09. How the Web Works

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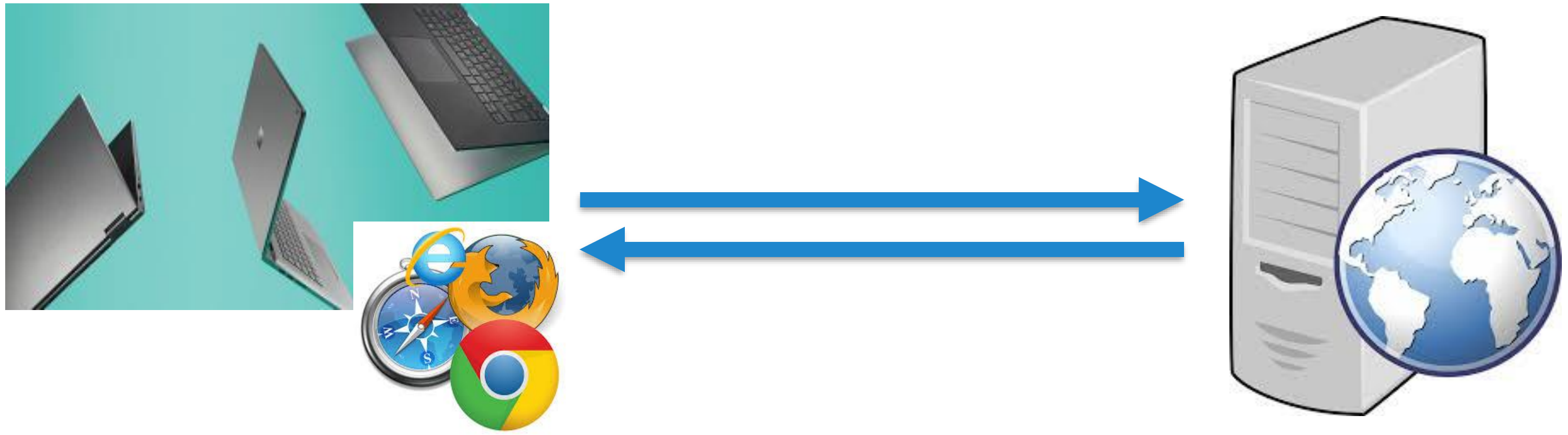
CMSC 23200

THE UNIVERSITY OF CHICAGO

Your interface to the web

- Your web browser contacts a web server



A 10,000 Foot View of Technologies

- Where things run:

HTTP(S)

HTML / CSS

JavaScript
(Angular/React)

Browser Extensions

Django (Python) / CGI (Perl) /
PHP / Node.js / Ruby on Rails

Databases (MySQL)

The Anatomy of a URL

- https://www.uchicago.edu/fun/funthings.htm?query=music&year=2024#topsection

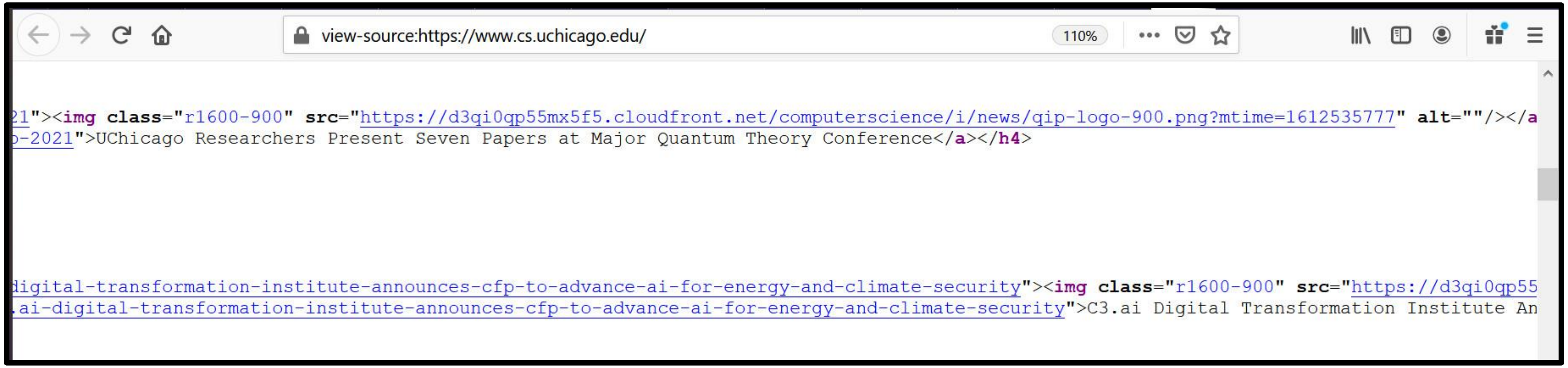
The Anatomy of a URL

- https://www.uchicago.edu/fun/funthings.htm?query=music&year=2024#topsection
  - Protocol: https
  - Hostname: www.uchicago.edu
    - .edu is the top level domain (TLD)
  - Path: /fun/funthings.html
  - Parameters: (key=value pairs, & delimited)
  - Named anchor: #topsection
- Some technologies (e.g., Django) parse the path differently (e.g., parameters in path)

The Anatomy of a Webpage

- view-source:https://www.cs.uchicago.edu/
- HTML (hypertext markup language)
  - Formatting of a page
  - All sorts of formatting: <div><p>Hi</p></div> <br />
  - Links: <a href=“blaseur.com”>Click here</a>
  - Pictures: <img src=“unicorn.jpg” />
  - Forms
  - Audio/video

