

Course Overview

SWE 432, Fall 2019

Web Application Development

Course Topics

- How do we organize, structure and share information?
- How to make applications that are delivered through browsers
 - JavaScript, front-end and back-end development, programming models, testing, performance, privacy, security, scalability, deployment, etc.
- How to design user interactions, focusing on browsers
 - User-centered design, user studies, information visualization, visual design, etc.

Logistics

- No textbook, but suggested readings will be listed on course schedule
- Lab-style work included in many lectures (**bring your laptop**)

Grading

- 50% Homework
 - 5 assignments, ~2 weeks to do each, all done individually
 - Some code-related assignments will be autograded; you can resubmit an unlimited number of times until the deadline and view your score
 - Also graded by hand for some non-functional issues
- 10% Quizzes
 - Pass/fail (Pass if you are in class and submit a quiz, fail if you don't)
 - Use laptop or phone to complete the quiz in class
- 20% Midterm Exam, 20% Final Exam (not cumulative)

Policies

- My promises to you:
- Quiz results will be available instantaneously in class; we will discuss quiz in real time
- Homework will be graded within 1 week of submission
- Exams will be graded within 1 week

Policies

- Lateness on homework:
 - 10% penalty if submitted UP TO 24 hours after deadline
 - No assignments will be accepted more than 24 hours late
 - Out of fairness: **no exceptions**
- Attendance & Quizzes:
 - You can miss up to 3 with no penalty
 - Again, out of fairness: **no exceptions** beyond this

Course Staff



- Prof. Thomas LaToza
 - Office hour: ENGR 4431
Wed 3:00 - 4:30pm or by appointment
 - Areas of research: software engineering, human-computer interaction, programming tools

Course Staff



- TAs: David Gonzalez
 - Office Hours: TBA

Honor Code

- Refresh yourself of the department honor code
- Homeworks are 100% individual
 - Discussing assignments at high level: ok, sharing code: not ok
 - If in doubt, ask the instructor
 - If you copy code, we WILL notice (see some of my recent research results in “code relatives”)
- Quizzes must be completed by you, and while in class

Web Sites vs Web Apps?

Interactive?

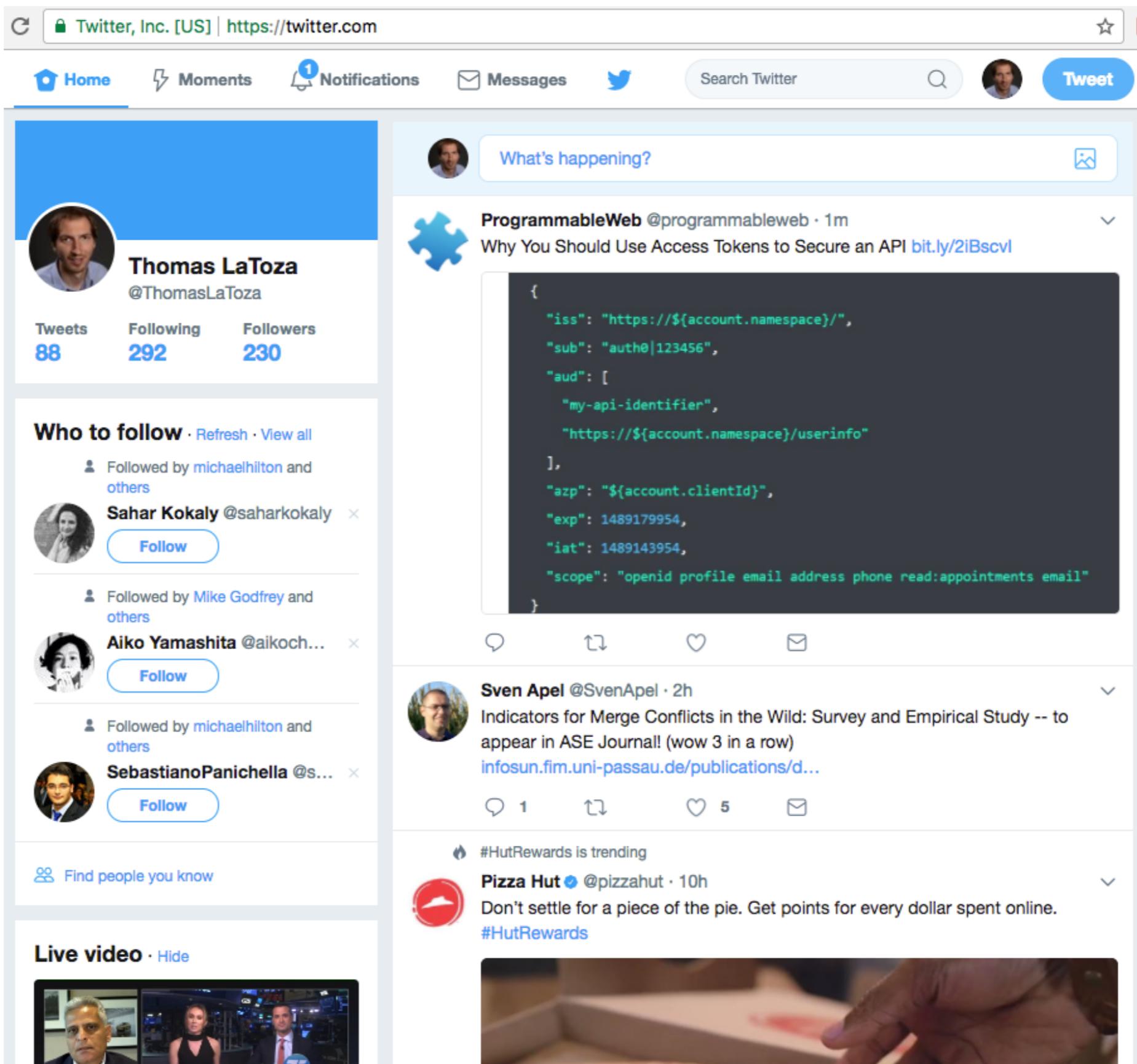
User-generated content?

Informational vs fun?

What is the web?

- A set of standards
 - TCP/IP, HTTP, URLs, HTML, CSS, ...
- A means for distributing structured and semi-structured information to the world
- Infrastructure

Perspectives in web development



Twitter, Inc. [US] | <https://twitter.com>

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Thomas LaToza (@ThomasLaToza) 88 Tweets 292 Following 230 Followers

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What's happening?

ProgrammableWeb @programmableweb · 1m
Why You Should Use Access Tokens to Secure an API bit.ly/2iBscvl

```
{
  "iss": "https://${account.namespace}/",
  "sub": "auth0|123456",
  "aud": [
    "my-api-identifier",
    "https://${account.namespace}/userinfo"
  ],
  "azp": "${account.clientId}",
  "exp": 1489179954,
  "iat": 1489143954,
  "scope": "openid profile email address phone read:appointments email"
}
```

[Comment](#) [Retweet](#) [Like](#) [Email](#)

Sven Apel @SvenApel · 2h
Indicators for Merge Conflicts in the Wild: Survey and Empirical Study -- to appear in ASE Journal! (wow 3 in a row)
infosun.fim.uni-passau.de/publications/d...

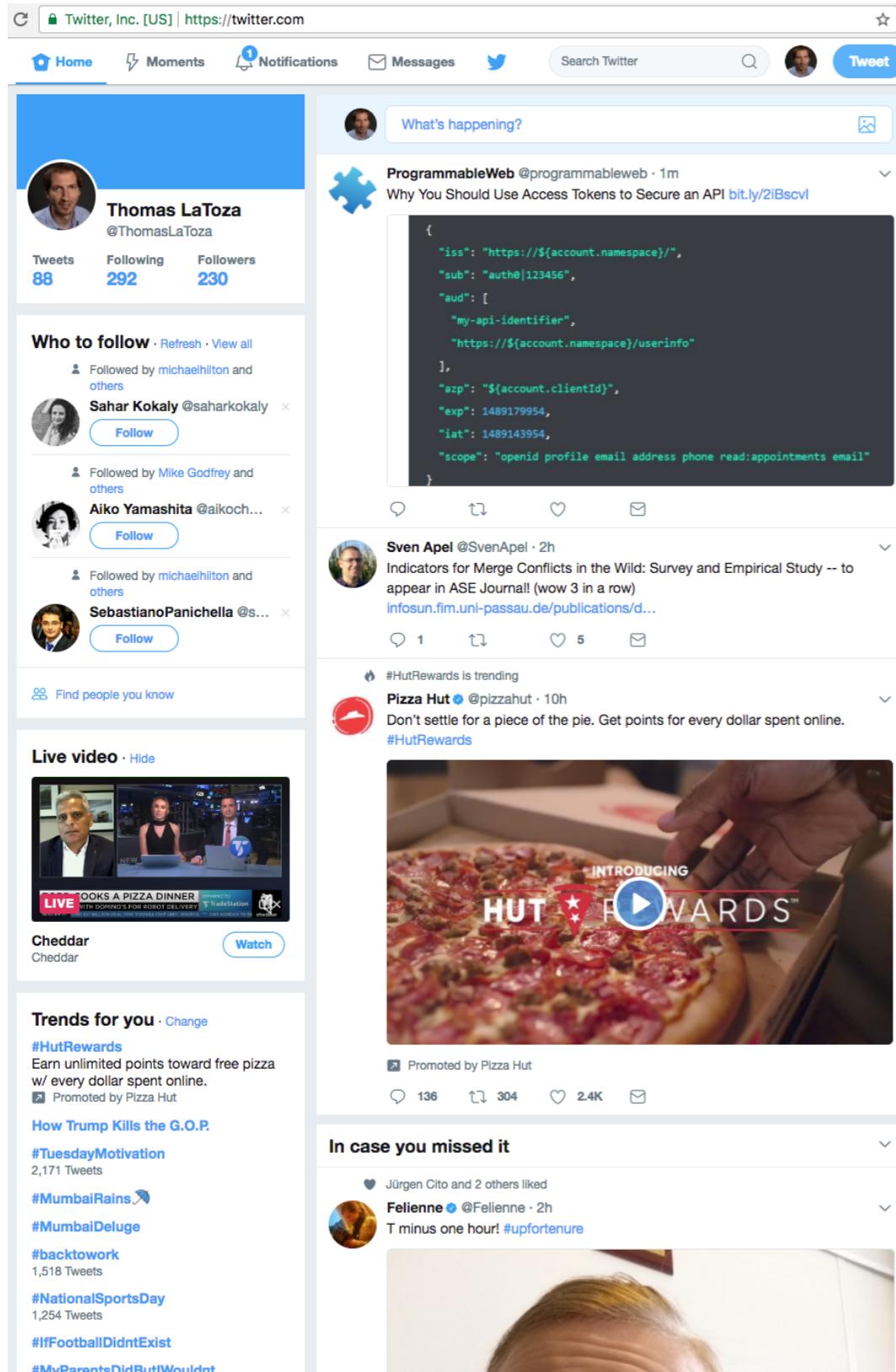
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#HutRewards is trending

