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2022

Web Architecture

Layers, Languages, Protocols

Fulvio Corno

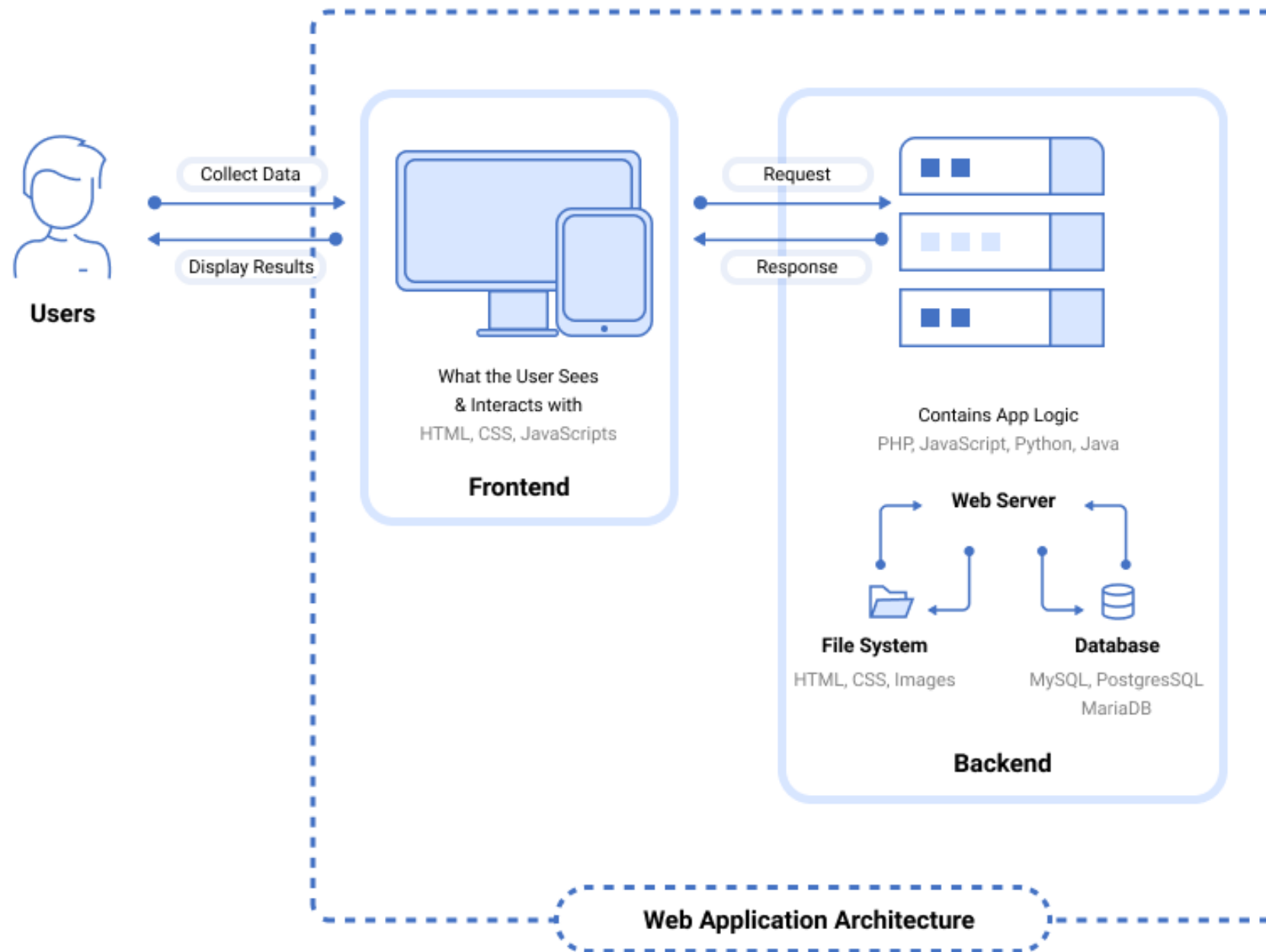
Luigi De Russis

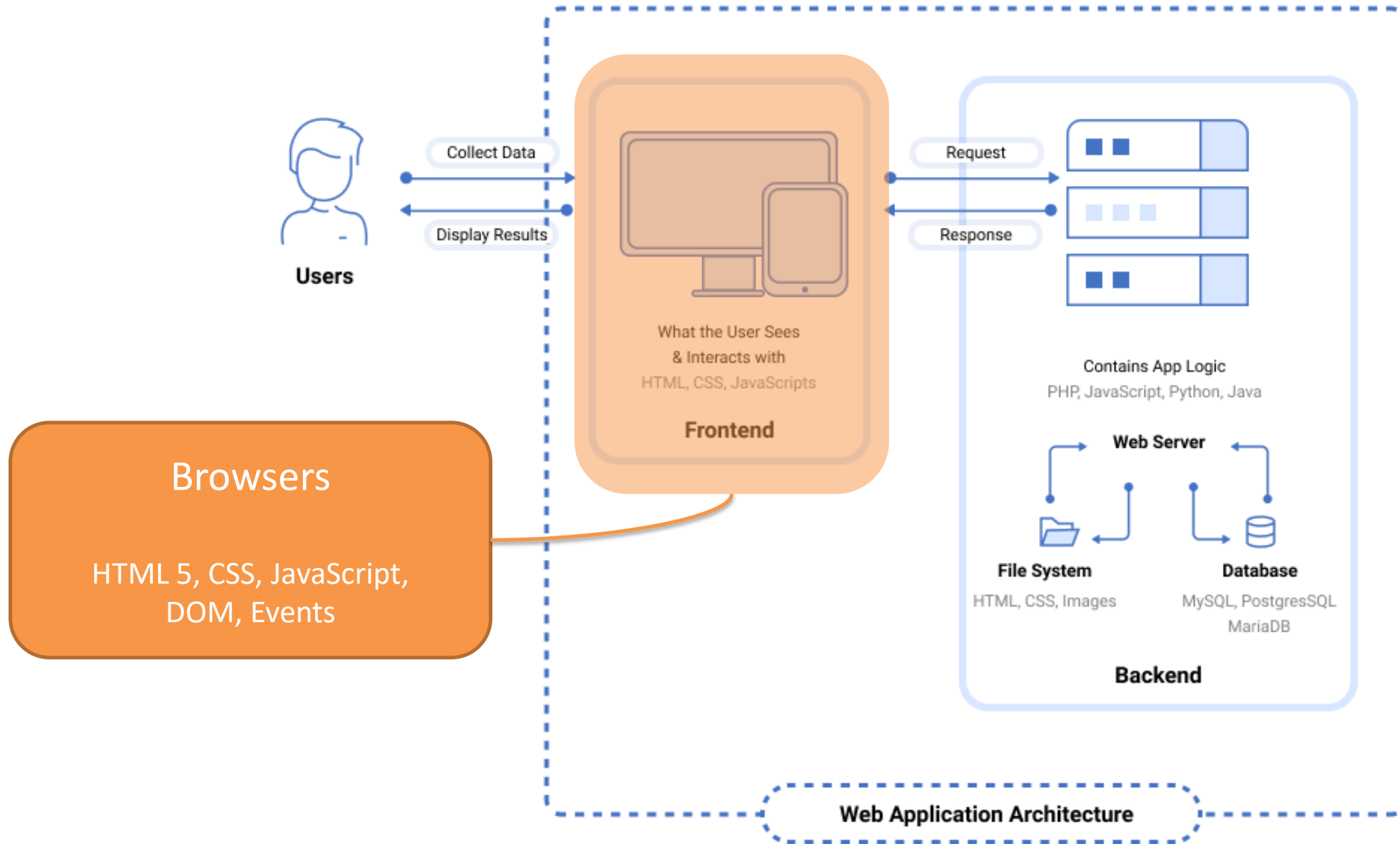
Enrico Masala



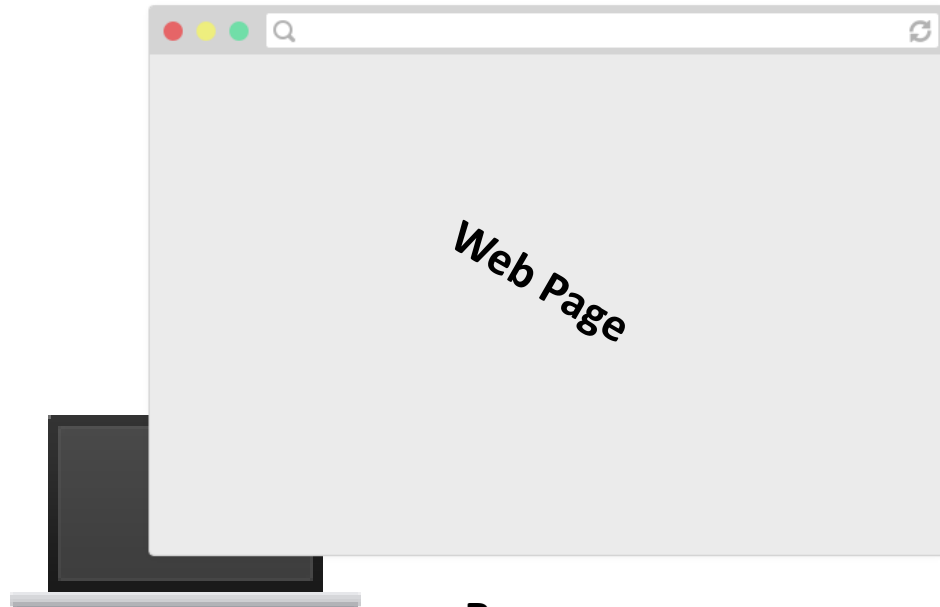
Goal

- Understand what is the Web and its architecture
 - main (logical) components
 - main network protocols
 - existing architectural patterns and languages
- Know the interaction and communication across components
- Learn the basics of how a browser works
- *NOTE: All the topics mentioned here will be presented in more details in the next lectures*