The Anatomy of a Webpage



view-source:https://www.cs.uchicago.edu/

110%

```
21"><img class="r1600-900" src="https://d3qi0qp55mx5f5.cloudfront.net/computerscience/i/news/qip-logo-900.png?mtime=1612535777" alt=""/></a
-2021">UChicago Researchers Present Seven Papers at Major Quantum Theory Conference</a></h4>




digital-transformation-institute-announces-cfp-to-advance-ai-for-energy-and-climate-security"><img class="r1600-900" src="https://d3qi0qp55
.ai-digital-transformation-institute-announces-cfp-to-advance-ai-for-energy-and-climate-security">C3.ai Digital Transformation Institute An
```

The Anatomy of a Webpage

- CSS (cascading style sheets)

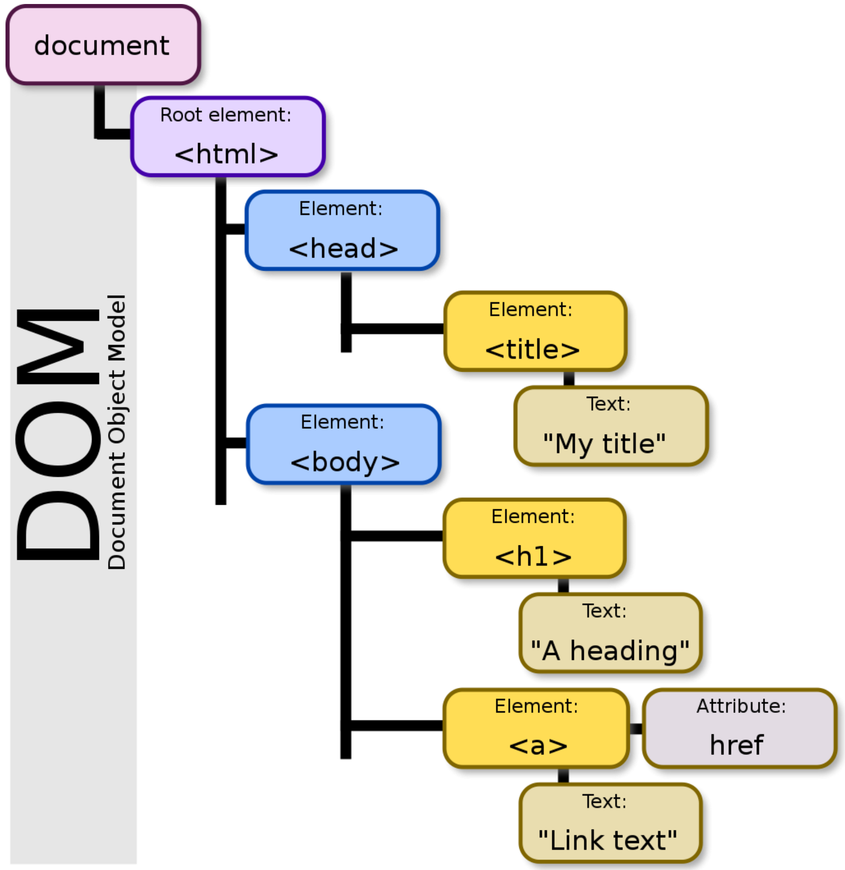
```
<link href="/css/main.css?updated=20181020002547" rel="stylesheet" media="all">
```

view-source:https://www.cs.uchicago.edu/css/main.css?updated=20181020002547

- #id (*intended* to be unique)
- .class (not intended to be unique)

The Anatomy of a Webpage

- DOM (document object model)



Typing Something into a Browser:

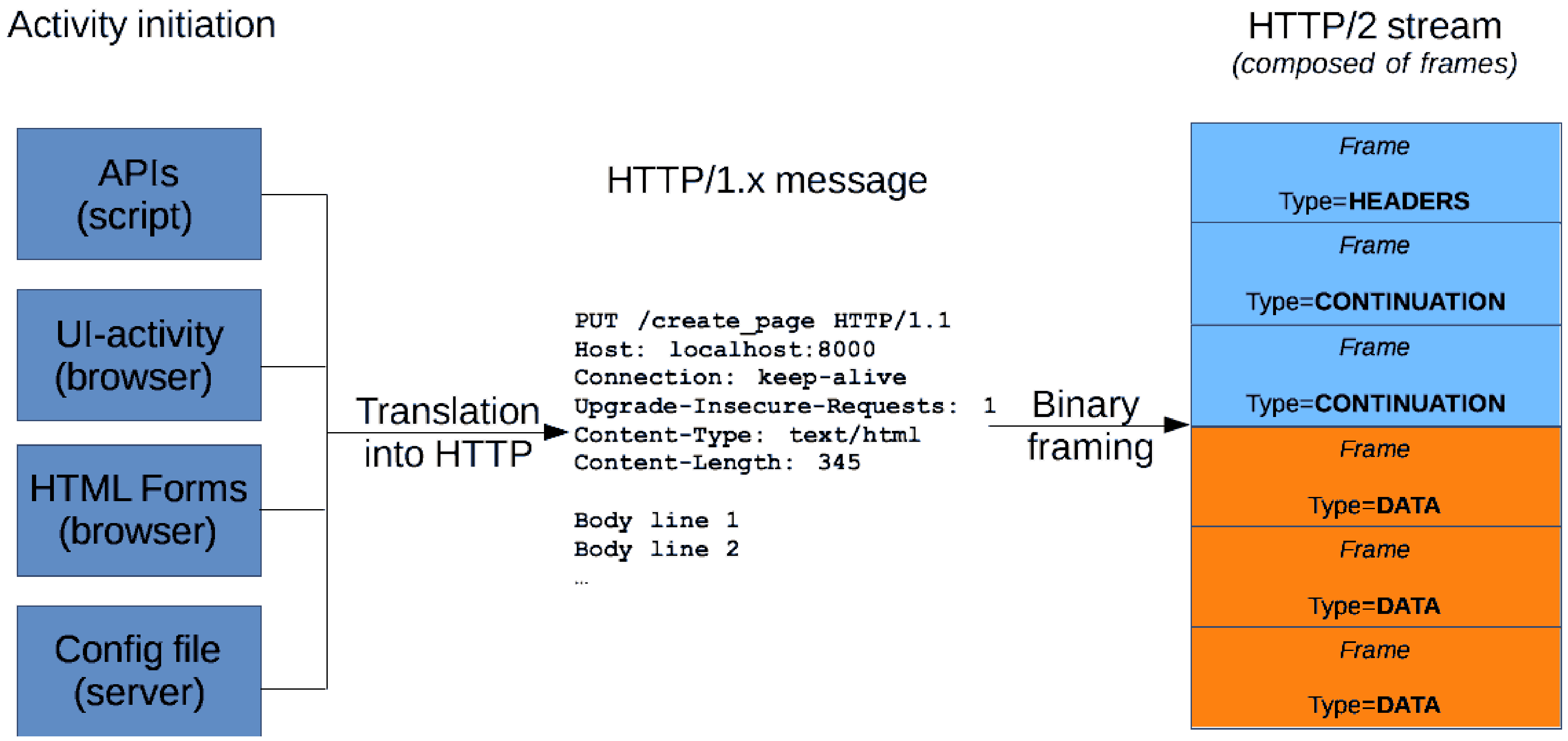
- DNS (domain name service)
  - www.cs.uchicago.edu resolves to IP address 128.135.164.125
- https://www.cs.uchicago.edu/
  - Protocol: https
  - Hostname: www.cs.uchicago.edu
  - Default file name (since none is listed): index.html (and similar)