Pizza Hut @pizzahut · 10h
Don't settle for a piece of the pie. Get points for every dollar spent online.
[#HutRewards](#)

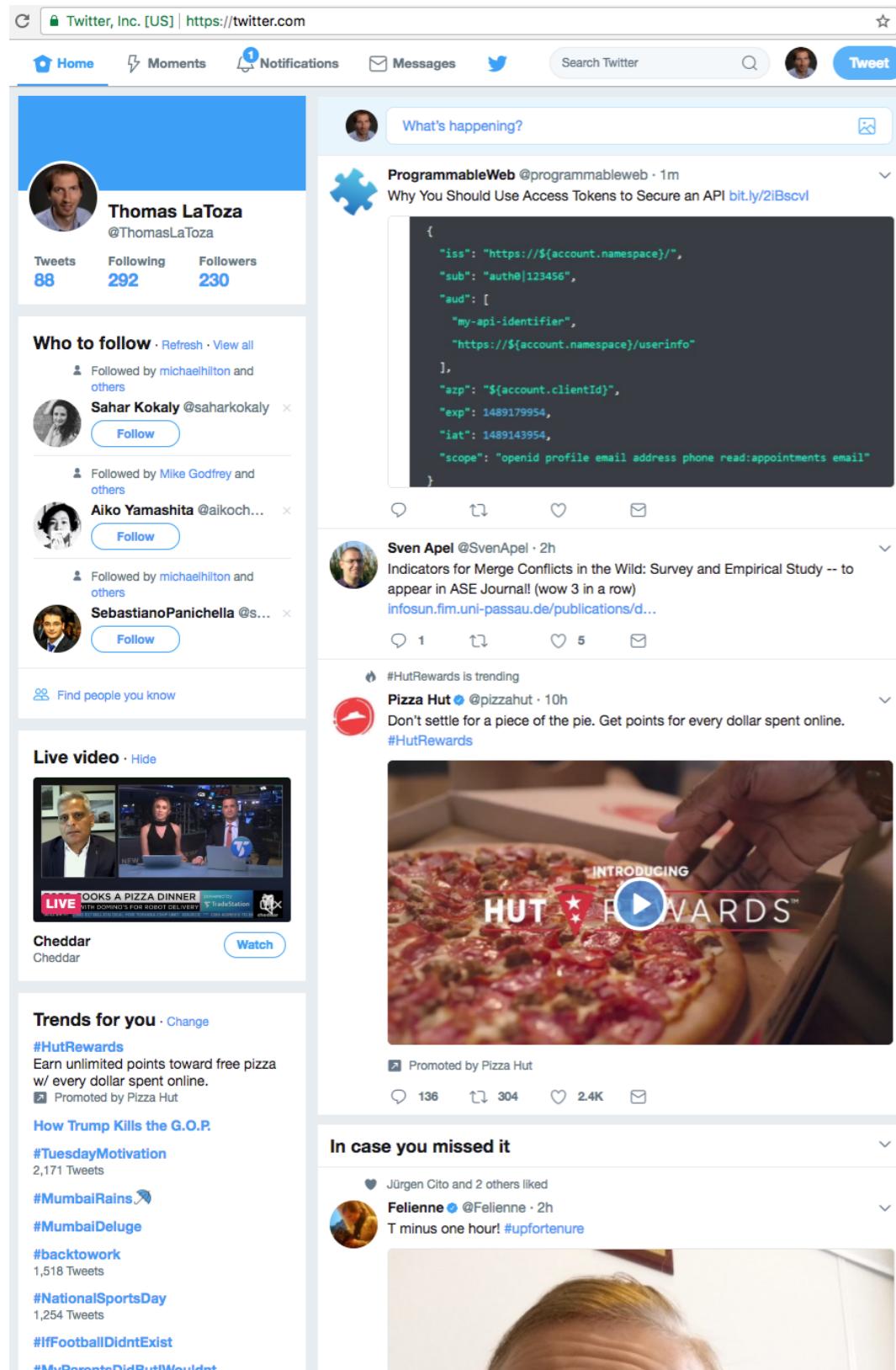


Systems Perspective



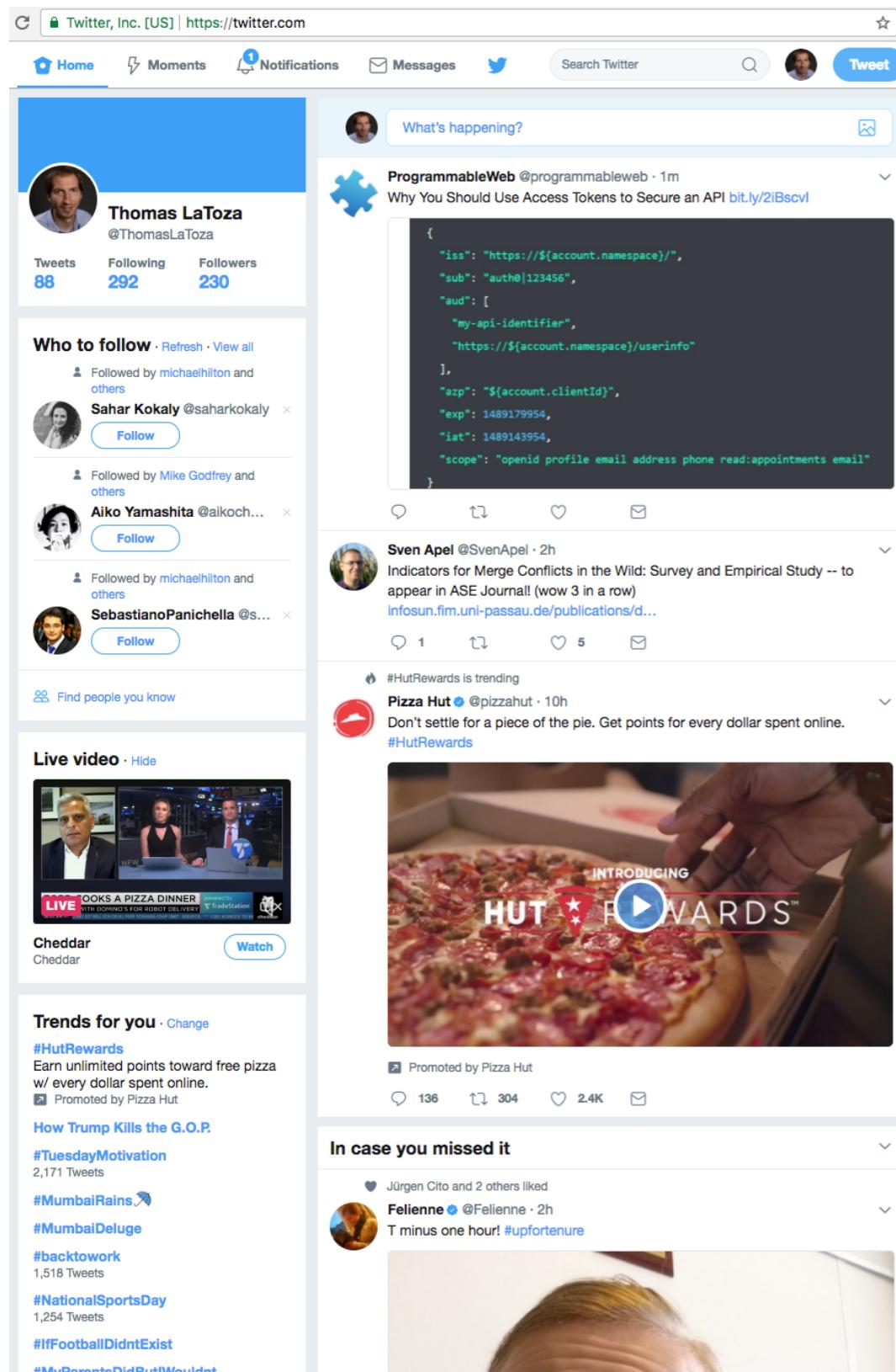
- How can we design **robust, efficient, & secure** interactions between computers?
- Individual web app may run on
 - Thousands of servers
 - Owned and managed by different orgs
- Millions of clients
- $>TBs$ of constantly changing data
- What happens when a server crashes?
- How do we prevent a malicious user from accessing user data on a server?

Software Engineering Perspective



- How can we design for **change** & **reuse**?
- Individual web app may
 - *Hundreds of* developers
 - *Millions of* lines of code
 - New updates deployed many times a day
 - Much functionality reused from code built by other organizations
 - Offer API that allows other web apps to be built on top of it
- How can a developer successfully make a change without understanding the whole system?
- What happens when a new developer joins?

Human-Computer Interaction (HCI) Perspective



- How can we design web apps that are **usable** for their intended purpose?
- Individual web app may
 - *Millions of users*
 - Tens of different needs
 - What happens when a new user interacts with the web app?
 - How can we make a web app less frustrating to use?