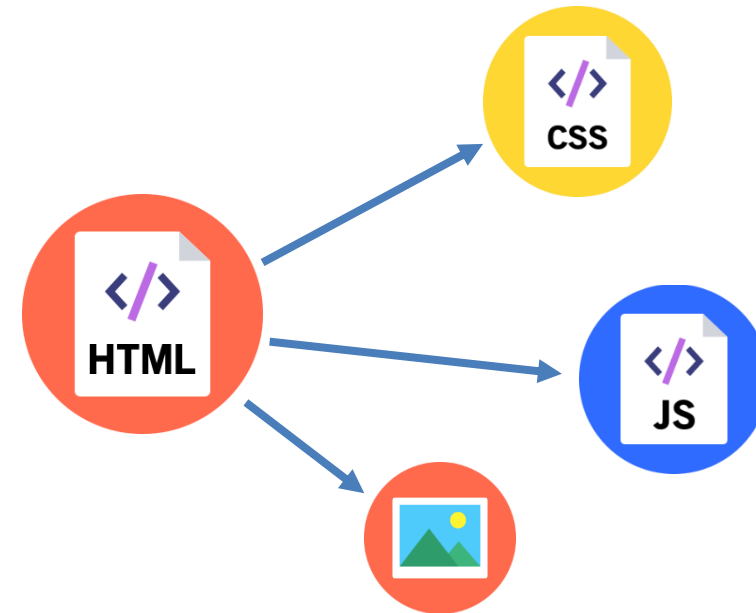




Browser



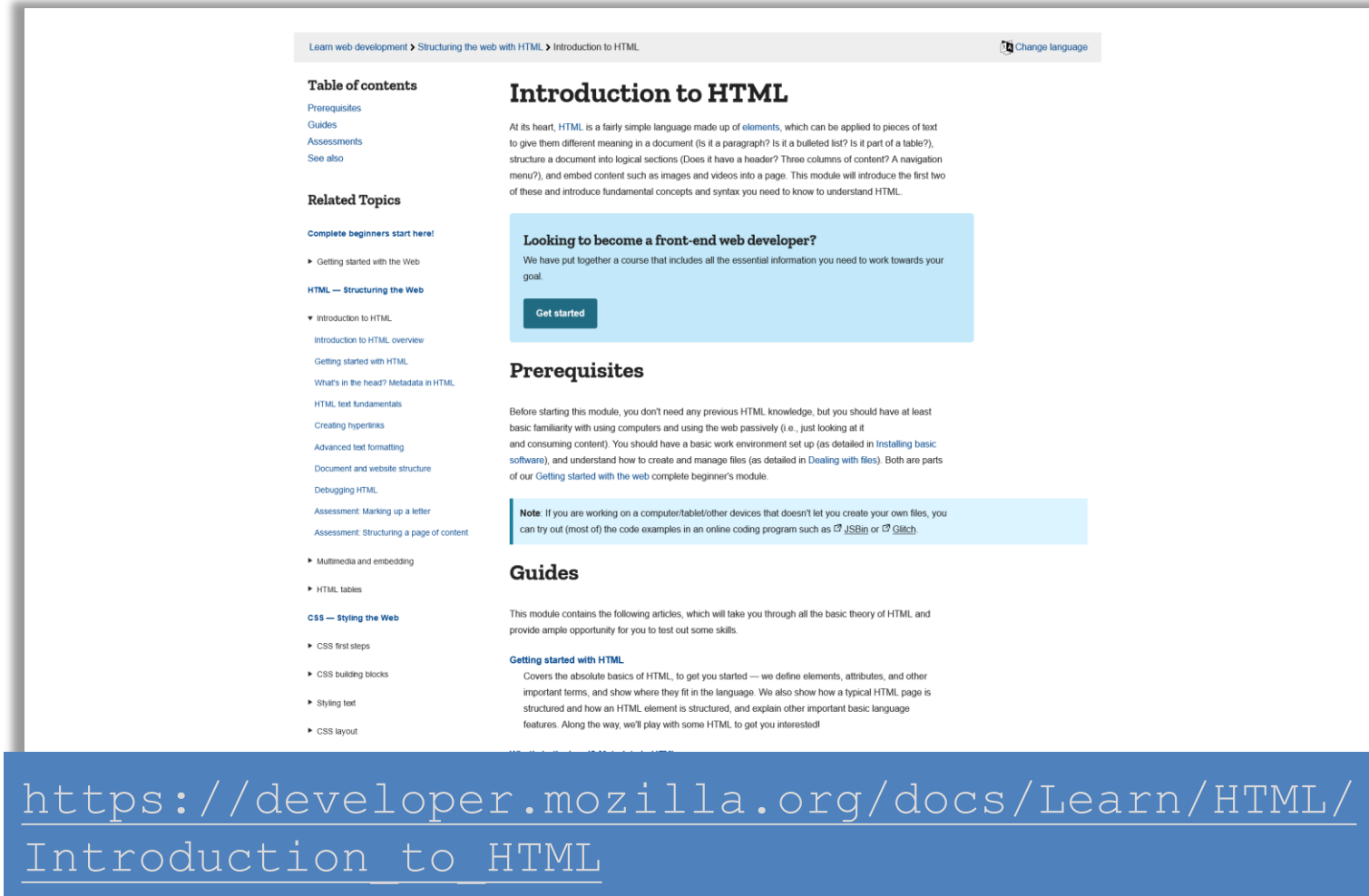
Browser



The HTML file might link to other **resources** (images, videos, ...) as well as **JavaScript** and **CSS** files, which the browser then also loads

These are stored or generated by a **server**

Quick Introduction to HTML



Learn web development > Structuring the web with HTML > Introduction to HTML [Change language](#)

Table of contents

- Prerequisites
- Guides
- Assessments
- See also

Related Topics

[Complete beginners start here!](#)

- ▶ [Getting started with the Web](#)

HTML — Structuring the Web

- ▼ [Introduction to HTML](#)
 - [Introduction to HTML overview](#)
 - [Getting started with HTML](#)
 - [What's in the head? Metadata in HTML](#)
 - [HTML text fundamentals](#)
 - [Creating hyperlinks](#)
 - [Advanced text formatting](#)
 - [Document and website structure](#)
 - [Debugging HTML](#)
 - [Assessment: Marking up a letter](#)
 - [Assessment: Structuring a page of content](#)
- ▶ [Multimedia and embedding](#)
- ▶ [HTML tables](#)

CSS — Styling the Web

- ▶ [CSS first steps](#)
- ▶ [CSS building blocks](#)
- ▶ [Styling text](#)
- ▶ [CSS layout](#)

Introduction to HTML

At its heart, HTML is a fairly simple language made up of **elements**, which can be applied to pieces of text to give them different meaning in a document (Is it a paragraph? Is it a bulleted list? Is it part of a table?), structure a document into logical sections (Does it have a header? Three columns of content? A navigation menu?), and embed content such as images and videos into a page. This module will introduce the first two of these and introduce fundamental concepts and syntax you need to know to understand HTML.

Looking to become a front-end web developer?

We have put together a course that includes all the essential information you need to work towards your goal.

[Get started](#)

Prerequisites

Before starting this module, you don't need any previous HTML knowledge, but you should have at least basic familiarity with using computers and using the web passively (i.e., just looking at it and consuming content). You should have a basic work environment set up (as detailed in [Installing basic software](#)), and understand how to create and manage files (as detailed in [Dealing with files](#)). Both are parts of our [Getting started with the web](#) complete beginner's module.

Note: If you are working on a computer/tablet/other devices that doesn't let you create your own files, you can try out (most of) the code examples in an online coding program such as [JSBin](#) or [Glitch](#).