HTTP Request

- HTTP = Hypertext Transfer Protocol
- Start line: method, target, protocol version
  - GET /index.html HTTP/1.1
  - Method: GET, PUT, POST, HEAD, OPTIONS
- HTTP Headers
  - Host, User-agent, Referer, many others
  - https://developer.mozilla.org/en-US/docs/Web/HTTP/Headers
- Body (not needed for GET, etc.)
- In Firefox: F12, “Network” to see HTTP requests

HTTP Request

- GET /index.html HTTP/1.1



```
PUT /create_page HTTP/1.1
Host: localhost:8000
Connection: keep-alive
Upgrade-Insecure-Requests: 1
Content-Type: text/html
Content-Length: 345

Body line 1
Body line 2
...
```

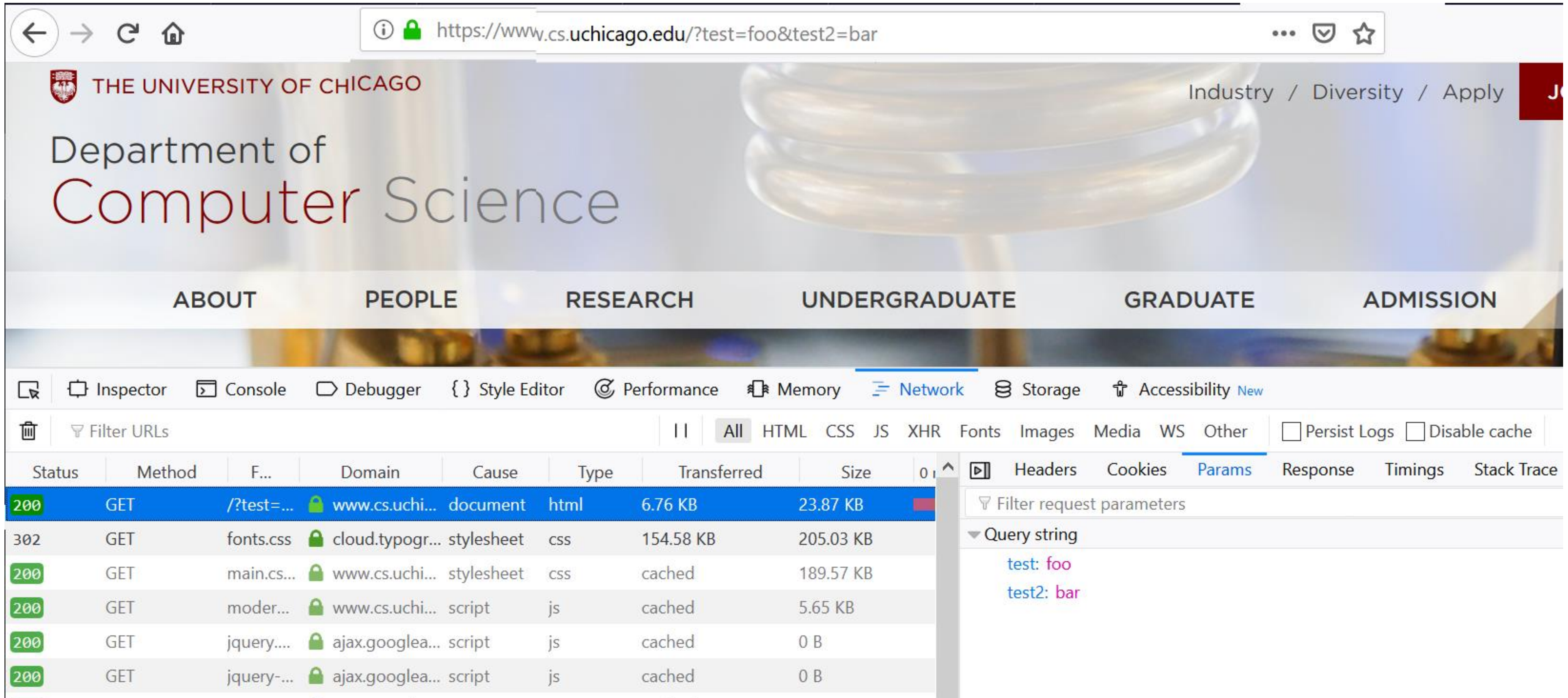
From https://developer.mozilla.org/en-US/docs/Web/HTTP/Messages

