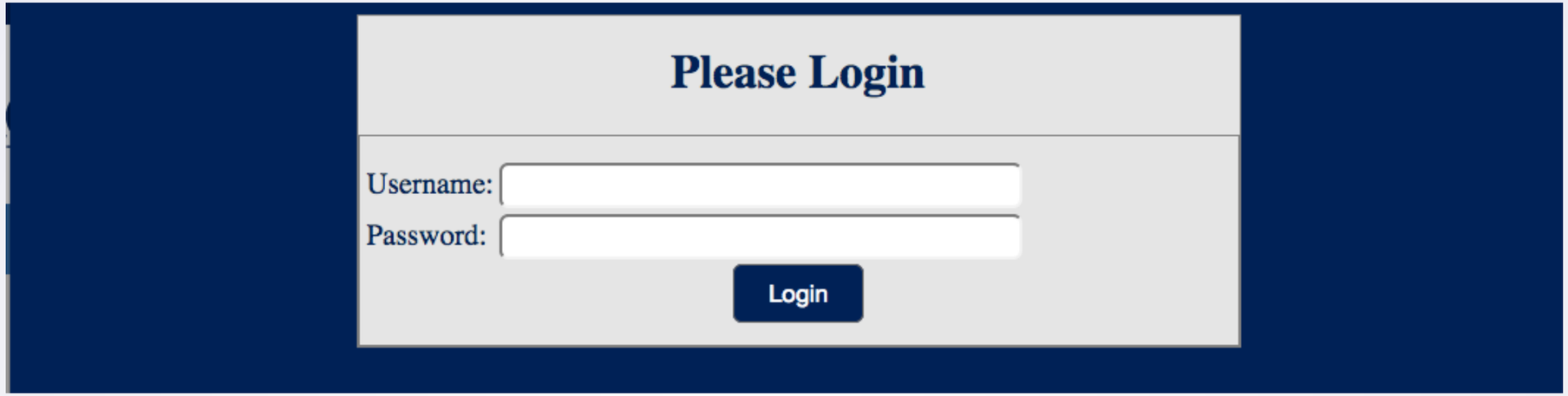
- Can re-style by class (can use with any tag)

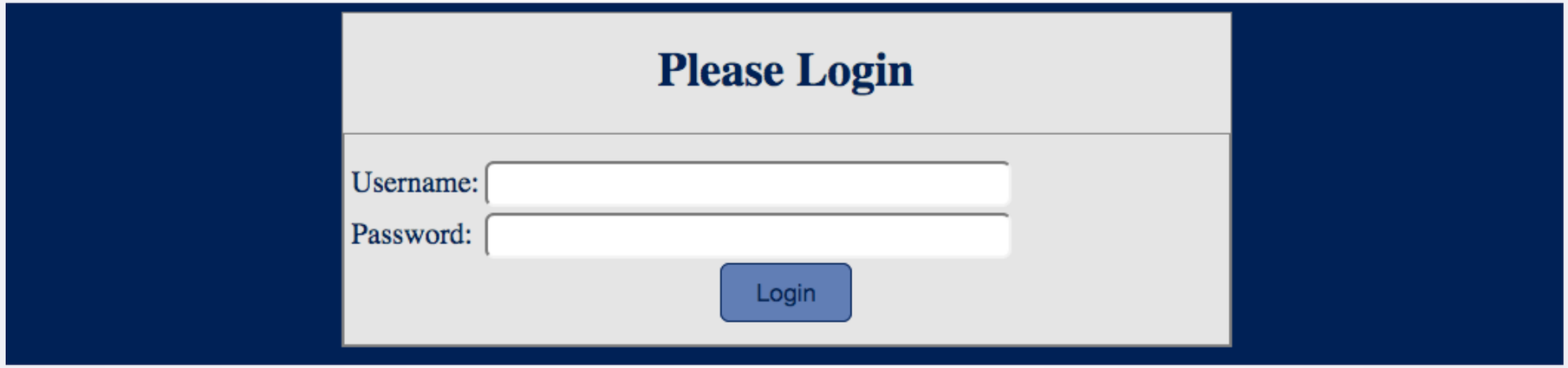
CSS Basics: Include External Stylesheet

```
<html>
  <head>
    <title>Another Page</title>
    <link type="text/css" rel="stylesheet" href="style.css" />
  </head>
```