Guides

This module contains the following articles, which will take you through all the basic theory of HTML and provide ample opportunity for you to test out some skills.

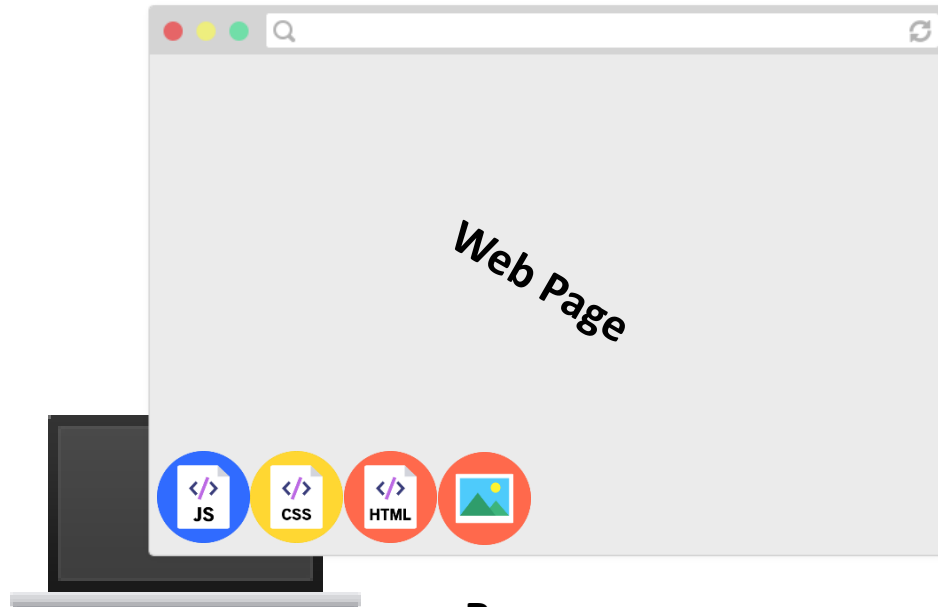
Getting started with HTML

Covers the absolute basics of HTML, to get you started — we define elements, attributes, and other important terms, and show where they fit in the language. We also show how a typical HTML page is structured and how an HTML element is structured, and explain other important basic language features. Along the way, we'll play with some HTML to get you interested!

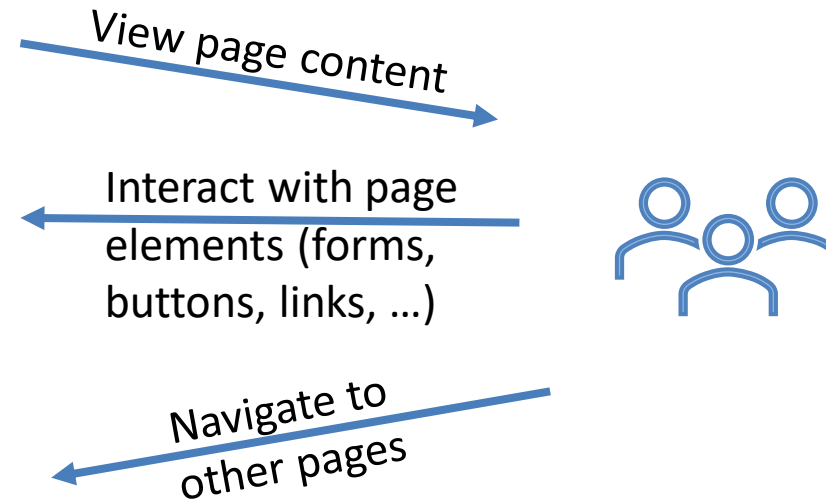
[What's in the head? Metadata in HTML](#)

[https://developer.mozilla.org/docs/Learn/HTML/Introduction to HTML](https://developer.mozilla.org/docs/Learn/HTML/Introduction_to_HTML)

Browser



Browser

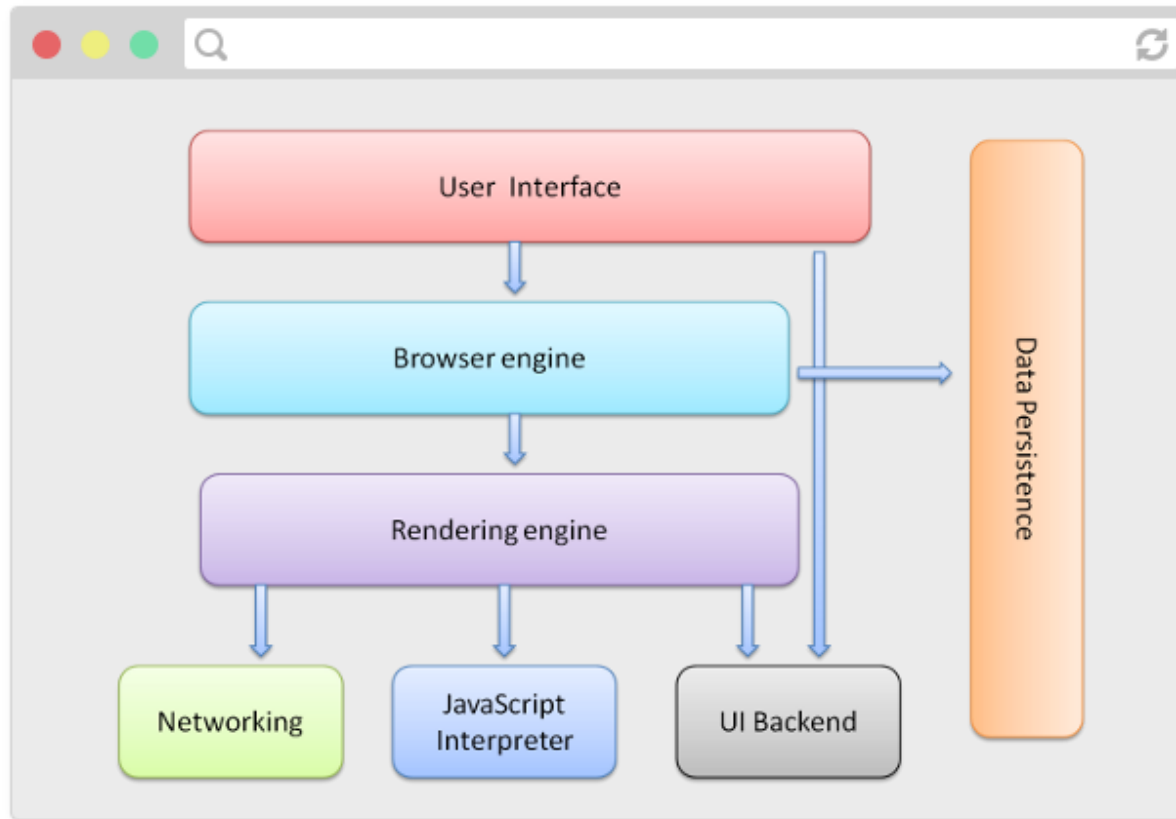


The content of the web page is described by HTML+CSS.

Clicking on a link brings the user to a **new page**.

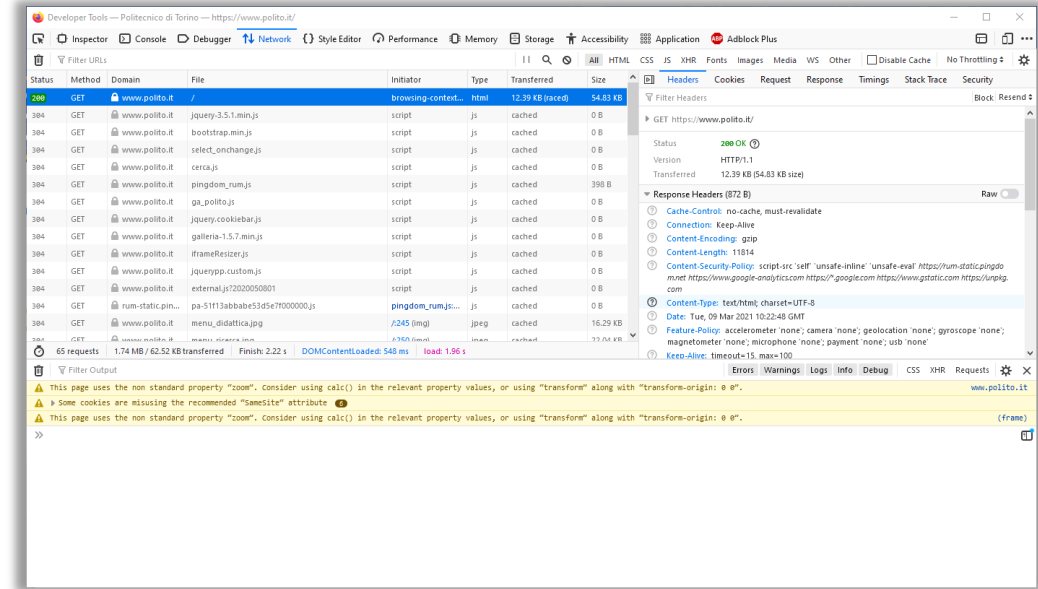
Interacting with other elements may generate **Events** inside the browser. Such Events are “captured” by JavaScript and may **update the page content**.