Sending Data to a Server

- GET request
  - Data at end of URL (following “?”)
- POST request
  - Typically used with forms
  - Data *not* in URL, but rather (in slightly encoded form) in the HTTP request body
- PUT request
  - Store an entity at a location

URL Parameters / Query String

- End of URL (GET request)
  - https://www.cs.uchicago.edu/?test=foo&test2=bar



https://www.cs.uchicago.edu/?test=foo&test2=bar

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ABOUT
PEOPLE
RESEARCH
UNDERGRADUATE
GRADUATE
ADMISSION
Inspector
Console
Debugger
Style Editor
Performance
Memory
Network
Storage
Accessibility New
Filter URLs
All HTML CSS JS XHR Fonts Images Media WS Other
Persist Logs
Disable cache
Headers Cookies Params Response Timings Stack Trace
Filter request parameters

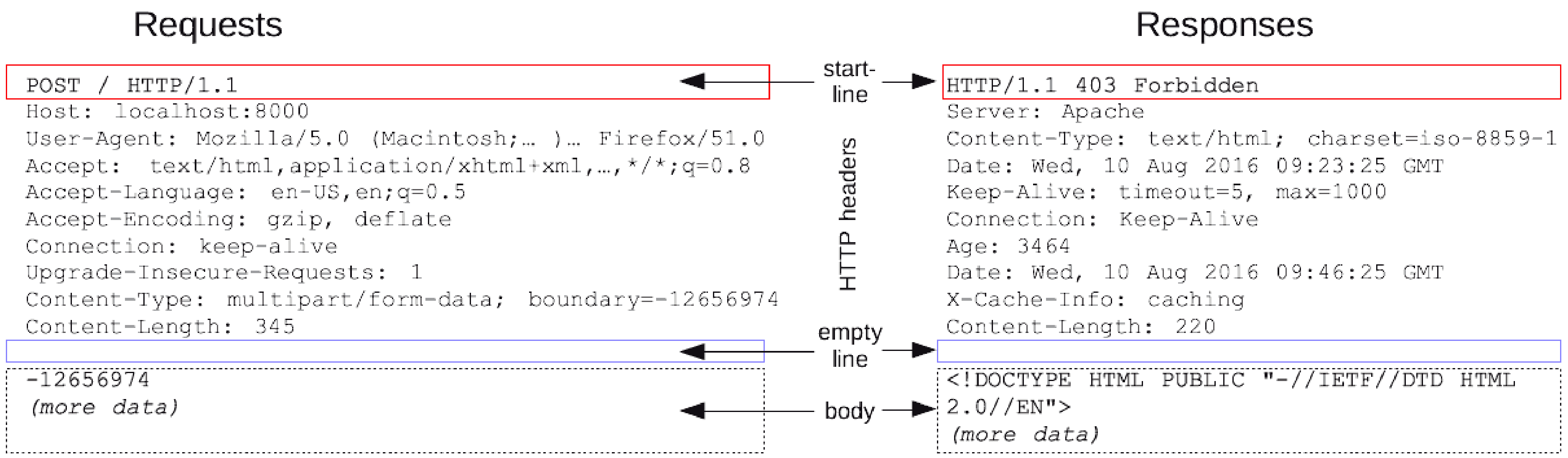
Status	Method	F...	Domain	Cause	Type	Transferred	Size
200	GET	/?test=...	www.cs.uchi...	document	html	6.76 KB	23.87 KB
302	GET	fonts.css	cloud.typogr...	stylesheet	css	154.58 KB	205.03 KB
200	GET	main.cs...	www.cs.uchi...	stylesheet	css	cached	189.57 KB
200	GET	moder...	www.cs.uchi...	script	js	cached	5.65 KB
200	GET	jquery....	ajax.googlea...	script	js	cached	0 B
200	GET	jquery-...	ajax.googlea...	script	js	cached	0 B

Query string
test: foo
test2: bar

HTTP Response

- Status: https://developer.mozilla.org/en-US/docs/Web/HTTP/Status
  - 200 (OK)
  - 404 (not found)
  - 301 (moved permanently)
  - 302 (moved temporarily)
- HTTP Headers
- Body

HTTP



```
POST / HTTP/1.1
Host: localhost:8000
User-Agent: Mozilla/5.0 (Macintosh;… )… Firefox/51.0
Accept: text/html,application/xhtml+xml,…,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Connection: keep-alive
Upgrade-Insecure-Requests: 1
Content-Type: multipart/form-data; boundary=-12656974
Content-Length: 345

-12656974
(more data)
```

```
HTTP/1.1 403 Forbidden
Server: Apache
Content-Type: text/html; charset=iso-8859-1
Date: Wed, 10 Aug 2016 09:23:25 GMT
Keep-Alive: timeout=5, max=1000
Connection: Keep-Alive
Age: 3464
Date: Wed, 10 Aug 2016 09:46:25 GMT
X-Cache-Info: caching
Content-Length: 220

<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML
2.0//EN">
(more data)
```