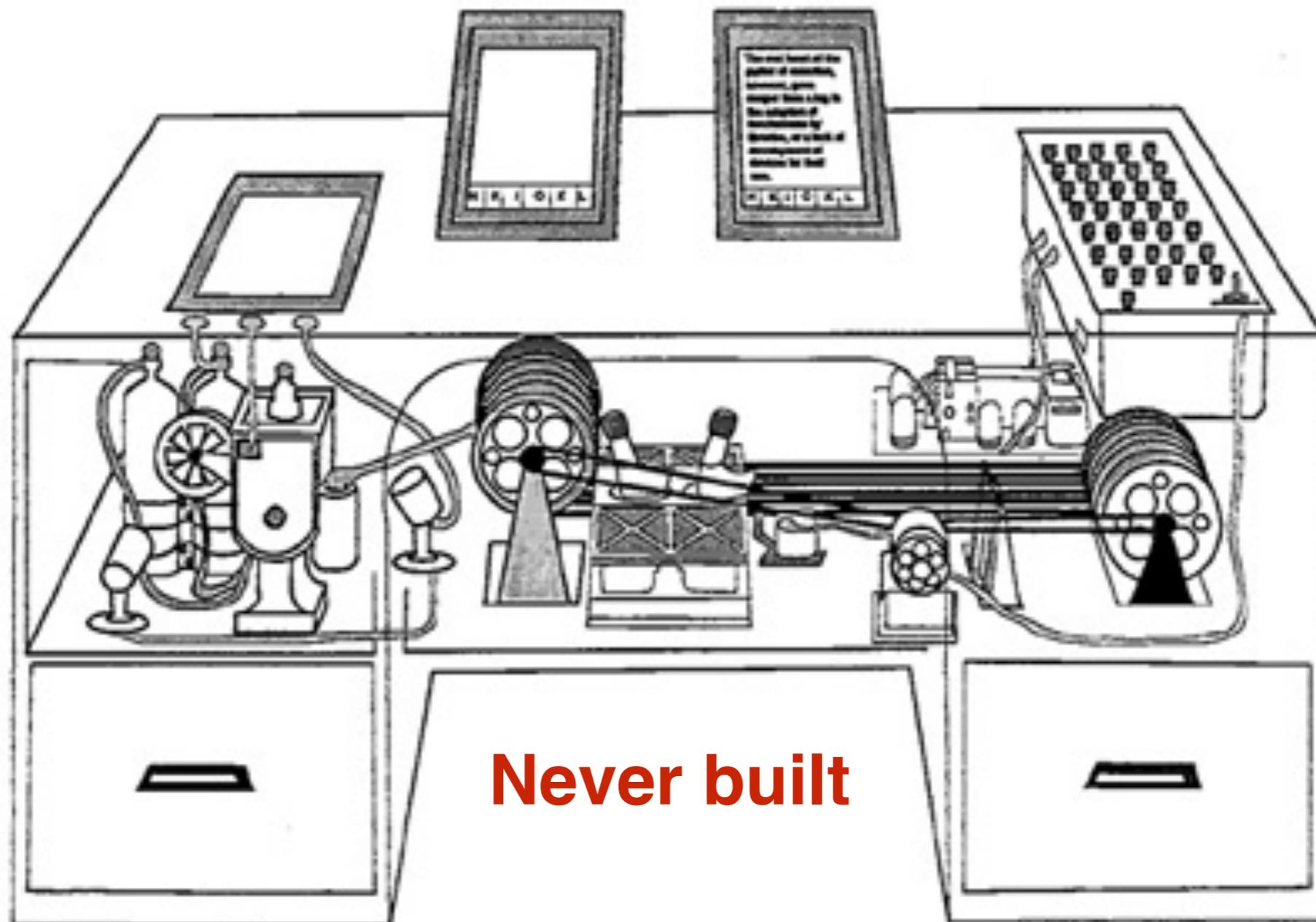
Pre-Web

- “As We May Think”, by Vannevar Bush, in The Atlantic Monthly, July 1945
- Recommended that scientists work on inventing machines for storing, organizing, retrieving and sharing the increasing vast amounts of human knowledge
- He targeted physicists and electrical engineers - there were no computer scientists in 1945

Pre-Web - Memex

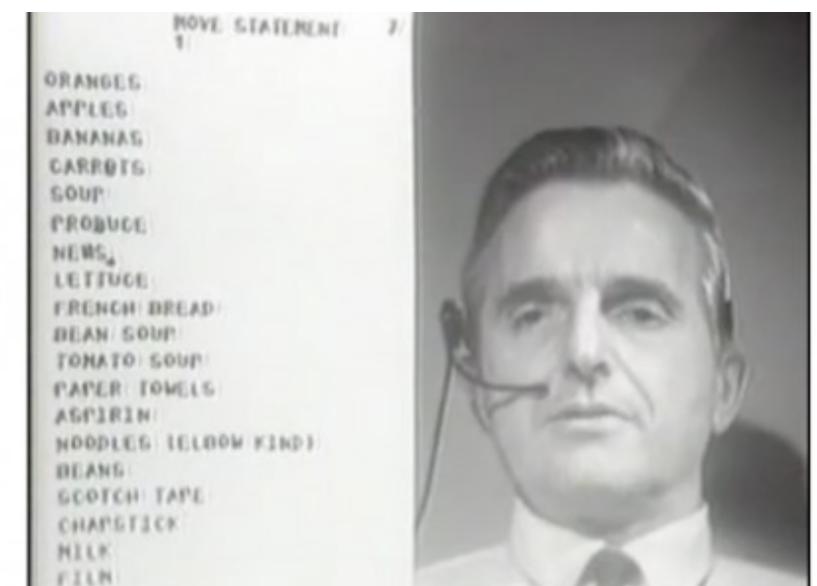
- MEMEX = MEMory EXtension
- Create and follow “associative trails” (links) and annotations between microfilm documents
- Technically based on “rapid selectors” Bush built in 1930’s to search microfilm
- Conceptually based on human associative memory rather than indexing

Pre-Web - Memex



Hypertext and the WWW

- 1965: Ted Nelson coins “hypertext” (the HT in **HTML**) - “beyond” the linear constraints of text
- Many hypertext/hypermedia systems followed, many not sufficiently scalable to take off
- 1968: Doug Engelbart gives “the mother of all demos”, demonstrating windows, hypertext, graphics, video conferencing, the mouse, collaborative real-time editor
- 1969: ARPANET comes online
- 1980: Tim Berners-Lee writes ENQUIRE, a notebook program which allows links to be made between arbitrary nodes with titles

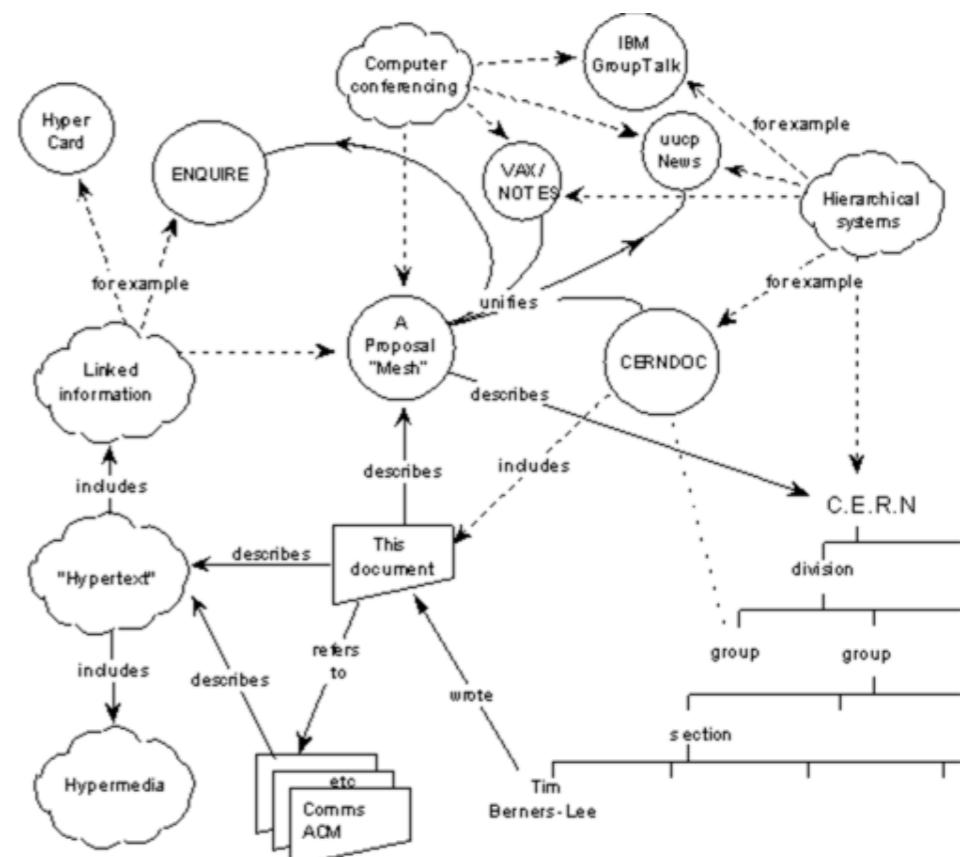


Origin of the Web

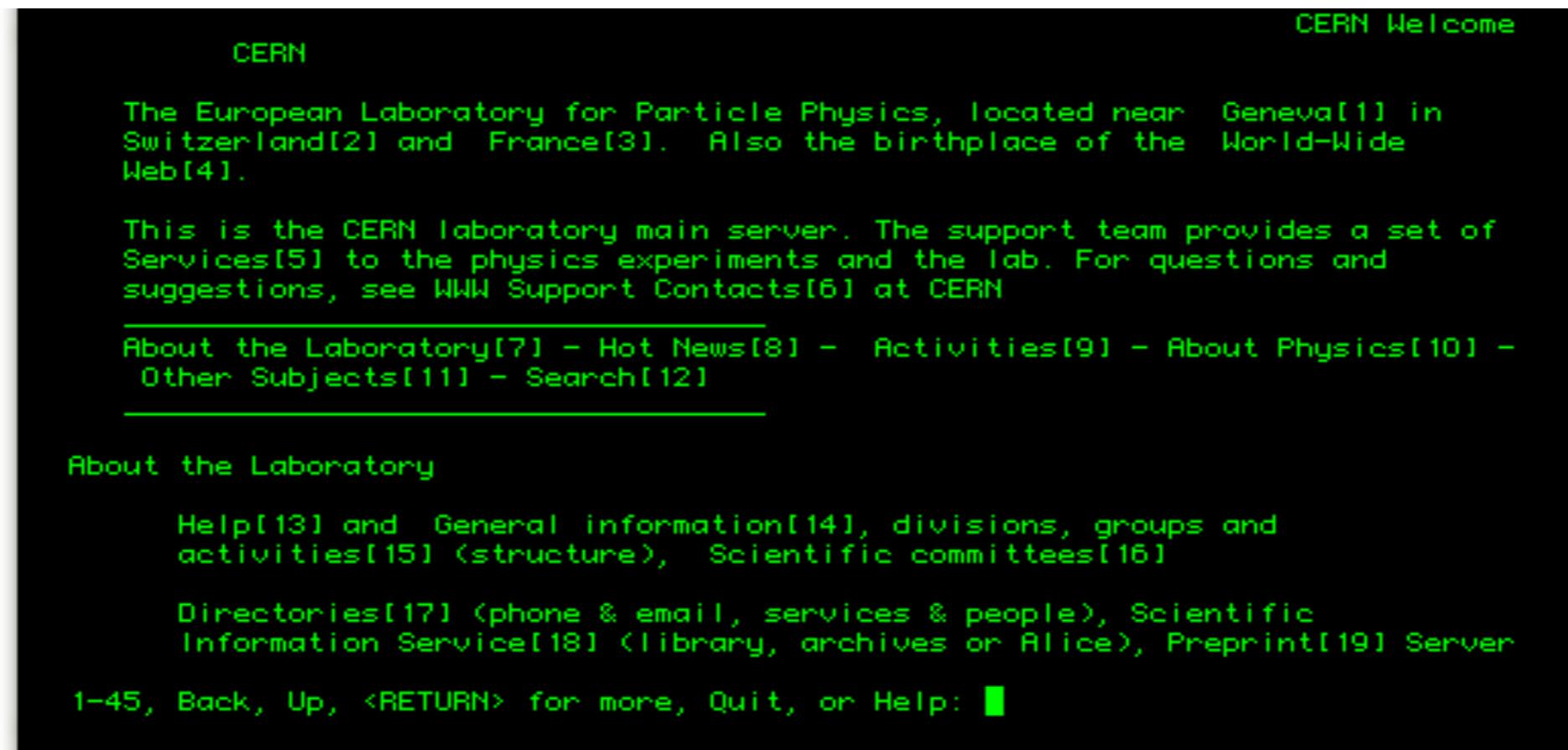
- 1989: Tim Berners-Lee, “Information Management: A Proposal”
- Became what we know as the WWW
- A “global” hypertext system full of links (which could be single directional, and could be broken!)