Conceptual Browser Architecture (from 10,000 feet)



- **User Interface:** the address bar, back/forward button, bookmarking menu, etc. Every part of the browser display except the window where you see the requested page
- The **Browser Engine** marshals actions between the UI and the rendering engine
- **Rendering Engine:** responsible for displaying the requested content. For example, if the requested content is HTML, the rendering engine parses HTML and CSS, and displays the parsed content on the screen
- **Networking:** for network calls such as HTTP requests, using different implementations for different platform behind a platform-independent interface
- **UI Backend:** used for drawing basic widgets like combo boxes and windows. This backend exposes a generic interface that is not platform specific. Underneath it uses operating system user interface methods
- **JavaScript Interpreter:** used to parse and execute JavaScript code
- **Data Persistence:** a persistence layer. The browser may need to save all sorts of data locally, such as cookies. Browsers also support storage mechanisms such as LocalStorage, IndexedDB, WebSQL and FileSystem

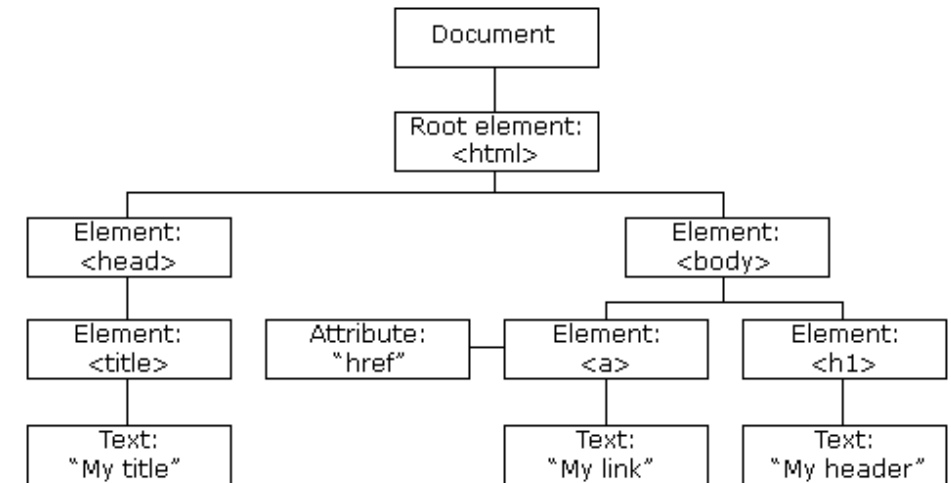
The screenshot shows a web browser displaying the Politecnico di Torino website. The main banner features the university's logo and the text "ScuDo Scuola di Dottorato - Doctoral School". The browser's developer tools are open, showing the HTML structure of the banner and the CSS styles for the 'body' element. The HTML shows a container with a fluid layout, and the CSS shows various Bootstrap classes and styles. The developer tools also show a console with warnings about non-standard properties and cookies.



Document Object Model (DOM)

"The W3C **Document Object Model** (DOM) is a *platform and language-neutral interface* that allows programs and scripts to dynamically *access and update* the content, structure, and style of a document."

- Standard **data structure** for representing the web page content
- Allows to get, change, add, or delete HTML elements
- Supported by all browsers
- **JavaScript programs can read and modify the DOM**
- Abstracts and standardizes APIs to
 - Browser
 - HTML





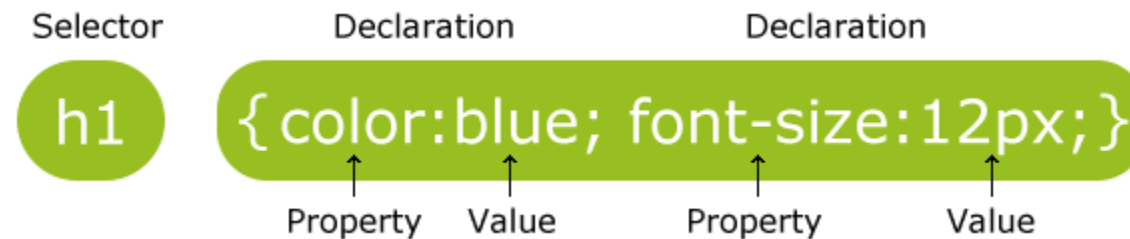
Cascading Style Sheets (CSS)

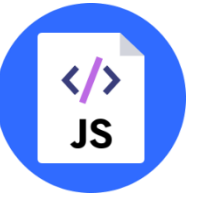
- Allow the definition of complex layouts
- Adapt web pages to
 - different resolutions
 - different devices (e.g., smartphones)
 - different preferences (e.g., color schemes)
 - to different media (e.g., text vs. video)
 - in a standard way



Cascading Style Sheets (CSS)

- A set of "*declarations*" applied to some "*selectors*"
 - Selectors identify portions of the DOM
 - Declarations set the value of some properties
 - Properties control everything
 - color, size, font, alignment, border, shadow, position, selection status, transitions, links, buttons, cursors, ...





JavaScript

- JS Interpreter Embedded in the Browser
 - Executes within a strict “**sandbox**”
- JS Scripts loaded by the HTML page
 - `<script src="/js/myscript.js" type="text/javascript"></script>`
- JS Scripts have read-write access to
 - Browser API
 - HTML DOM (including form data)
 - User events and actions



Users

Collect Data

Display Results



What the User Sees
& Interacts with
HTML, CSS, JavaScripts

Frontend

Request

Response



Contains App Logic
PHP, JavaScript, Python, Java

Web Server



File System

HTML, CSS, Images



Database

MySQL, PostgreSQL
MariaDB

Backend

HTTP Protocol

URI, HTTP methods, JSON data

Web Application Architecture

HTTP protocol

RFC 2616, RFC 2617
<http://www.w3.org/Protocols>

```
GET / HTTP/1.1
Host: www.polito.it
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:86.0) Gecko/20100101 Firefox/86.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate, br
DNT: 1
Connection: keep-alive
Cookie: __utma=55042356.701936439.1606736391.1615238467.1615289682.230; __utmz=55042356. [...]
Upgrade-Insecure-Requests: 1
Pragma: no-cache
Cache-Control: no-cache
```

(HTTP Request)

HTTP protocol

RFC 2616, RFC 2617
<http://www.w3.org/Protocols>

```
GET / HTTP/1.1
Host: www.polito.it
User-Agent: Mozilla/5.0 (Windows NT 6.0; rv:2.0) Gecko/20100101 Firefox/4.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
DNT: 1
Connection: keep-alive
Cookie: __utma=55042356.709152221.1327388800.1327388800.1327388800
Upgrade-Insecure-Requests: 1
Pragma: no-cache
Cache-Control: no-cache
```

```
HTTP/1.1 200 OK
Date: Tue, 09 Mar 2021 14:21:35 GMT
Server: Apache
Strict-Transport-Security: max-age=31536000
Content-Security-Policy: script-src 'self' 'unsafe-inline' 'unsafe-eval' [...]
X-Frame-Options: SAMEORIGIN
X-Content-Type-Options: nosniff
X-XSS-Protection: 1; mode=block
Referrer-Policy: no-referrer-when-downgrade
Feature-Policy: accelerometer 'none'; camera 'none'; geolocation 'none'; [...]
Last-Modified: Tue, 09 Mar 2021 14:03:41 GMT
Cache-Control: no-cache, must-revalidate
Vary: Accept-Encoding
Content-Encoding: gzip
Content-Length: 11905
Keep-Alive: timeout=15, max=100
Connection: Keep-Alive
Content-Type: text/html; charset=UTF-8
```

```
<!doctype html>
<html xmlns="http://www.w3.org/1999/xhtml" lang="it">
<head>
  <meta charset="UTF-8">
  <title>Politecnico di Torino</title>
  . . .
```

(HTTP Response)