From https://developer.mozilla.org/en-US/docs/Web/HTTP/Messages

HTTPS

- Simply an HTTP request sent over TLS!
  - That is, the request and response are encrypted
- An extension of HTTP over TLS (i.e., the request/response itself is encrypted)
- Which CAs (certificate authorities) does your browser trust?
  - Firefox: Options → Privacy & Security → (all the way at the bottom) View Certificates

Keeping State Using Cookies

- Cookies enable persistent state
- Set-Cookie HTTP header
- Cookie HTTP header
  - *Cookie: name=value; name2=value2; name3=value3*
- Cookies are **automatically sent** with all requests your browser makes
- Cookies are *bound to an origin* (only sent to the origin that set them)

Keeping State Using Cookies

- Session cookies (until you close your browser) vs. persistent cookies (until the expiration date)
- *Secure* cookies = only sent over HTTPS, not HTTP
- *HTTPonly* cookies are not accessible to JavaScript, etc.
- View cookies: “Application” tab in Chrome developer tools, “Storage” in Firefox

Authorization Tokens = Cookies

- You log into a website, and it presents you an authorization token (typically a hash of some secret)
- Subsequent HTTP requests automatically embed this authorization token

Other Ways to Keep State

- Local storage
- Flash cookies
- (Many more)

JavaScript

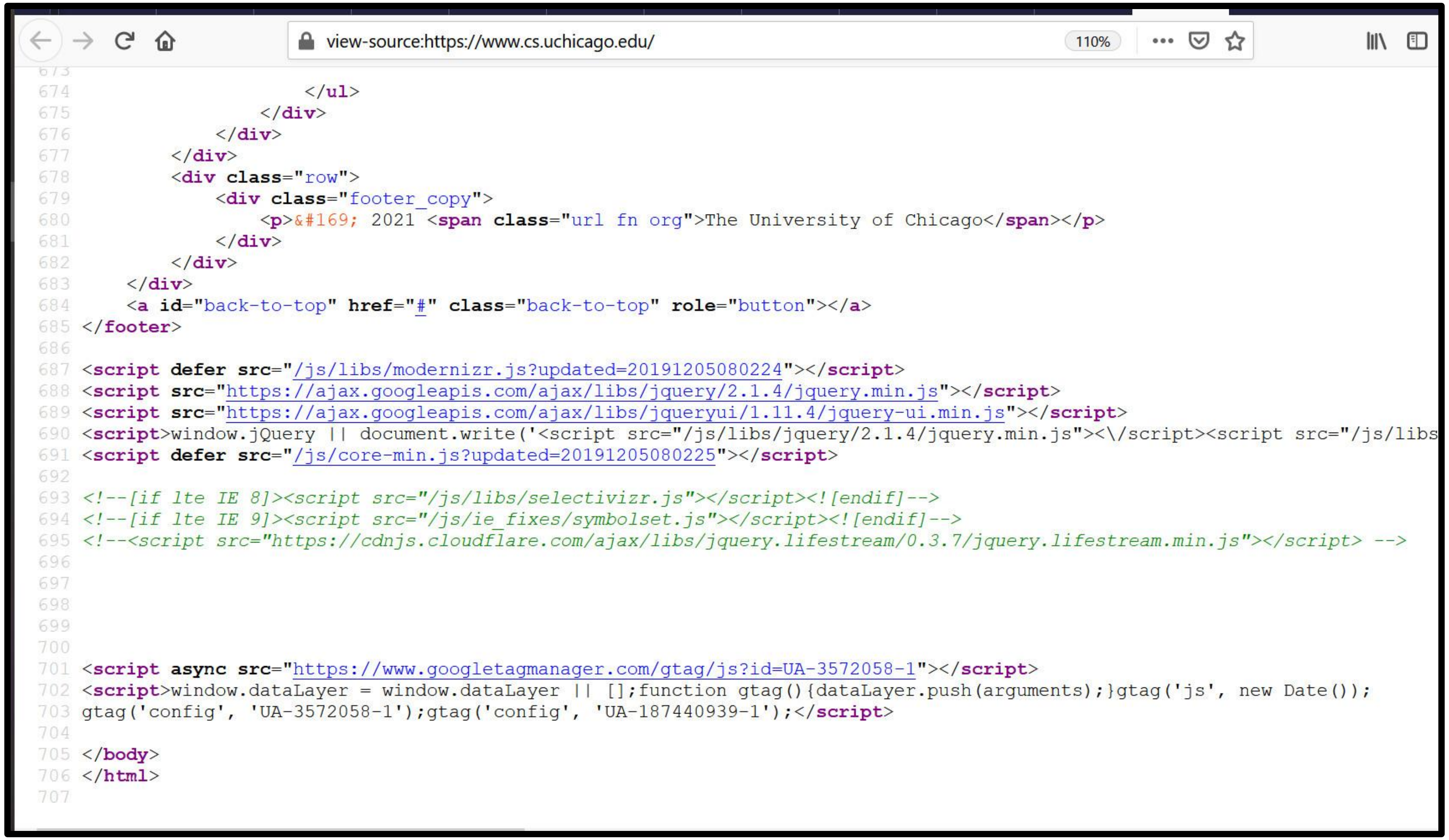
Interactive Pages?