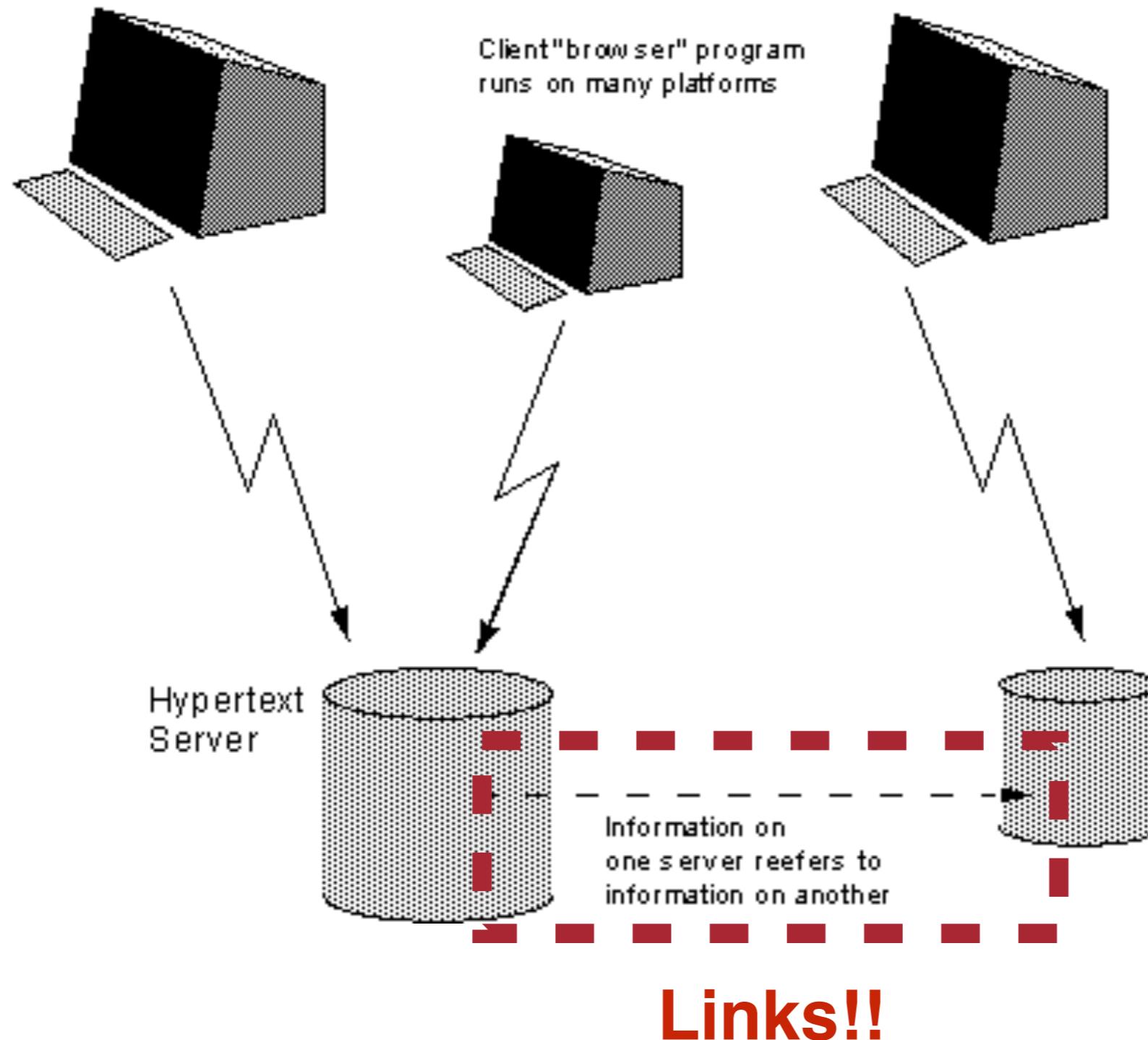
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Early Browsers

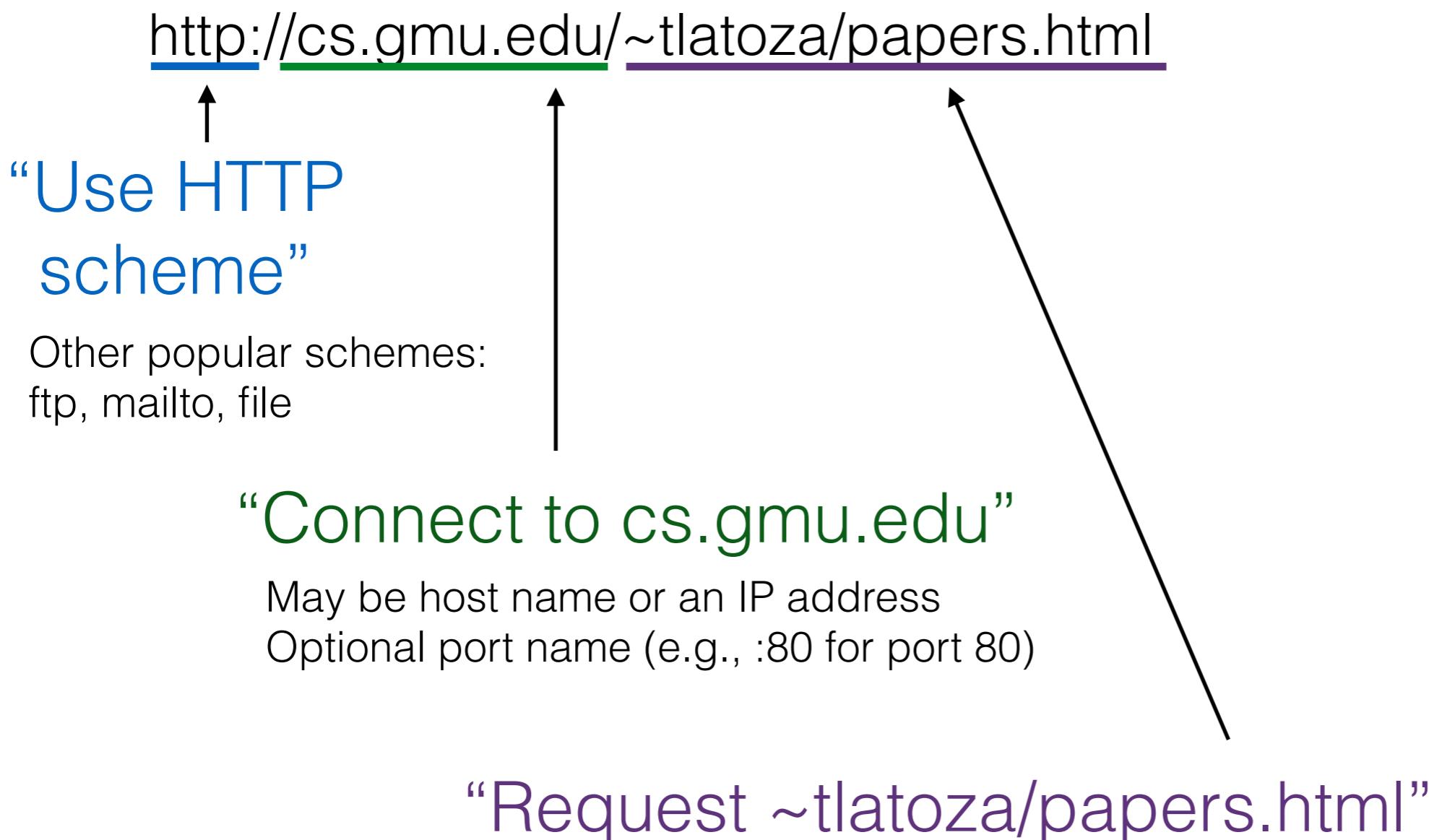


Original WWW Architecture



URI: Universal Resource Identifier

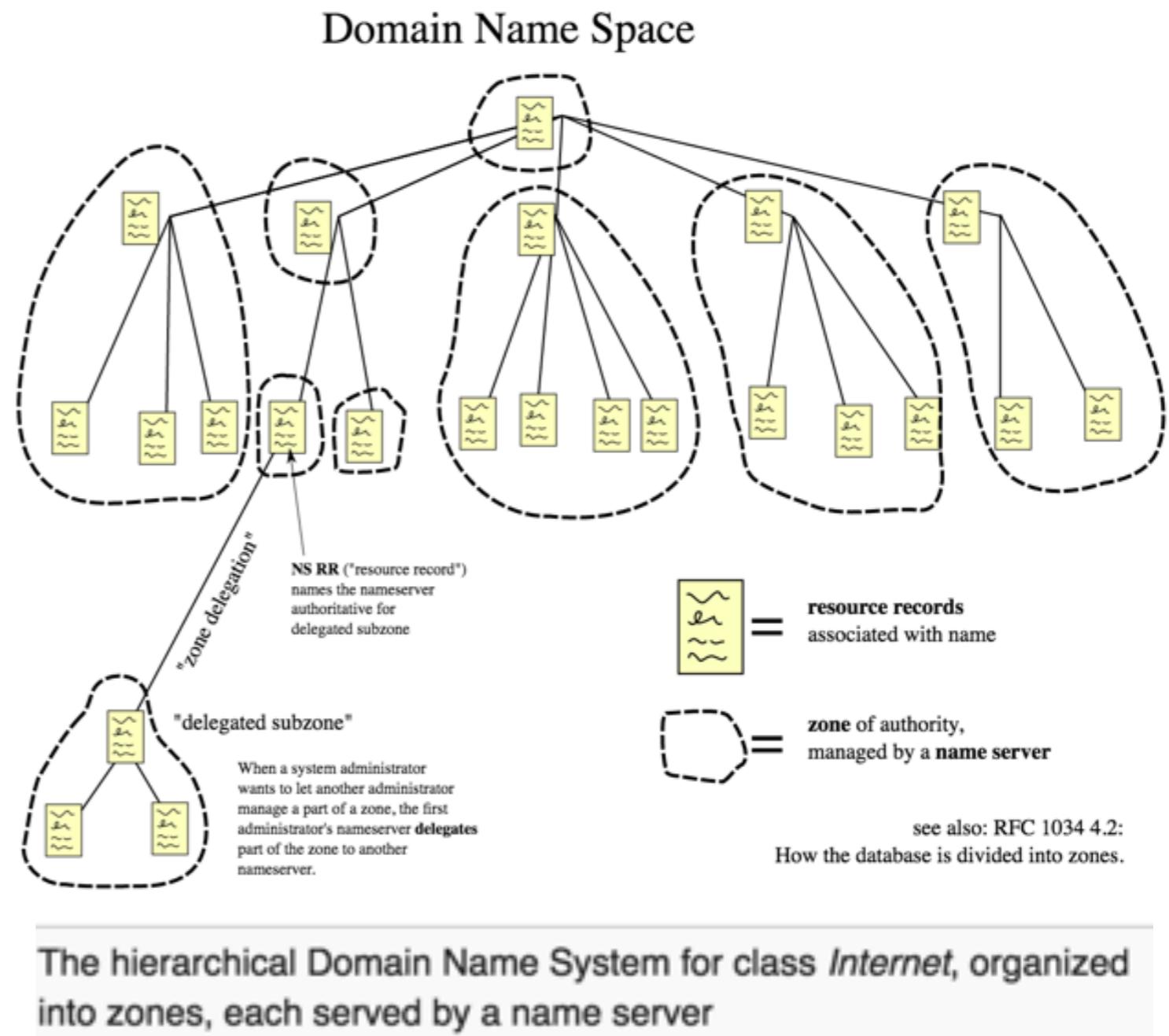
URI: <scheme>://<authority><path>?<query>