Header

Blank line

Body

HTTP Response Body

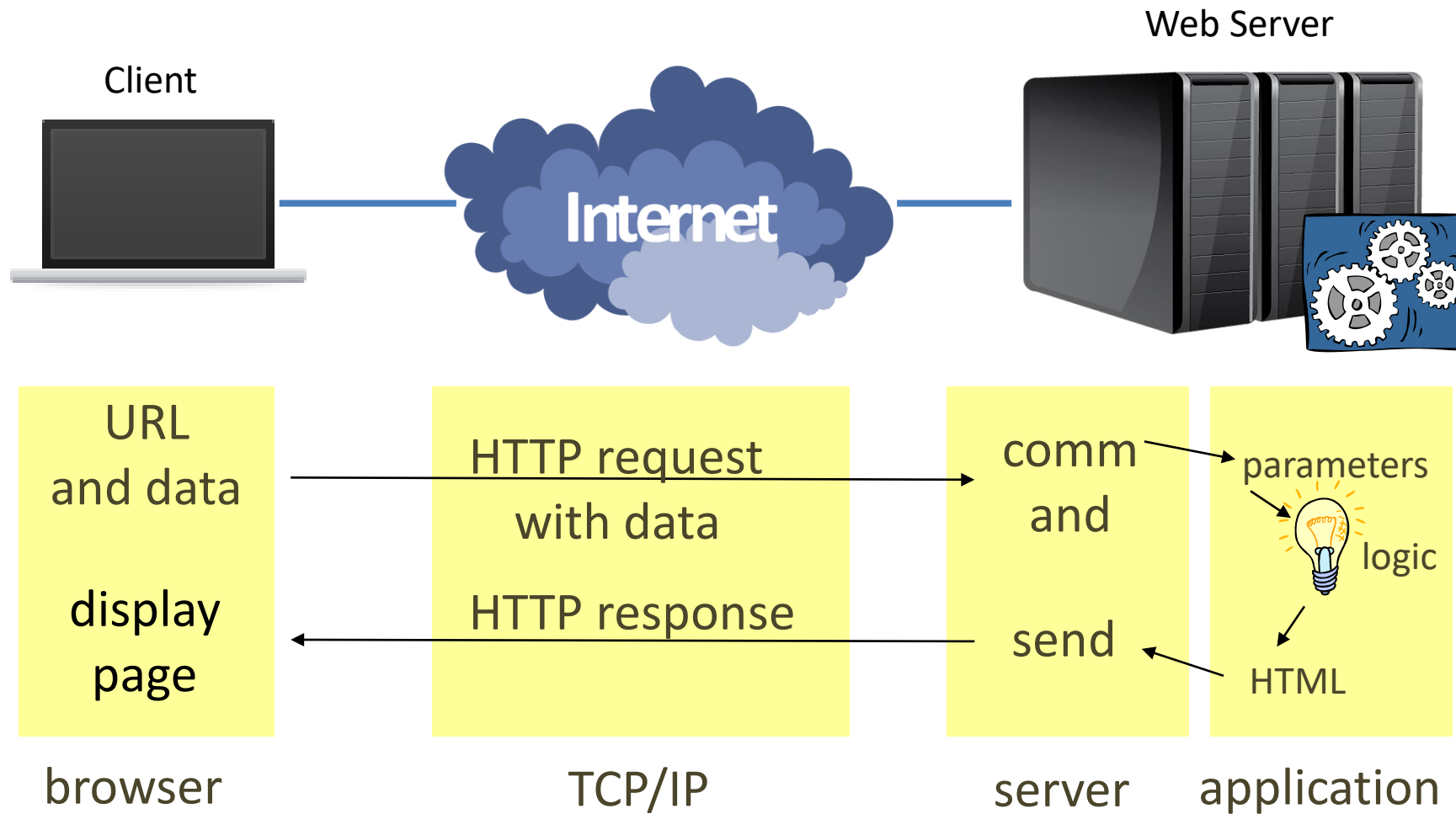
Generation

- **Empty** Response Body
 - Errors
- **Static** file (exists in the server)
 - HTML (seldom)
 - Images, JavaScript, CSS, ...
- **Dynamically** generated on-the-fly by the server
 - HTML (generated with templates)
 - JSON data

File and Content Type

- HTTP does not care about the meaning of the payload
- Web content
 - HTML, CSS, JS
 - Used by the **browser**
- Data content (API)
 - JSON, XML, binary data, ...
 - Used by **JavaScript** code

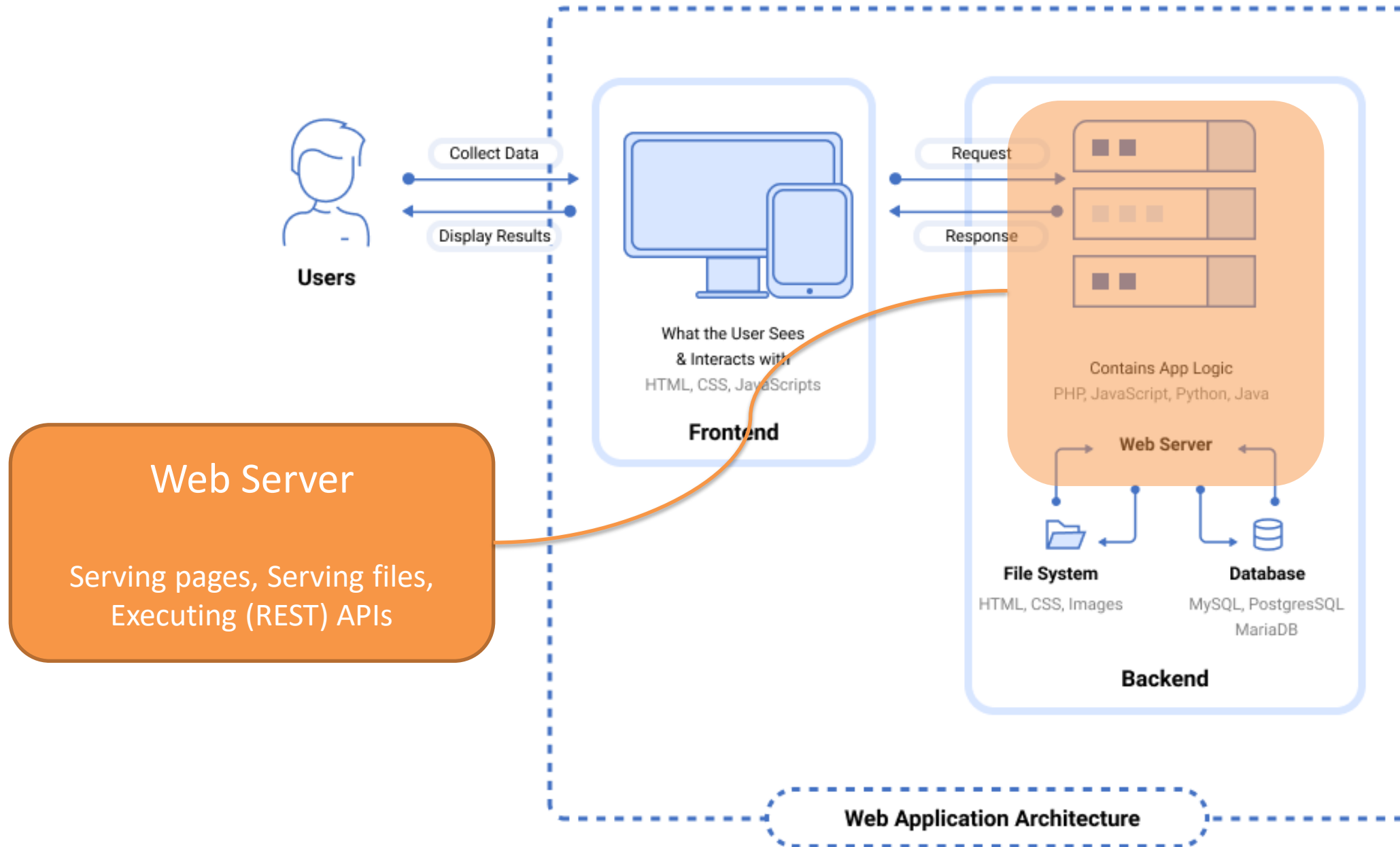
Dynamic Web Transaction



HTTP Methods

HTTP method ↕	RFC ↕	Request has Body ↕	Response has Body ↕	Safe ↕	Idempotent ↕	Cacheable ↕
GET	RFC 7231	Optional	Yes	Yes	Yes	Yes
HEAD	RFC 7231	Optional	No	Yes	Yes	Yes
POST	RFC 7231	Yes	Yes	No	No	Yes
PUT	RFC 7231	Yes	Yes	No	Yes	No
DELETE	RFC 7231	Optional	Yes	No	Yes	No
CONNECT	RFC 7231	Optional	Yes	No	No	No
OPTIONS	RFC 7231	Optional	Yes	Yes	Yes	No
TRACE	RFC 7231	No	Yes	Yes	Yes	No
PATCH	RFC 5789	Yes	Yes	No	No	No