- JavaScript!
  - The core idea: Let’s run code on the <u>**client’s**</u> computer
- Math, variables, control structures
- Imperative, object-oriented, or functional
- Modify the DOM
- Request data (e.g., through AJAX)
- Can be multi-threaded (web workers)

Common Javascript Libraries

- JQuery (easier to specify access to DOM)
  - `$(".test").hide()` hides all elements with class="test"
- JQueryUI
- Bootstrap
- Angular / React
- Google Analytics *(sigh)*

Importing Javascript Libraries



view-source:https://www.cs.uchicago.edu/

```
          </ul>
        </div>
      </div>
    </div>
    <div class="row">
      <div class="footer_copy">
        <p>&#169; 2021 <span class="url fn org">The University of Chicago</span></p>
      </div>
    </div>
  </div>
  <a id="back-to-top" href="#" class="back-to-top" role="button"></a>
</footer>

<script defer src="/js/libs/modernizr.js?updated=20191205080224"></script>
<script src="https://ajax.googleapis.com/ajax/libs/jquery/2.1.4/jquery.min.js"></script>
<script src="https://ajax.googleapis.com/ajax/libs/jqueryui/1.11.4/jquery-ui.min.js"></script>
<script>window.jQuery || document.write('<script src="/js/libs/jquery/2.1.4/jquery.min.js"><\/script><script src="/js/libs
<script defer src="/js/core-min.js?updated=20191205080225"></script>

<!--[if lte IE 8]><script src="/js/libs/selectivizr.js"></script><![endif]-->
<!--[if lte IE 9]><script src="/js/ie_fixes/symbolset.js"></script><![endif]-->
<!--<script src="https://cdnjs.cloudflare.com/ajax/libs/jquery.lifestream/0.3.7/jquery.lifestream.min.js"></script> -->





<script async src="https://www.googletagmanager.com/gtag/js?id=UA-3572058-1"></script>
<script>window.dataLayer = window.dataLayer || [];function gtag(){dataLayer.push(arguments);}gtag('js', new Date());
gtag('config', 'UA-3572058-1');gtag('config', 'UA-187440939-1');</script>

</body>
</html>
```

Do You Have the Right .js File?

- Subresource integrity (SRI): https://developer.mozilla.org/en-US/docs/Web/Security/Subresource_Integrity
- <script src="https://example.com/example-framework.js" integrity="sha384-oqVuAfXRKap7fdgcCY5uykM6+R9GqQ8K/uxy9rx7HNQlGYl1kPzQho1wx4JwY8wC"></script>
- cat FILENAME.js | openssl dgst -sha384 -binary | openssl base64 –A

Patching JavaScript Libraries

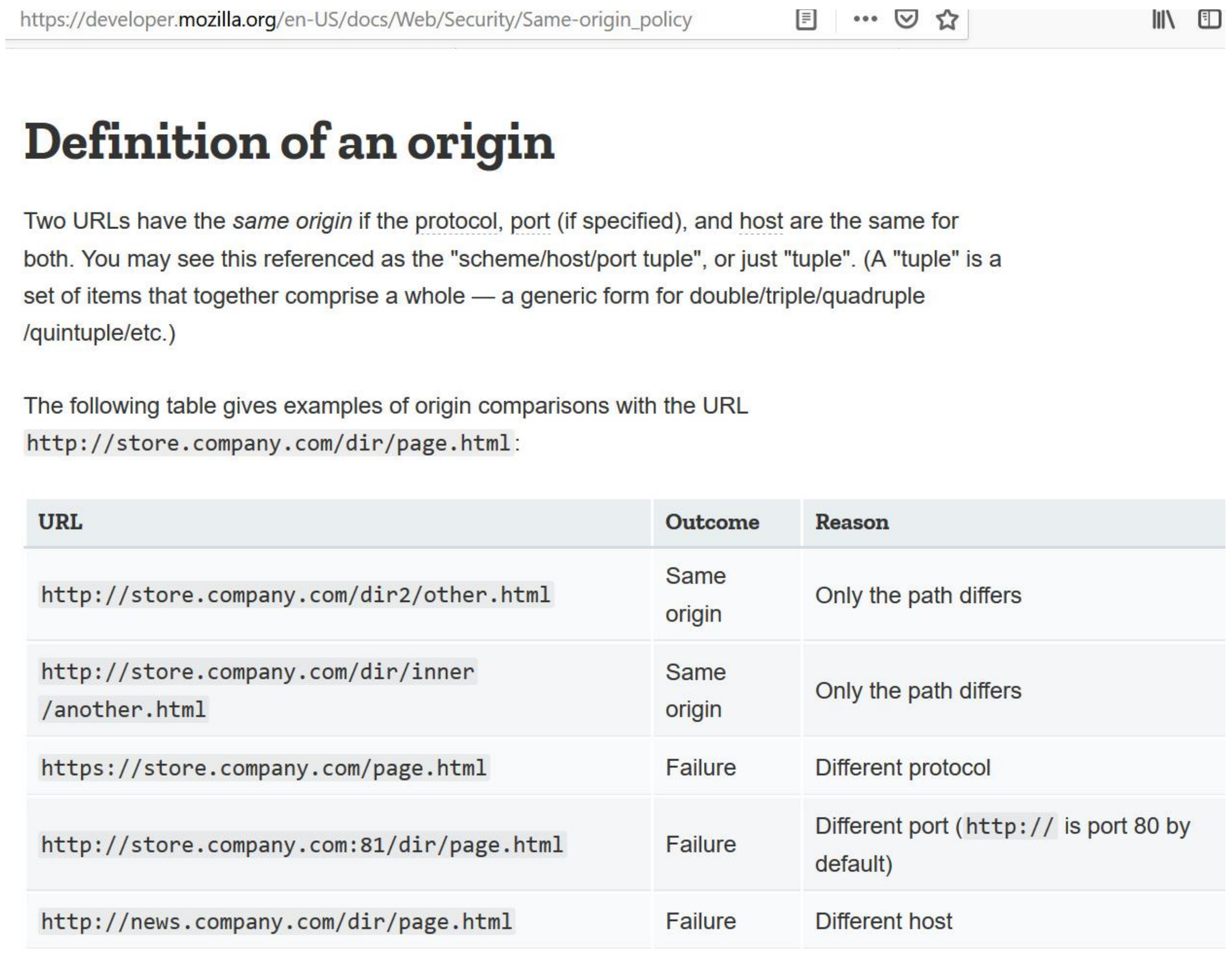
- Many outdated (and sometimes vulnerable) JavaScript libraries continue to be used
- Very complex chain of dependencies!
  - How do you determine if a given change is for good or evil?