More details: https://en.wikipedia.org/wiki/Uniform_Resource_Identifier

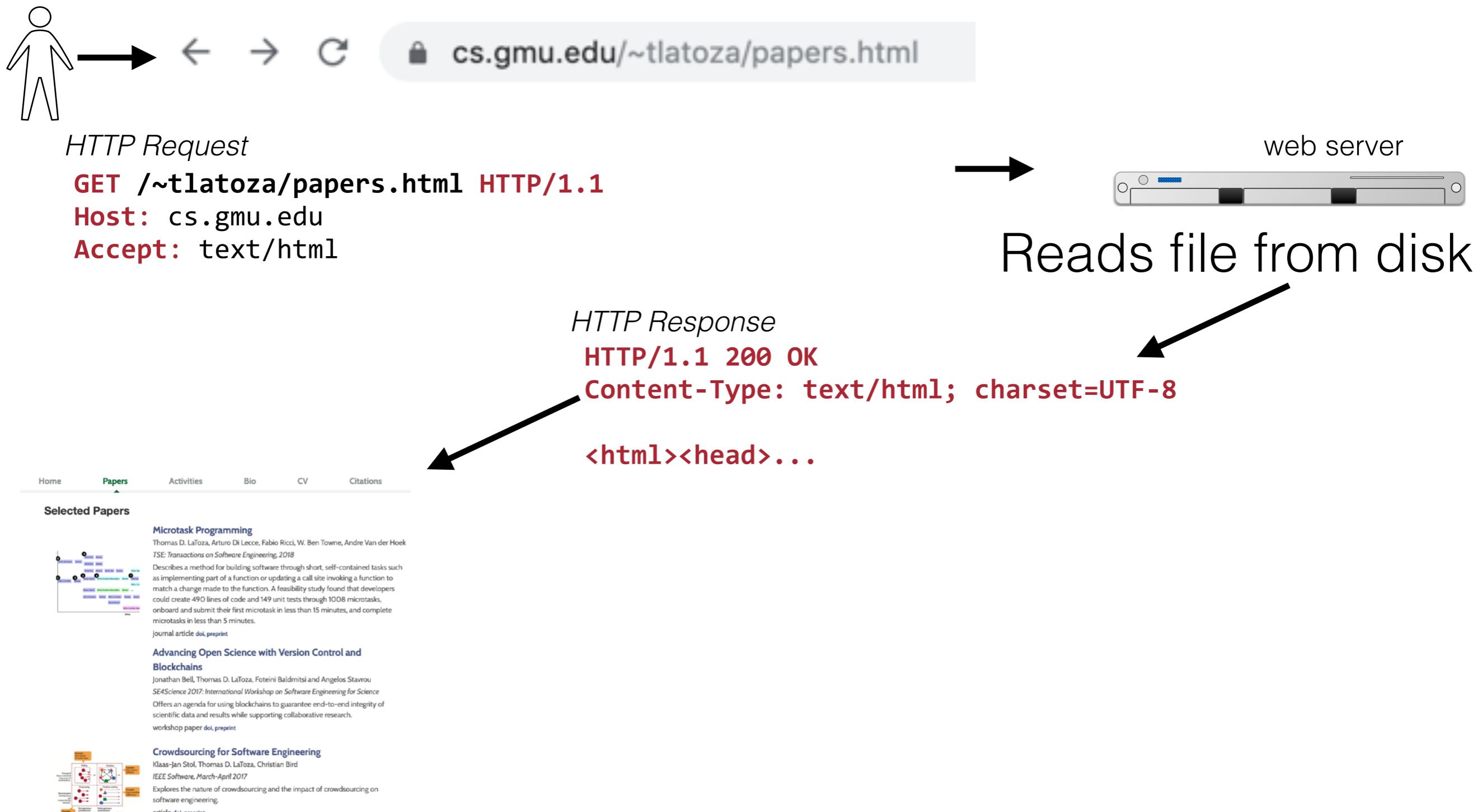
DNS: Domain Name System

- Domain name system (DNS) (~1982)
 - Mapping from names to IP addresses
- E.g. cs.gmu.edu -> 129.174.125.139

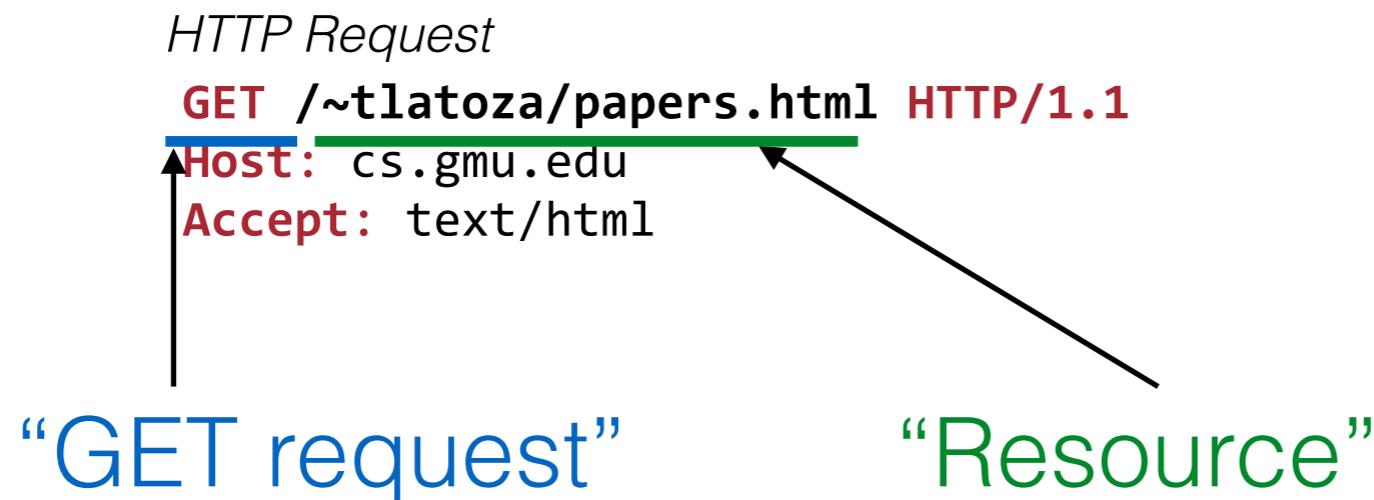


HTTP: HyperText Transfer Protocol

High-level protocol built on TCP/IP that defines how data is transferred on the web



HTTP Requests



Other popular types:
POST, PUT, DELETE, HEAD

- Request may contain additional *header lines* specifying, e.g. client info, parameters for forms, cookies, etc.
- Ends with a carriage return, line feed (blank line)
- May also contain a message body, delineated by a blank line

HTTP Responses

```
HTTP/1.1 200 OK
Date: Mon, 23 May 2005 22:38:34 GMT
Content-Type: text/html; charset=UTF-8
Content-Encoding: UTF-8
Content-Length: 138
Last-Modified: Wed, 08 Jan 2003 23:11:55 GMT
Server: Apache/1.3.3.7 (Unix) (Red-Hat/Linux)
ETag: "3f80f-1b6-3e1cb03b"
Accept-Ranges: bytes
Connection: close

<html>
<head>
  <title>An Example Page</title>
</head>
<body>
  Hello World, this is a very simple HTML document.
</body>
</html>
```

[HTML data]

“OK response”

Response status codes:

1xx Informational

2xx Success

3xx Redirection

4xx Client error

5xx Server error

“HTML returned content”

Common MIME types:

application/json

application/pdf

image/png

Properties of HTTP

- Request-response
 - Interactions always initiated by client request to server
 - Server responds with results
- Stateless
 - Each request-response pair independent from every other
 - Any state information (login credentials, shopping carts, etc.) needs to be encoded somehow

HTML: HyperText Markup Language

HTML is a **markup language** - it is a language for describing parts of a document

< i >



< /i > →



HTML: HyperText Markup Language

- NOT a programming language
- Tags are added to markup the text, encompassed with <>'s
- Simple markup tags: , <i>, <u> (bold, italic, underline)

```
<b>This text is bold!</b>
```



This text is bold!

Web vs. Internet

Web	HTML	CSS	Browser
Internet	Application layer	DNS, FTP, HTTP , IMAP, POP, SSH, Telnet, TLS/SSL, ...	
	Transport layer	TCP, UDP, ...	
	Internet layer	IP, ICMP, IPSec, ...	
	Link layer	PPP, MAC (Ethernet, DSL, ISDN, ...), ...	