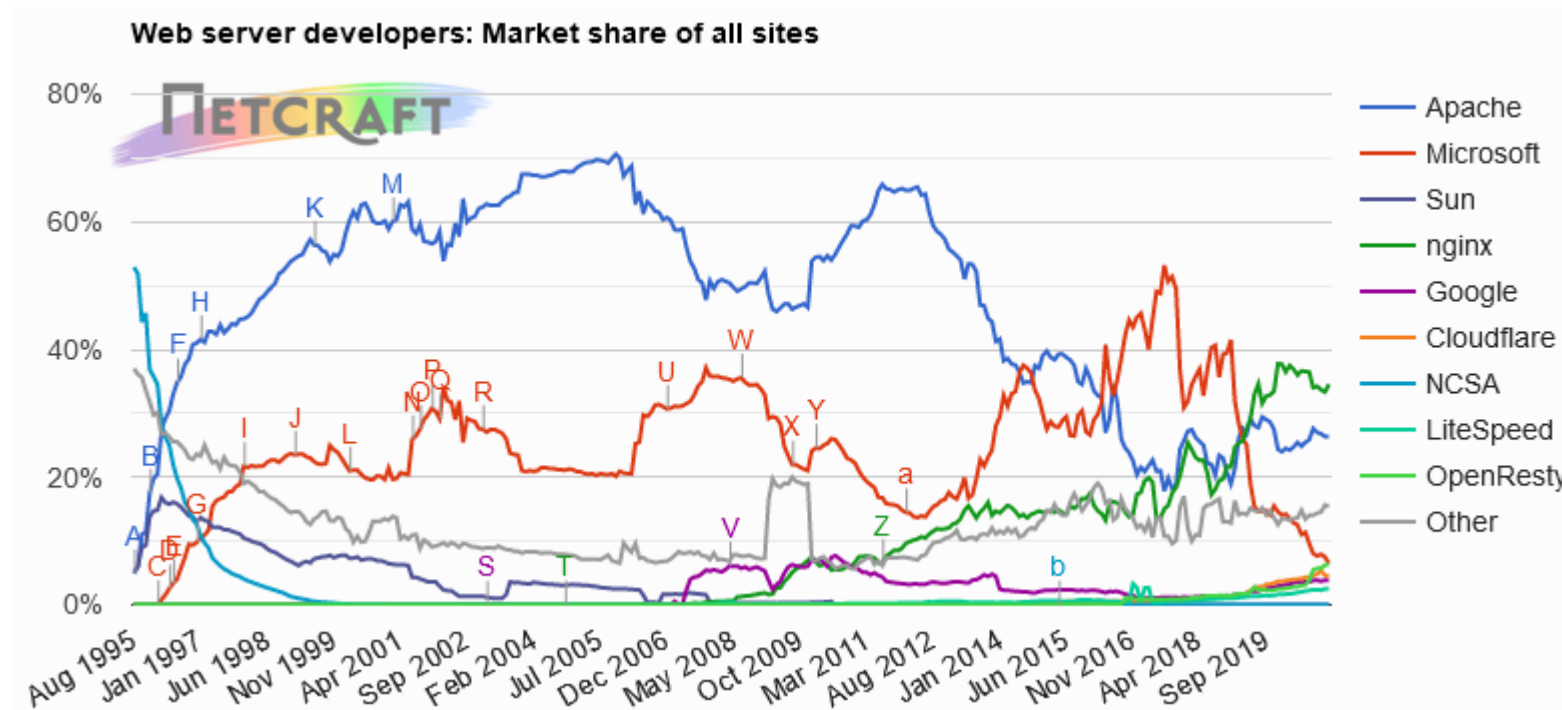
https://en.wikipedia.org/wiki/Hypertext_Transfer_Protocol#Request_methods



Web Server

- A web server delivers web resources in response to a request
 - manages the HTTP protocol to handle requests and provide responses
- It either **reads** or **generates** a web page
 - receives client requests
 - reads *static page* from the filesystem
 - asks the application server to generate *dynamic pages* (server-side)
 - provides a file (HTML, CSS, JS, JSON, ...) back to the client
- One HTTP connection for each request
- Multi-process, multi-threaded or process pool

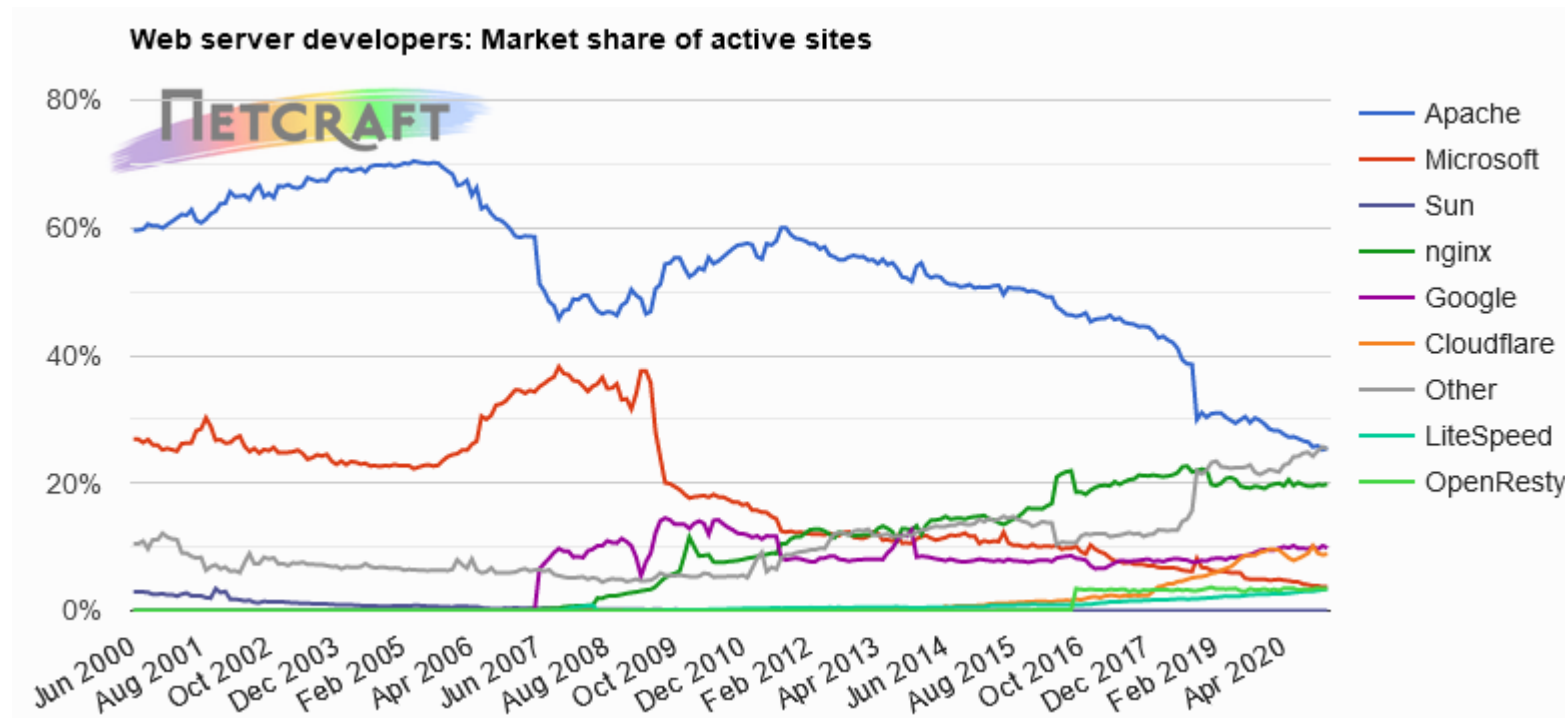
Web Server



Source: <http://news.netcraft.com/>

<https://news.netcraft.com/archives/2021/02/26/february-2021-web-server-survey.html>