Core Web Defense: Same-Origin Policy

Same-Origin Policy

- Prevent malicious DOM access
- Origin = URI scheme, host name, port
- Only if origin that loaded script matches can a script access the DOM
  - Not where the script ultimately comes from, but what origin *loads* the script

Same-Origin Policy (SOP)



https://developer.mozilla.org/en-US/docs/Web/Security/Same-origin_policy

Definition of an origin

Two URLs have the *same origin* if the protocol, port (if specified), and host are the same for both. You may see this referenced as the "scheme/host/port tuple", or just "tuple". (A "tuple" is a set of items that together comprise a whole — a generic form for double/triple/quadruple /quintuple/etc.)

The following table gives examples of origin comparisons with the URL `http://store.company.com/dir/page.html`:

URL	Outcome	Reason
`http://store.company.com/dir2/other.html`	Same origin	Only the path differs
`http://store.company.com/dir/inner/another.html`	Same origin	Only the path differs
`https://store.company.com/page.html`	Failure	Different protocol
`http://store.company.com:81/dir/page.html`	Failure	Different port (`http://` is port 80 by default)
`http://news.company.com/dir/page.html`	Failure	Different host

Iframes (Inline Frames)

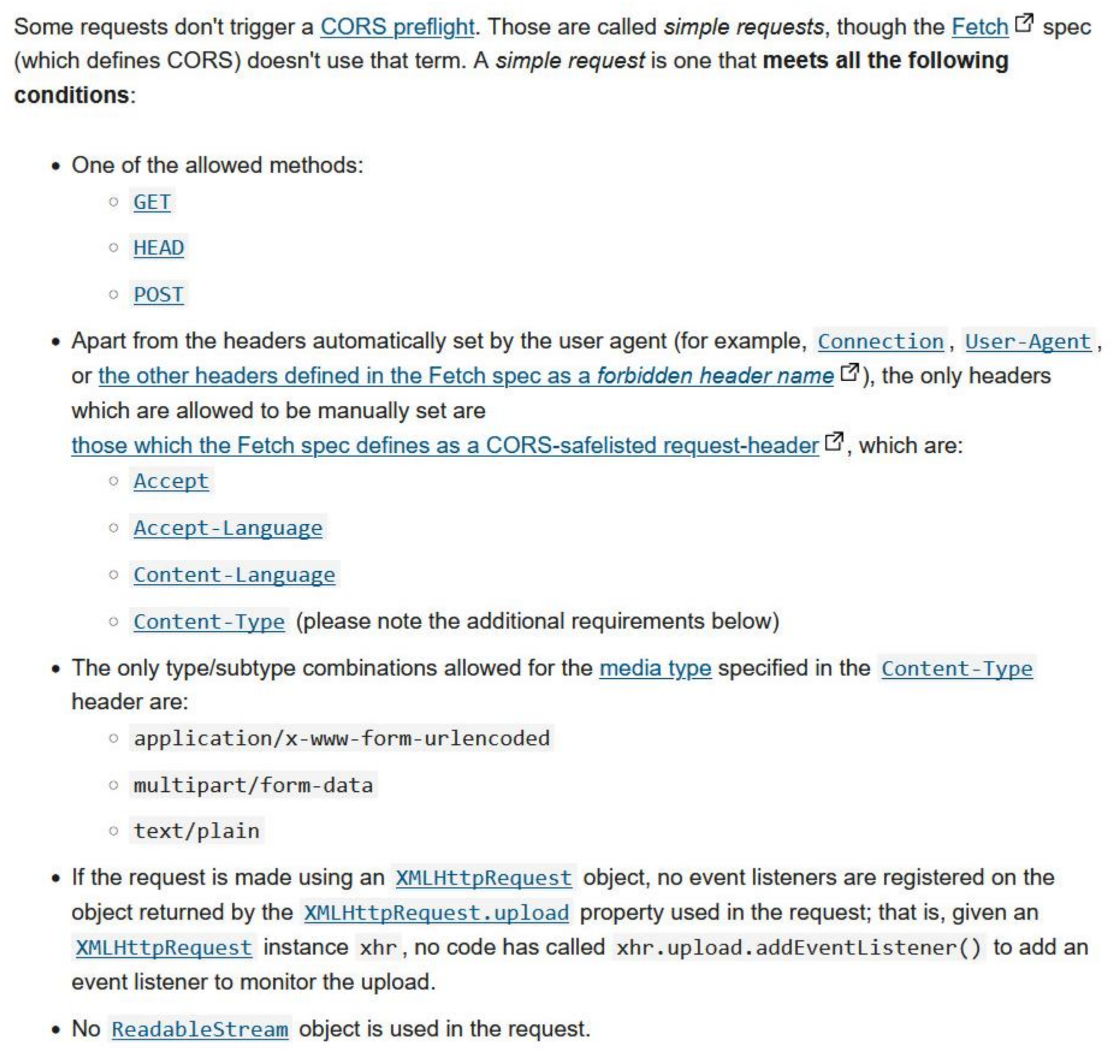
- Enable you to embed a webpage inside another webpage