The Modern Web

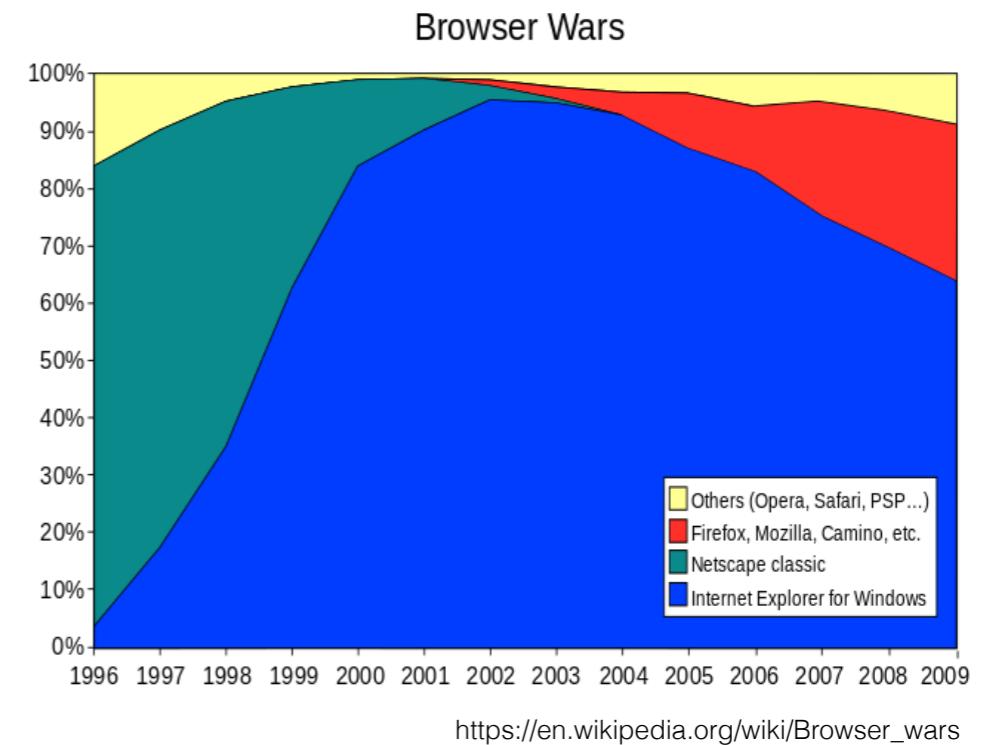
- Evolving competing architectures for organizing content and computation between browser (client) and web server
- 1990s: static web pages
- 1990s: server-side scripting (CGI, PHP, ASP, ColdFusion, JSP, ...)
- 2000s: single page apps (JQuery)
- 2010s: front-end frameworks (Angular, React, Vue...), microservices

Static Web Pages

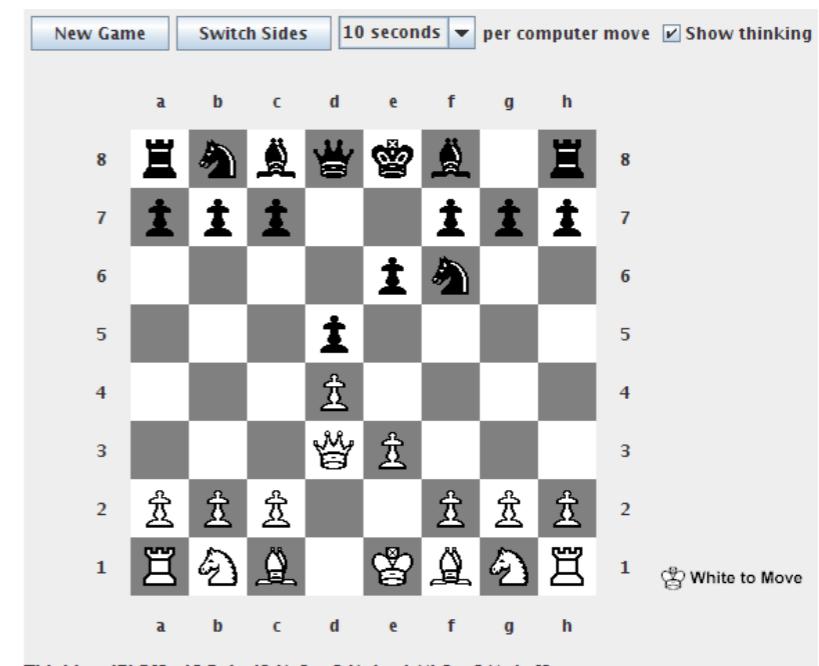
- URL corresponds to directory location on server
 - e.g. `http://domainName.com/img/image5.jpg` maps to `img/image5.jpg` file on server
- Server responds to HTTP request by returning requested files
- Advantages
 - Simple, easily cacheable, easily searchable
- Disadvantages
 - No interactivity

Web 1.0 Problems

- At this point, most sites were “read only”
- Lack of standards for advanced content - “browser war”



- No rich client content... the best you could hope for was a Java applet



https://en.wikipedia.org/wiki/Java_applet

Dynamic Web Pages



SWE 432 Section 002 Fall 2016 Syllabus and Schedule

"Design and Implementation of Software for the Web"

Class Hours: Tuesdays and Thursdays, 12:00pm-1:15pm Robinson Hall B228

Grades, Readings available as pdfs: Blackboard

Resources (Announcements, Schedule, Assignments, Discussion):

Piazza - <https://piazza.com/gmu/fall2016/swe432001/home>

Instructor: Prof. Jonathan Bell

bellj@gmu.edu

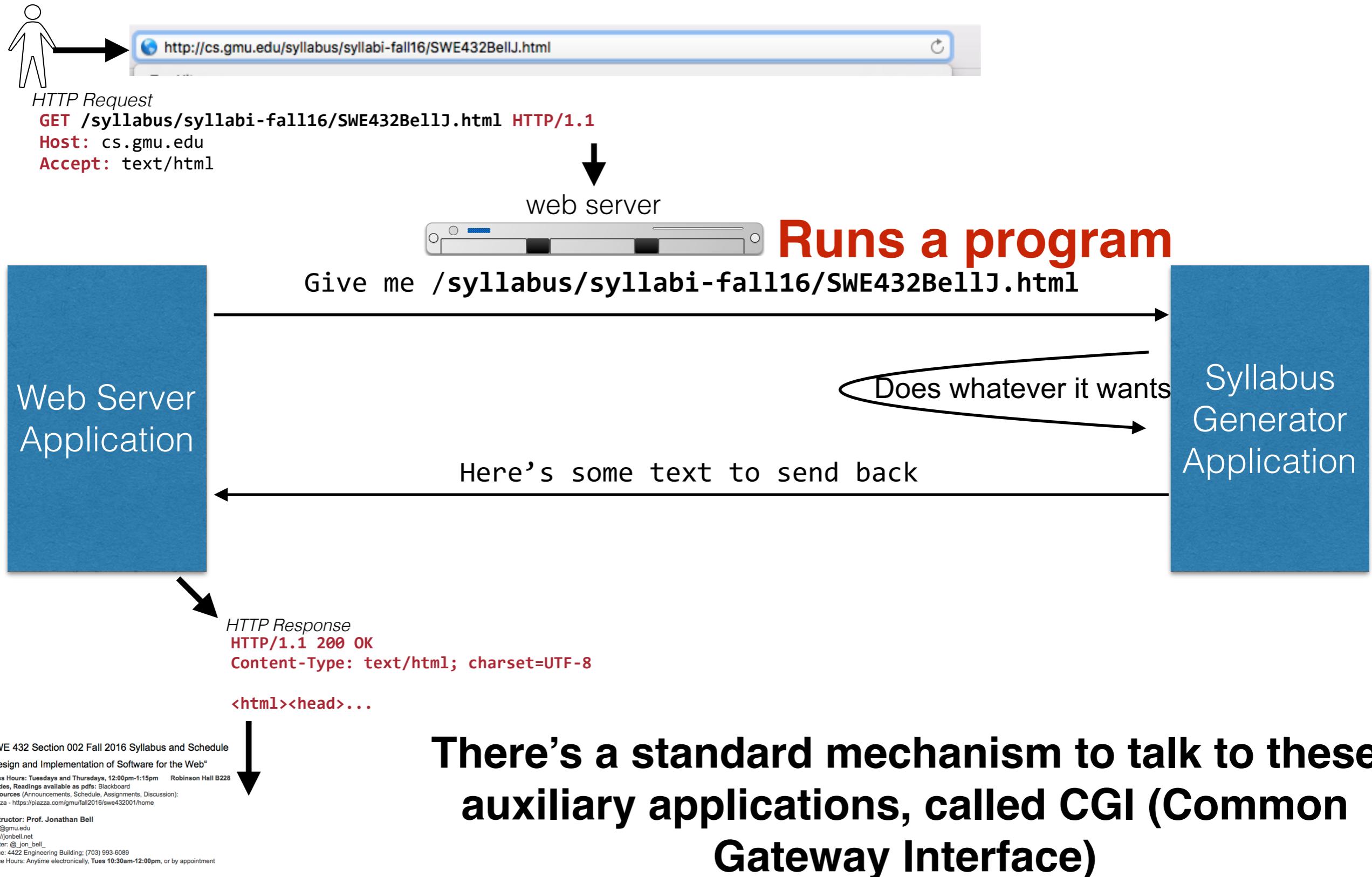
<http://jonbell.net>

Twitter: @_jon_bell_

Office: 4422 Engineering Building; (703) 993-6089

Office Hours: Anytime electronically, Tues 10:30am-12:00pm, or by appointment

Dynamic Web Pages



Server Side Scripting

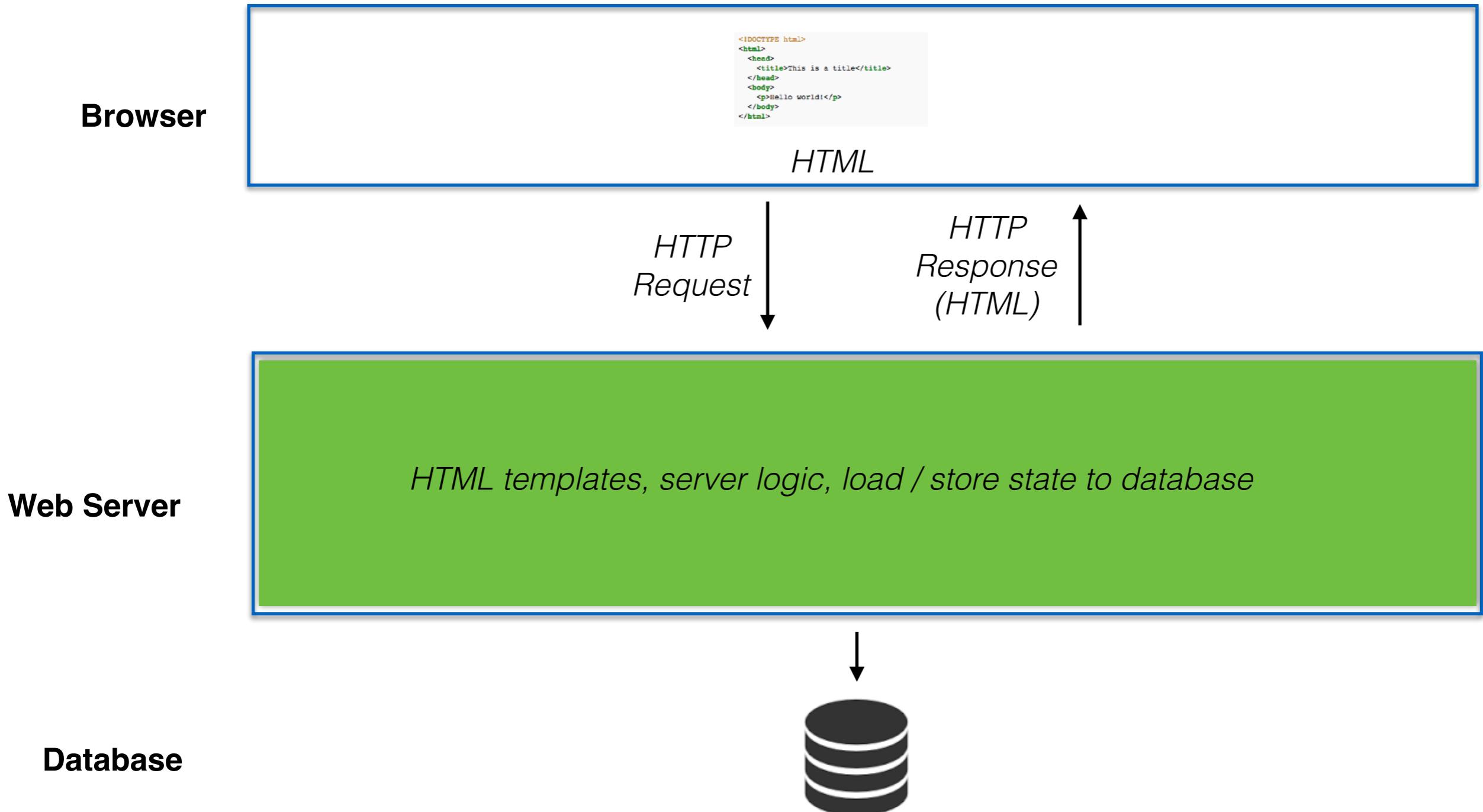
- Generate HTML on the server through scripts

```
<!DOCTYPE html>
<html>
  <head>
    <title>PHP Test</title>
  </head>
  <body>
    <?php echo '<p>Hello World</p>'; ?>
  </body>
</html>
```

```
<html>
<head><title>First JSP</title></head>
<body>
<%
  double num = Math.random();
  if (num > 0.95) {
%
    <h2>You'll have a luck day!</h2><p>(<%= num %>)</p>
<%
  } else {
%
    <h2>Well, life goes on ... </h2><p>(<%= num %>)</p>
<%
  }
%>
```