Web Server

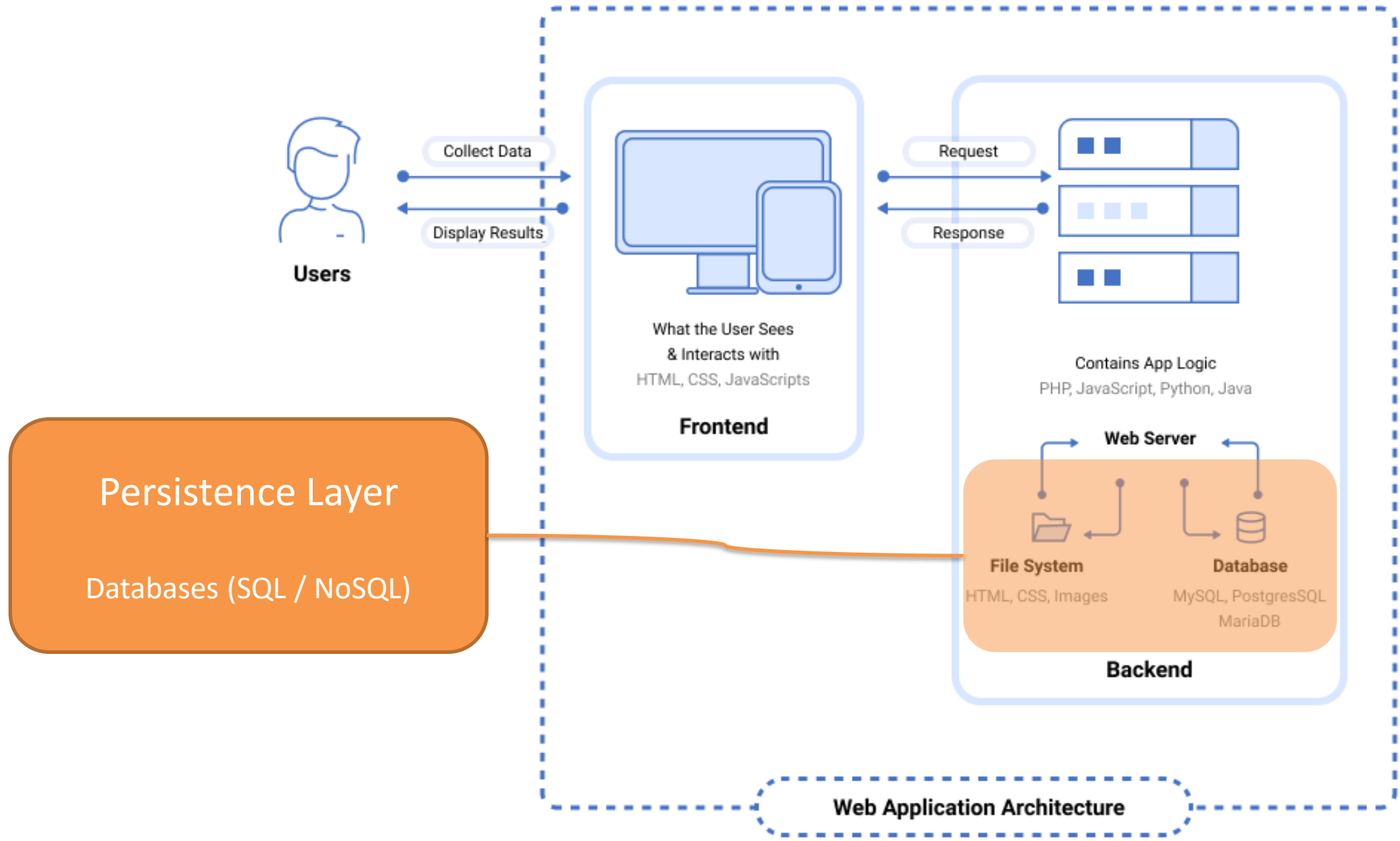


Source: <http://news.netcraft.com/>

<https://news.netcraft.com/archives/2021/02/26/february-2021-web-server-survey.html>

Web server with Node.js

- Node.js provides a module 'http' that implements a basic web server
- **Express**: a simple and extensible web server, easy to extend with many available extensions - <http://expressjs.com/>
- Other alternatives:
 - **Fastify**: focuses on performance
 - **Koa**: by Express authors, simplifies callbacks using 'ES6 generators' (yield instruction)
 - **Meteor**: full-stack, more complex and complete, also with a client-side component to synchronize state
 - **Sails.js**: based on MVC+ORM principles
 - ... many more



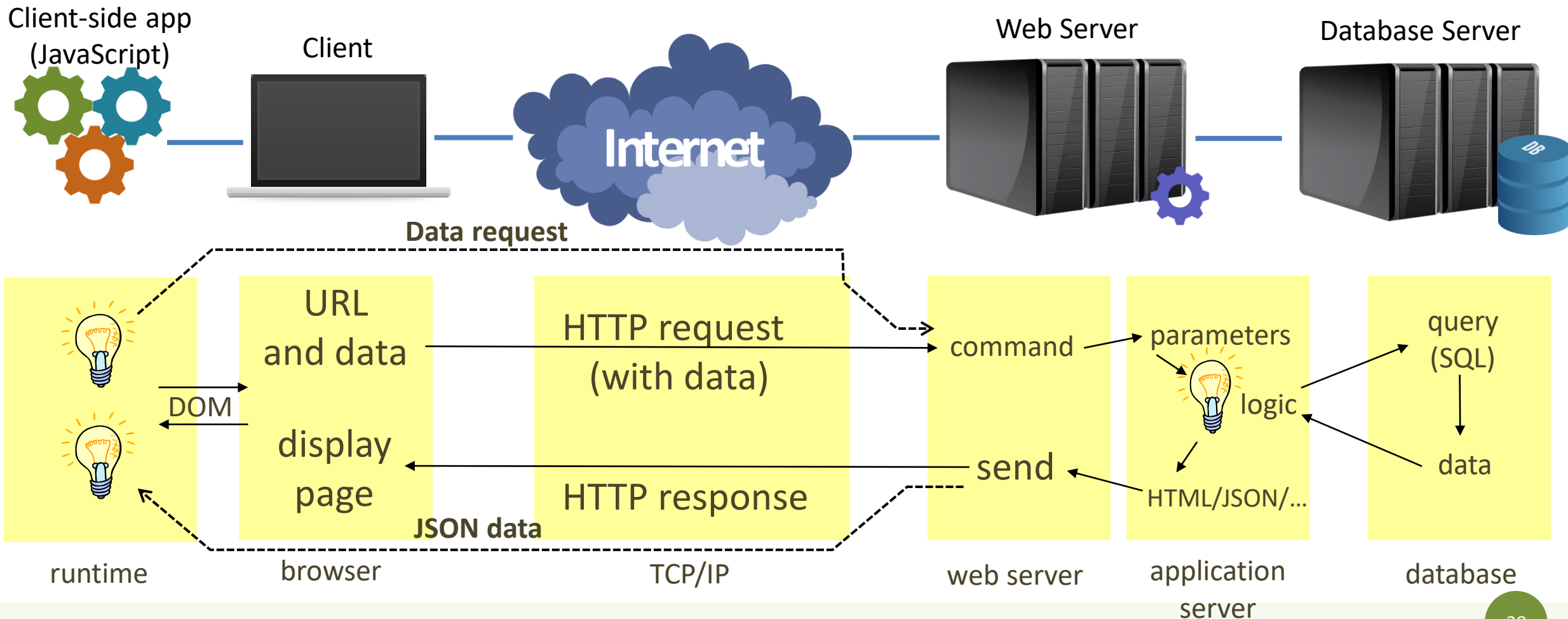
Web Architecture

ARCHITECTURAL PATTERNS

"Traditional" Architectural Pattern

- The "Rich-Client" is the "traditional" approach, now
- The server sends a new HTML page for each request it receives
 - with related resources (i.e., images, CSS, ...)
 - some parts of those pages can be, then, dynamically updated with asynchronous JavaScript requests
- A web application is doing **server-side rendering**, and a *multi-page* web application is created

All The Layers At Work...



Modern Patterns

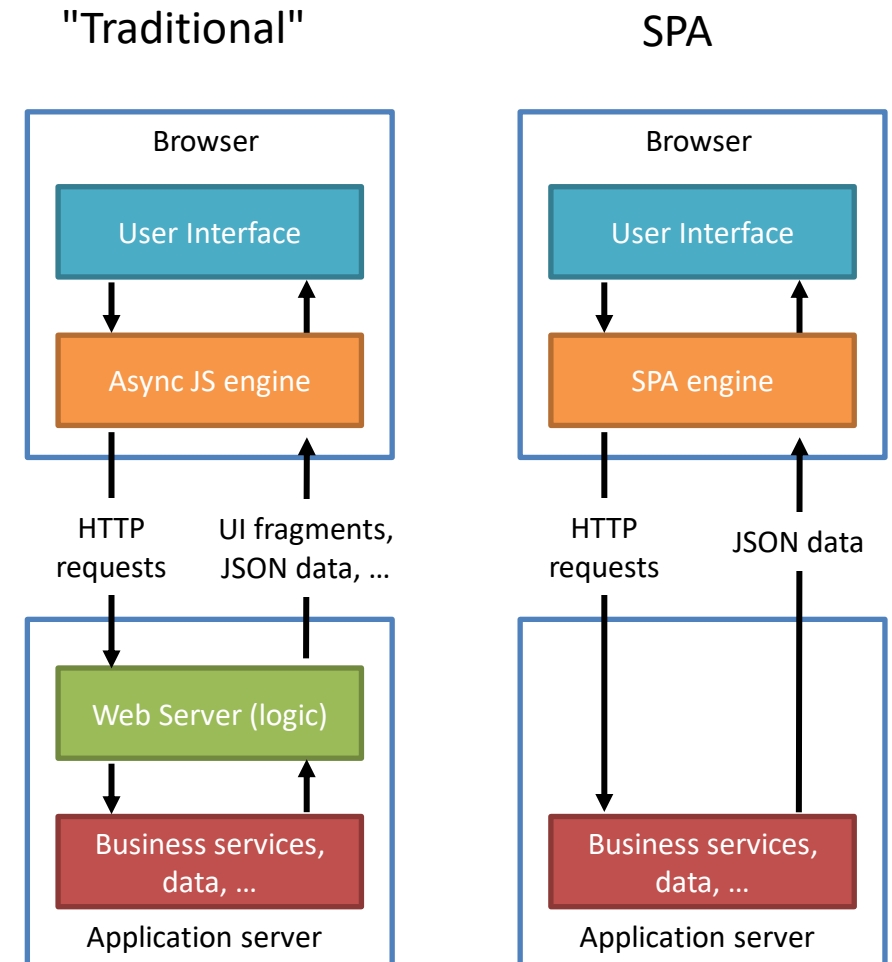
Other three patterns to architect a web application exist, roughly