- Generally want to load CSS from another file (on server)
  - Lets you easily use same style for many pages (same look + feel)
  - Lets you easily change style of all pages at once

CSS: Can Do Fancier Things





- Reformat button when hovered over
  - With :hover

Fancier CSS

```
.btn {
    border-radius: 6px;
    background-color: #001A57;
    border: 1pt solid #666666;
    color: white;
    padding: 8px 20px;
    text-align: center;
    text-decoration: none;
    font-size: 16px;
    margin: 0 auto;
    display: block;
}
.btn:hover {
    background-color: #607AB7;;
    border: 1pt solid #001A57;
    color: #001A57;
}
```

- Our button from this page
- Several properties to make
  - Nice curved corners
  - Large, centered text
  - Centered in parent area
- .btn:hover
  - Changes colors on hover

More Fancy CSS?

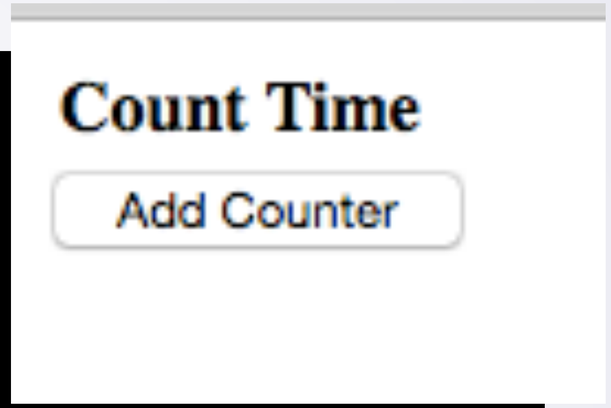
- Much more you can do with CSS
  - We aren't going to be too picky about fancy looking sites
    - (not a UI/UX class)
  - More interested in server side
  - …but you should be able to make it look nicer than black + white
- https://developer.mozilla.org/en-US/docs/Web/CSS

Ok, but… It Still Doesn't Do Anything..

- HTML + CSS: can make a nice looking page
- Won't "do" anything.
  - Could send data to server with **form**s, load a whole new page
  - This is how everything worked in the mid 1990s…
- Modern webpages are interactive, do things with no reload
  - Use JavaScript (actual programming language)

JavaScript Example: A Page With Some JS

```
<body>
  <table id="counters">
    <tr>
      <th>Count</th>
      <th>Time</th>
    </tr>
  </table>
  <button onClick="addCounter()">Add Counter</button>
</body>
```