- Early approaches emphasized embedding server code *inside* html pages
- Examples: CGI

Server Side Scripting Site



Limitations

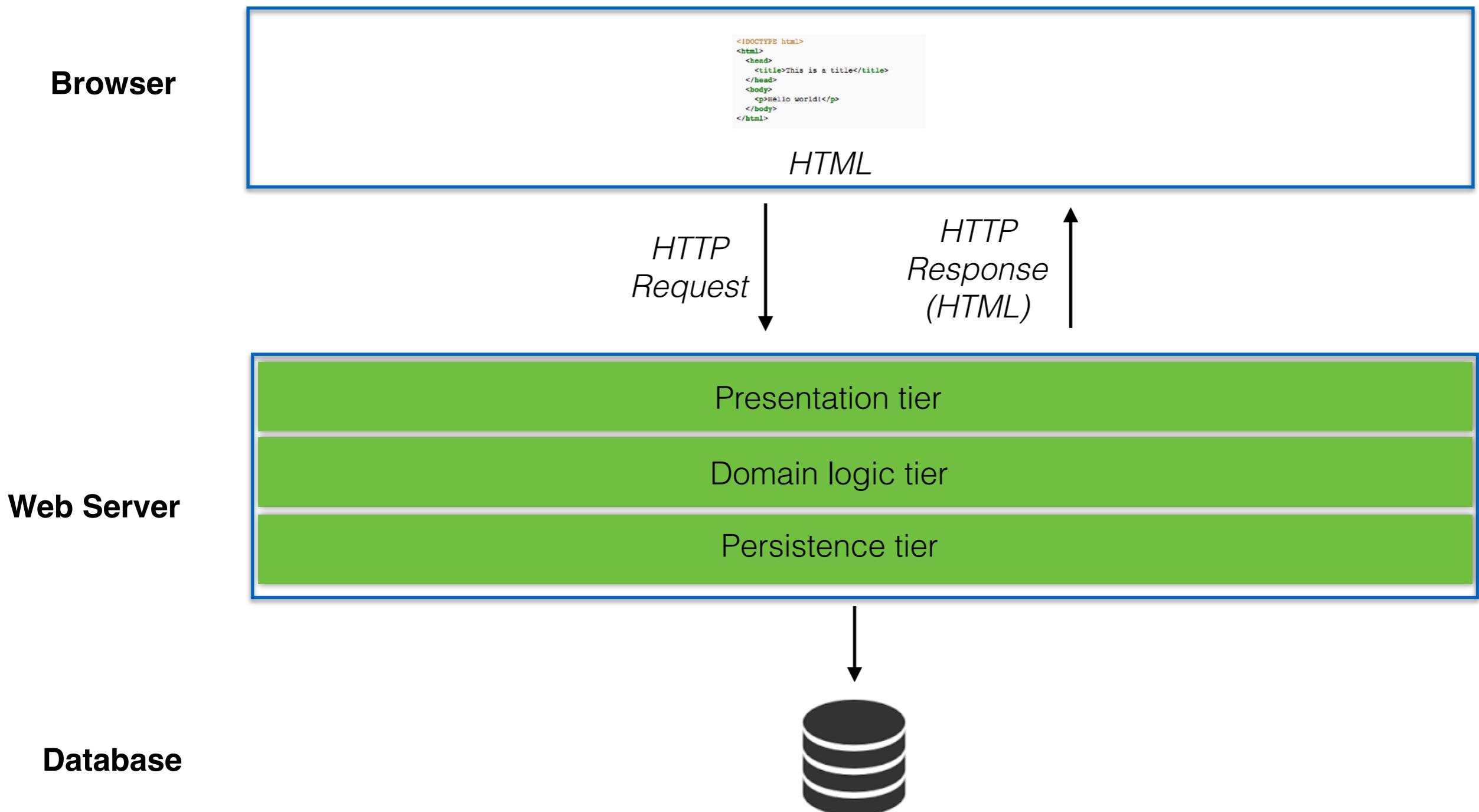
- Poor **modularity**
 - Code representing logic, database interactions, generating HTML presentation all tangled
 - Example of a Big Ball of Mud [1]
 - Hard to understand, difficult to maintain
 - Still a step up over static pages!

[1] <http://www.laputan.org/mud/>

Server Side Frameworks

- Framework that structures server into tiers, organizes logic into classes
- Create separate tiers for presentation, logic, persistence layer
- Can understand and reason about domain logic without looking at presentation (and vice versa)
- Examples: ASP.NET, JSP

Server Side Framework Site



Limitations

- Need to load a whole new web page to get new data
 - Users must *wait* while new web page loads, decreasing responsiveness & interactivity
 - If server is slow or temporarily non-responsive, ***whole user interface hangs!***
 - Page has a discernible *refresh*, where old content is replaced and new content appears rather than seamless transition

Single Page Application (SPA)

- Client-side logic sends messages to server, receives response
- Logic is associated with a single HTML pages, written in Javascript
- HTML elements dynamically added and removed through DOM manipulation

```
<b>Projects:</b>
<ol id="new-projects"></ol>

<script>
$( "#new-projects" ).load( "/resources/load.html #projects li" );
</script>

</body>
</html>
```

- Processing that does not require server may occur entirely client side, dramatically increasing responsiveness & reducing needed server resources
- Classic example: Gmail

SPA Enabling Technologies

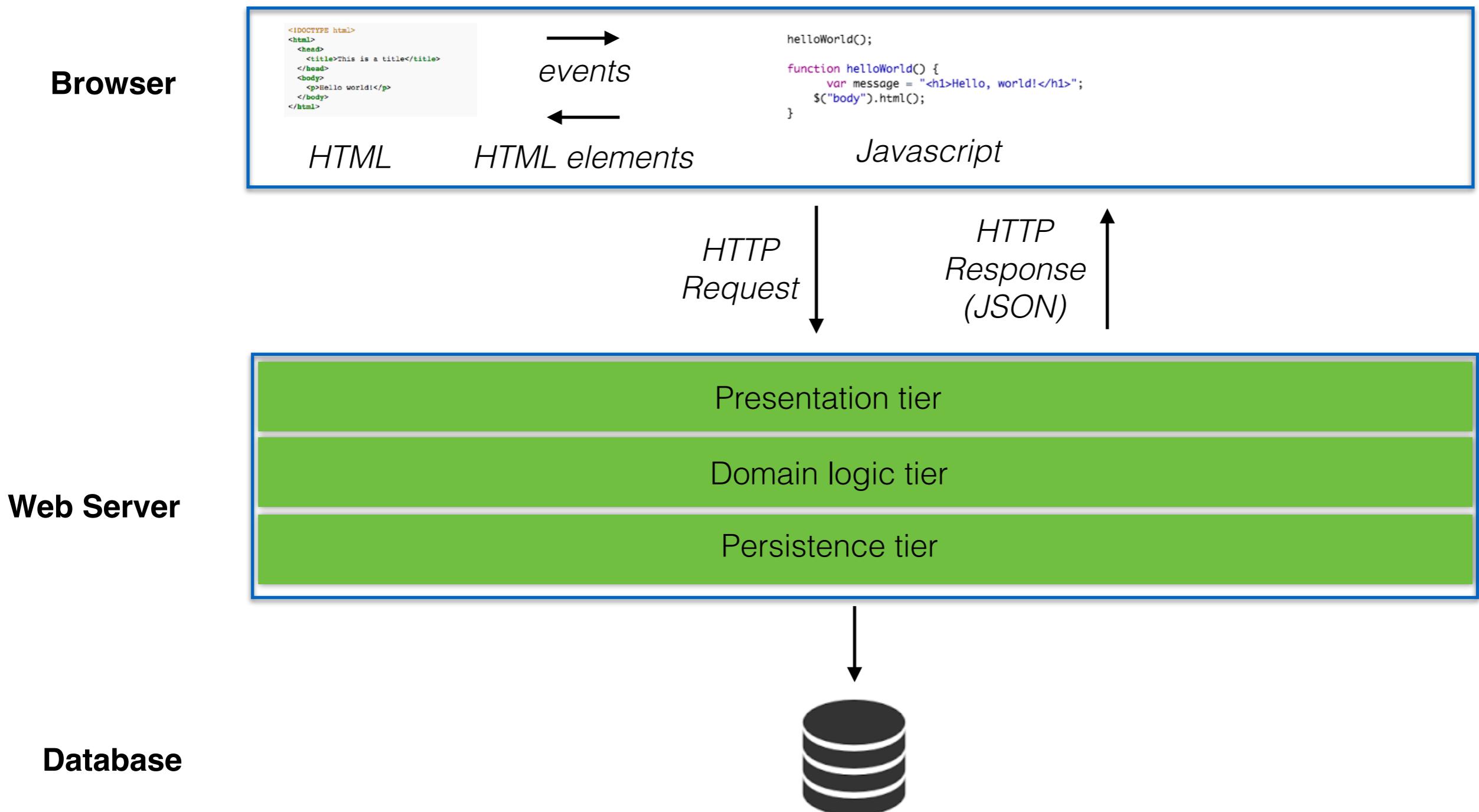
- AJAX: Asynchronous Javascript and XML
 - Set of technologies for sending asynchronous request from web page to server, receiving response
- DOM Manipulation
 - Methods for updating the HTML elements in a page *after* the page may already have loaded
- JSON: JavaScript Object Notation
 - Standard syntax for describing and transmitting Javascript data objects
- JQuery
 - Wrapper library built on HTML standards designed for AJAX and DOM manipulation