1. **Single-Page Application (SPA)**

- the server sends the exact same web page for every unique URL
- the page runs JavaScript to change the content and the aspect
- by querying another (logical) server which provides "raw" information

Single-Page Application

- An *evolution* of the "traditional" approach
 - JavaScript starts with an (almost empty) HTML
 - add all the content dynamically
 - instead of asking for data to update some parts of a well-formed page
- Goal: to serve an outstanding User Experience with no page reloading and no extra time waiting
- Examples: Google Docs, Trello



SPA: Disadvantages

- Search Engine Optimization (SEO) is hard
 - Google launched a new scheme to increase single-page app SEO optimization, but this means extra work for the developer
- Browser history is not working
 - Web History API exists to tackle this problem and to allow a developer to emulate the back and forth action
- Security issues
 - Given that "all the logic is in the client", special care should be taken when handling access control. Cross-Site Scripting (XSS) is a problem as well.
- Client-side rendering can be slow!

Modern Patterns

Other three patterns to architect a web application exist, roughly

1. Single-Page Application (SPA)

- the server sends the exact same web page for every unique URL
- the page runs JavaScript to change the content and the aspect
- by querying another (logical) server which provides "raw" information

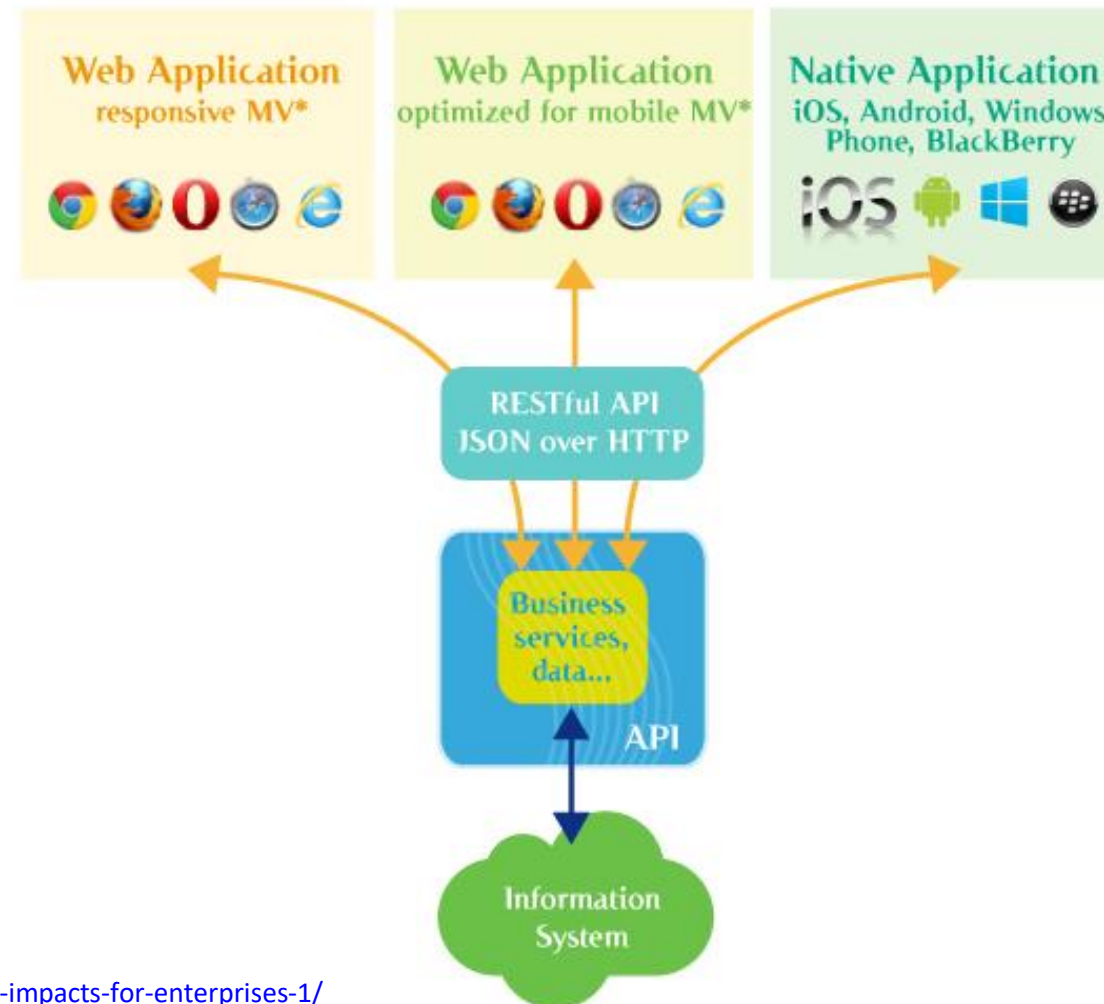
2. Isomorphic Application

- Combination of SPA with server-side rendering

3. Progressive Web App (PWA)

- Web applications that emulate "native" apps

Supporting mobile development



<http://blog.octo.com/en/new-web-application-architectures-and-impacts-for-enterprises-1/>

Client-side, server-side, databases

Websites ↕	Popularity (unique visitors per month) ^[1] ↕	Front-end (Client-side) ↕	Back-end (Server-side) ↕	Database ↕
Google ^[2]	1,600,000,000	JavaScript, TypeScript	C, C++, Go, ^[3] Java, Python, Node	Bigtable, ^[4] MariaDB ^[5]
Facebook	1,100,000,000	JavaScript, Flow	Hack, PHP (HHVM), Python, C++, Java, Erlang, D, ^[6] XHP, ^[7] Haskell ^[8]	MariaDB, MySQL, ^[9] HBase, Cassandra ^[10]
YouTube	1,100,000,000	JavaScript	C, C++, Python, Java, ^[11] Go ^[12]	Vitess, BigTable, MariaDB ^{[5][13]}
Yahoo	750,000,000	JavaScript	PHP	PostgreSQL, HBase, Cassandra, MongoDB, ^[14]
Amazon	500,000,000	JavaScript	Java, C++, Perl ^[15]	PostgreSQL, RDS, RDS Aurora ^[16]
Wikipedia	475,000,000	JavaScript	PHP	MariaDB ^[17]
Twitter	290,000,000	JavaScript	C++, Java, ^[18] Scala, ^[19] Ruby	MySQL ^[20]
Bing	285,000,000	JavaScript	C++, C#	Microsoft SQL Server, Cosmos DB
eBay	285,000,000	JavaScript	Java, ^[21] JavaScript, ^[22] Scala ^[23]	Oracle Database
MSN	280,000,000	JavaScript	C#	Microsoft SQL Server
LinkedIn	260,000,000	JavaScript	Java, JavaScript, ^[24] Scala	Voldemort ^[25]
Pinterest	250,000,000	JavaScript	Python (Django), ^[26] Erlang	MySQL, Redis ^[27]
WordPress.com	240,000,000	JavaScript	PHP	MariaDB ^[28]

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

References

- HTTP/1.x vs. HTTP/2 – The Difference Between the Two Protocols Explained - <https://cheapsslsecurity.com/p/http2-vs-http1/>
- How Browsers Work: Behind the scenes of modern web browsers - <https://www.html5rocks.com/en/tutorials/internals/howbrowserswork/>
- Inside look at modern web browser
 - Part 1: <https://developers.google.com/web/updates/2018/09/inside-browser-part1>
 - Part 2: <https://developers.google.com/web/updates/2018/09/inside-browser-part2>
 - Part 3: <https://developers.google.com/web/updates/2018/09/inside-browser-part3>
 - Part 4: <https://developers.google.com/web/updates/2018/09/inside-browser-part4>

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