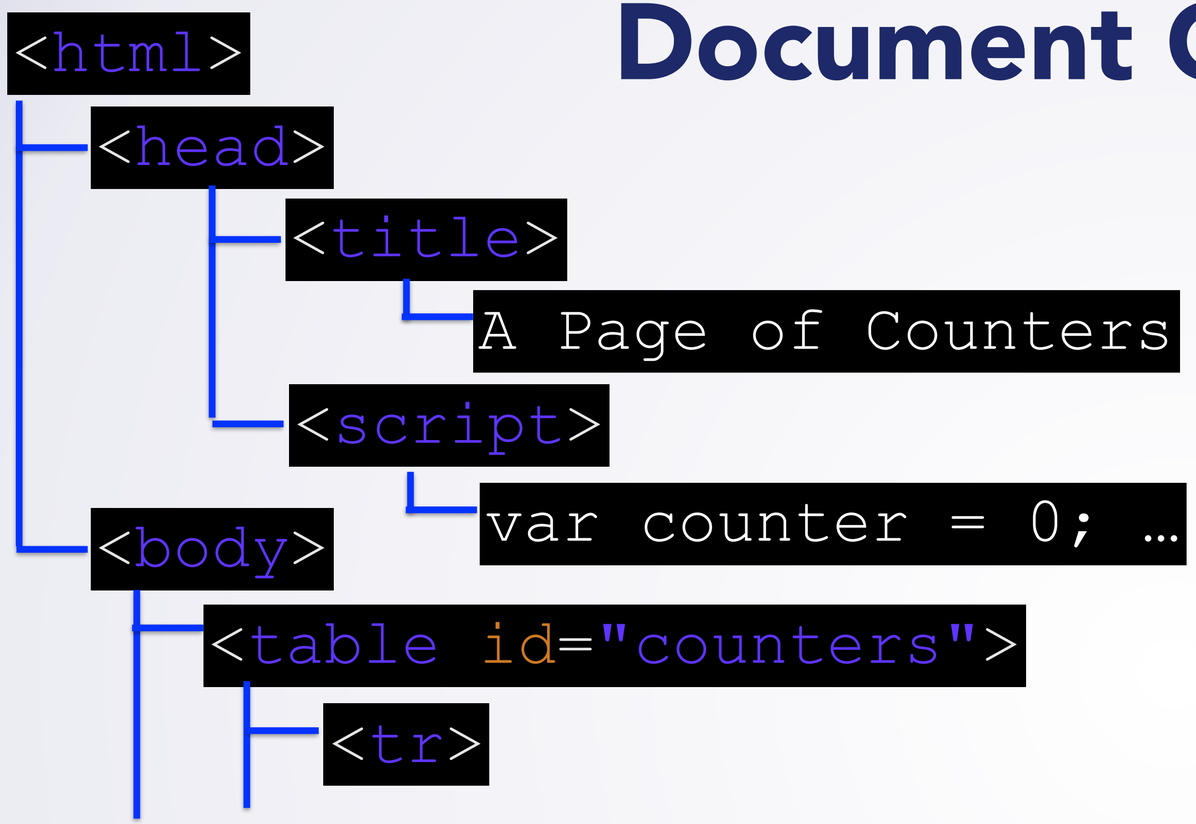
- Here is the body of a page. Has:
  - A table (with only a header row)
  - A button (whose onClick is some JavaScript—-calls a function not shown here)

JavaScript Example (Cont'd)

```
<head>
    <title>A Page of Counters</title>
    <script>
      var counter=0;
      function addCounter() {
        var elt = document.getElementById("counters");
        elt.innerHTML = elt.innerHTML + "<tr><td> " +
          counter + " </td> <td>  " +
          new Date().toLocaleString() + "</td></tr>";
        counter++;
      }
    </script>
  </head>
```