JSON

```
{  
  "firstName": "John",  
  "lastName": "Smith",  
  "isAlive": true,  
  "age": 25,  
  "address": {  
    "streetAddress": "21 2nd Street",  
    "city": "New York",  
    "state": "NY",  
    "postalCode": "10021-3100"  
  },  
  "phoneNumbers": [  
    {  
      "type": "home",  
      "number": "212 555-1234"  
    },  
    {  
      "type": "office",  
      "number": "646 555-4567"  
    },  
    {  
      "type": "mobile",  
      "number": "123 456-7890"  
    }  
  "children": [],  
  "spouse": null  
}
```

<https://en.wikipedia.org/wiki/JSON>

Single Page Application Site



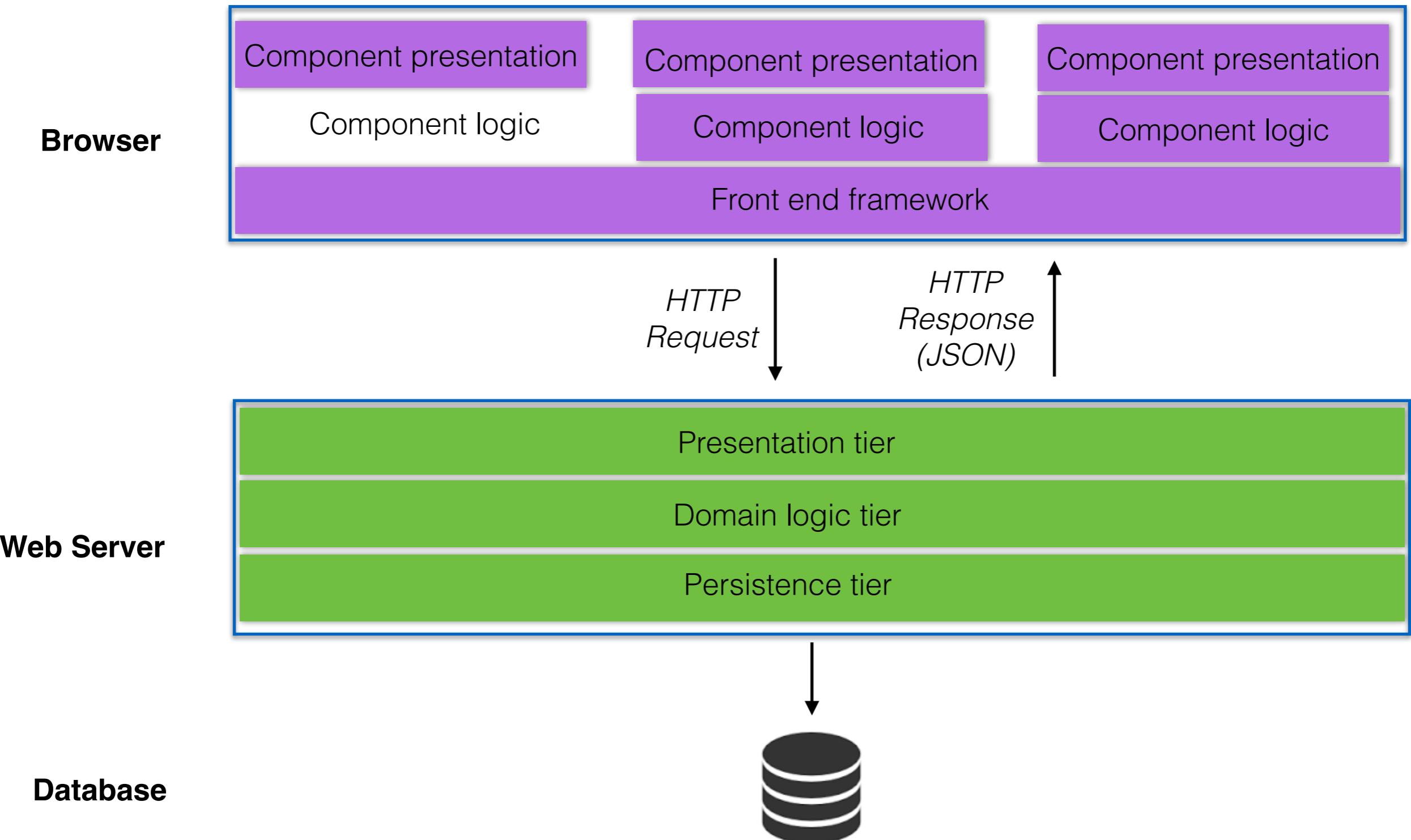
Limitations

- Poor modularity *client-side*
 - As logic in client grows increasingly large and complex, becomes Big Ball of Mud
 - Hard to understand & maintain
 - DOM manipulation is *brittle* & *tightly coupled*, where small changes in HTML may cause unintended changes (e.g., two HTML elements with the same id)
 - Poor reuse: logic tightly coupled to individual HTML elements, leading to code duplication of similar functionality in many places

Front End Frameworks

- Client is organized into separate *components*, capturing model of web application data
- Components are reusable, have encapsulation boundary (e.g., class)
- Components separate *logic* from *presentation*
- Components dynamically generate corresponding code based on component state
 - In contrast to HTML element manipulation, *framework* generates HTML, not user code, decreasing coupling
- Examples: Meteor, Ember, Angular, Aurelia, React

Front End Framework Site



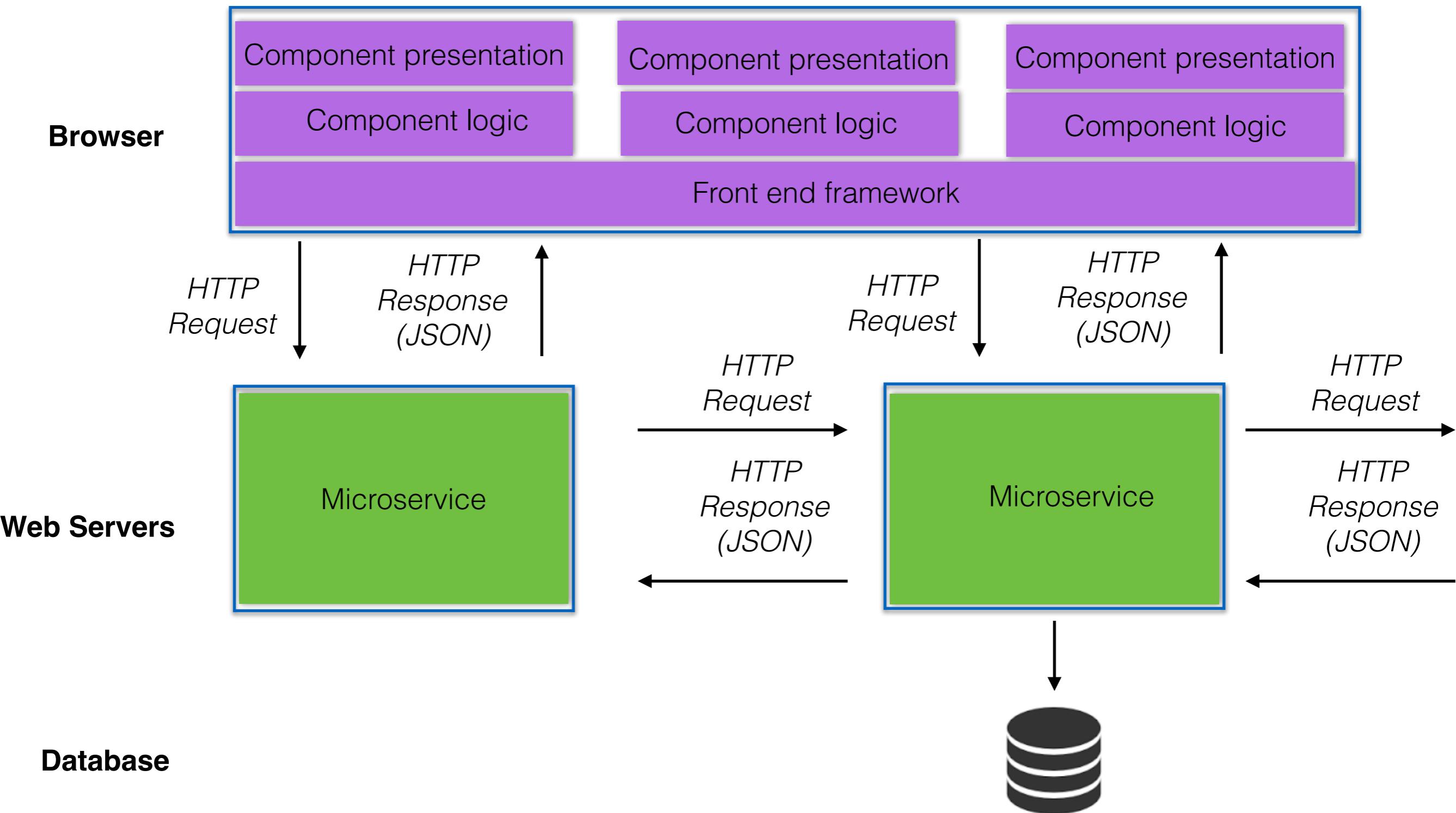
Limitations

- Duplication of logic in client & server
 - As clients grow increasingly complex, must have logic in both client & server
 - May even need to be written twice in different *languages!* (e.g., Javascript, Java)
 - Server logic closely coupled to corresponding client logic. Changes to server logic require corresponding client logic change.
 - Difficult to reuse server logic

Microservices

- Small, focused web server that communicates through *data* requests & responses
 - Focused *only* on logic, not presentation
- Organized around capabilities that can be reused in multiple context across multiple applications
- Rather than horizontally scale identical web servers, vertically scale server infrastructure into many, small focused servers

Microservice Site



Architectural Styles

- Architectural style specifies
 - how to partition a system
 - how components identify and communicate with each other
 - how information is communicated
 - how elements of a system can evolve independently

Constant change in web architectural styles

- Key drivers
 - Maintainability (new ways to achieve better modularity)
 - Reuse (organizing code into modules)
 - Scalability (partitioning monolithic servers into services)
 - Responsiveness (movement of logic to client)
 - Versioning (support continuous roll-out of new features)
- Web standards have enabled *many* possible solutions
- Explored through ***many, many*** frameworks, libraries, and programming languages