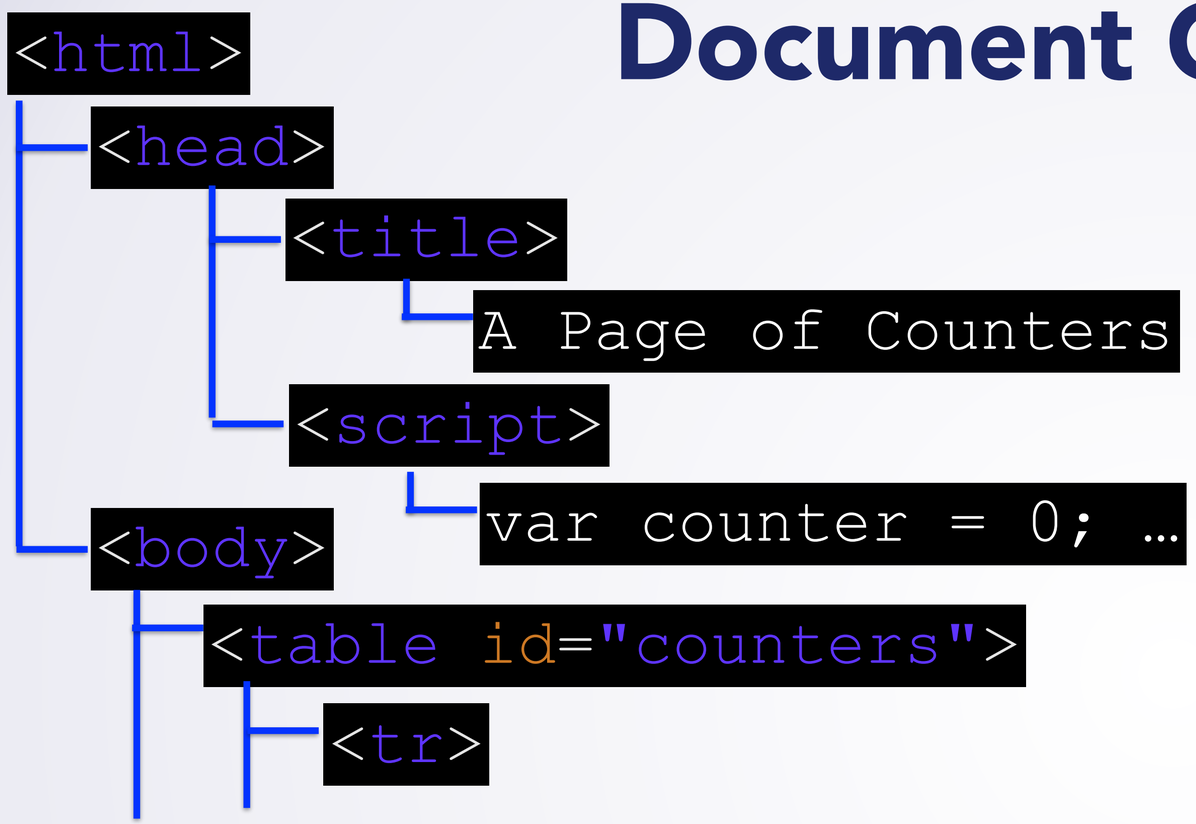
- The JavaScript that goes with it:
  - Press button->add counter / current date to table

Document Object Model



- To understand what happened, you need to know about the **DOM**
  - **Document Object Model**: API for HTML + XML documents
    - Language agnostic (same API in JavaScript, C, Java, Python,…)
- Think of HTML as describing a **tree** of objects

Document Object Model



- DOM specifies ways to manipulate the tree
  - Find elements meeting some criteria
  - Get children of a particular element
  - Modify an element
  - Create an element

JavaScript Example Revisited

```
<head>
    <title>A Page of Counters</title>
    <script>
      var counter=0;
      function addCounter() {
        var elt = document.getElementById("counters");
        elt.innerHTML = elt.innerHTML + "<tr><td> " +
          counter + " </td> <td>  " +
          new Date().toLocaleString() + "</td></tr>";
        counter++;
      }
    </script>
  </head>
```

JavaScript Example: Revisited

```
<body>
  <table id="counters">
    <tr>
      <th>Count</th>
      <th>Time</th>
    </tr>
  </table>
  <button onClick="addCounter()">Add Counter</button>
</body>
```

elt

elt.innerHTML

JavaScript Example Revisited

```
<head>
    <title>A Page of Counters</title>
    <script>
      var counter=0;
      function addCounter() {
        var elt = document.getElementById("counters");
        elt.innerHTML = elt.innerHTML + "<tr><td> " +
          counter + " </td> <td>  " +
          new Date().toLocaleString() + "</td></tr>";
        counter++;
      }
    </script>
  </head>
```

Accomplish Same Task w/o Reparsing

```
<script>
  var counter=0;
  function addCounter() {
    var elt = document.getElementById("counters");
    var tr = document.createElement("tr");
    var td1 = document.createElement("td");
    var td2 = document.createElement("td");
    td1.textContent = counter;
    td2.textContent = new Date().toLocaleString();
    tr.appendChild(td1);
    tr.appendChild(td2);
    elt.appendChild(tr);
    counter++;
  }
</script>
```

More JavaScript

- As a programming language:
  - First class functions
  - Dynamically typed
  - Has Objects
  - C-/Java- like syntax (mostly)
- See:
  - https://developer.mozilla.org/en-US/docs/Web/JavaScript/A_re-introduction_to_JavaScript
  - https://developer.mozilla.org/en-US/docs/Web/JavaScript

JSON: JavaScript Object Notation

- In JavaScript, you write down objects like this:
  - var pt = { x : 3, y: 4, moveLeft: function() { this.x — ; } };
  - i.e., A comma separated sequence of **field: value**
  - Note that methods are just fields whose values are functions!
- JavaScript Object Notation (JSON) is a common data format
  - Can't put function values in
  - Only string, number, true, false, arrays, objects, null
  - Arrays are written with [], objects with {}
  - Field names are quoted: { "x" : 3, "y" : 4 , "colors": ["orange", "pink"] }

More JavaScript: Later

- JavaScript can also contact the server
  - Get a response (later), and then do something with it
  - Server can send responses that are not HTML
    - Could send JSON, or XML -> easy to parse
    - JS on client can take data, show in appropriate way
- AJAX: Asynchronous JavaScript And XML
  - We'll talk about this later when we start into server side web code

XML

```
<?xml version="1.0" encoding="UTF-8"?>
<transactions>
  <merchant id="1234" password="xyz"/>
  <create ref="t0">
    <name>Joe Smith</name>
    <num>123456789</num>
    <expires>2018-12-05</expires>
    <cvn>123</cvn>
    <amount>45.23</amount>
  </create>
  <commit ref="t1">
    <id>adsf234ASdr234Z</id>
  </commit>
</transactions>
```

- Similar looking to HTML (tags, attributes, nesting)
  - No predefined tags: make any tags with any meaning you want
  - Stricter /more uniform rules (all tags must be closed)

XML

- Why XML?
  - Extensible
  - Human readable
  - Ubiquitous: parsers for it in most languages
    - DOM: similar to HTML (but different)
- C++: xerces
  - You'll use later
- Other XML tools
  - E.g., XSLT (not going to use/cover, but you might find useful sometime)

Web APIs

- Many website provide APIs
  - Programatic ways to interact with website (possibly used by your own JS)
  - Usually by HTTP: GET, POST, PUT, DELETE,…
- Request format?
  - Conform to HTTP format
  - Use URI to specify what to query/update/etc
    - GET /api/courses/*DEPT*/*NUM*
  - Include information in POST data
    - Format? JSON, XML,…
- Response? Easy to parse (JSON, XML,…)

REST APIs

- Representational State Transfer (REST, or RESTful API)
  - Commonly used design principles
  - Ask many people: "Uses HTTP protocol"
  - http://www.ics.uci.edu/~fielding/pubs/dissertation/rest_arch_style.htm

REST APIs

- Representational State Transfer (REST, or RESTful API)
  - Client-server
  - Stateless (request contains all info needed, does not rely on previous)
  - Cacheable (can control cache-ability)
  - Uniform Interface (identify resources, manipulate representations)
    - E.g., Request by URI, manipulate textual representation of data
  - Layerable Systems (transparent to client—-can't really tell)
  - [Maybe] Code on Demand
    - E.g., JavaScript

APIs

- Why do people think "HTTP API"
  - Because HTTP follows the REST rules
- Why do people like HTTP-based APIs?
  - Much work done for you
    - Web-servers parse incoming requests
    - Web-browsers parse incoming responses
    - Both "speak" the same language for errors
    - Can transfer any data/ any meta-data over HTTP
    - Can name resources in useful [and easy to read] ways

Wrap Up

- Today:
  - HTML, CSS, JavaScript, JSON, XML
  - Super-quick intro: not main content of class
  - But useful technologies to know/use: web big example in servers
  - References to more learning
- Next time:
  - Dive into servers: UNIX Daemons
- Homework 1:
  - Start? Http request/response parsing…
  - Coming soon: Unix Daemons (this class), networking (650)