Image from https://www.thoughtco.com/when-to-use-iframes-3468667

CORS (Relaxes SOP)

- Cross-Origin Resource Sharing
  - Specifies when specific other origins can make a request for data on a different origin
- https://developer.mozilla.org/en-US/docs/Web/HTTP/CORS
- `Access-Control-Allow-Origin: https://foo.example`
- `Access-Control-Allow-Methods: POST, GET, OPTIONS`
- `Access-Control-Allow-Headers: X-PINGOTHER, Content-Type`
- `Access-Control-Max-Age: 86400`

When CORS is Not Needed

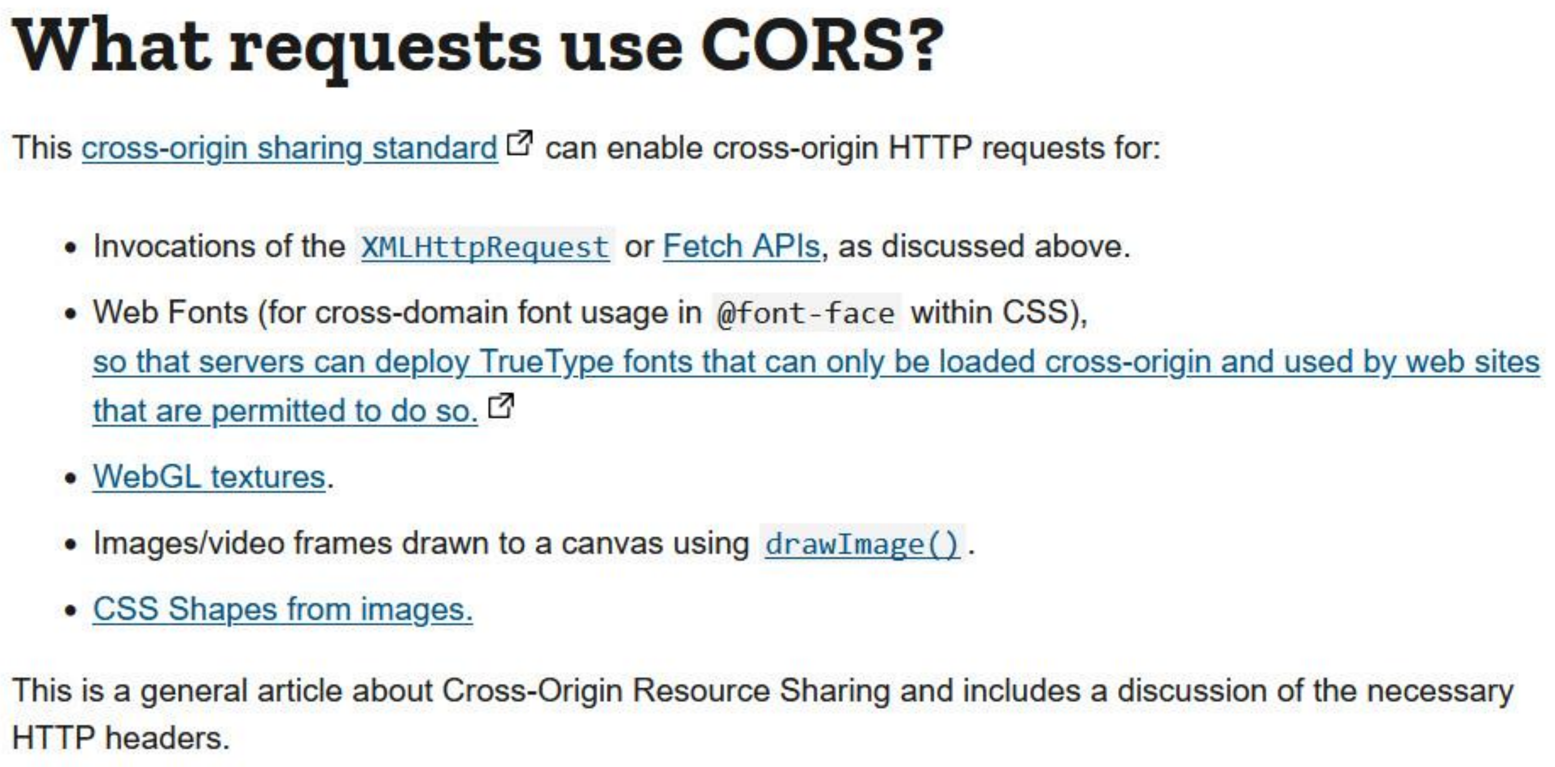


Some requests don't trigger a CORS preflight. Those are called *simple requests*, though the Fetch spec (which defines CORS) doesn't use that term. A *simple request* is one that **meets all the following conditions**:

- One of the allowed methods:
  - `GET`
  - `HEAD`
  - `POST`
- Apart from the headers automatically set by the user agent (for example, `Connection`, `User-Agent`, or the other headers defined in the Fetch spec as a *forbidden header name*), the only headers which are allowed to be manually set are those which the Fetch spec defines as a CORS-safelisted request-header, which are:
  - `Accept`
  - `Accept-Language`
  - `Content-Language`
  - `Content-Type` (please note the additional requirements below)
- The only type/subtype combinations allowed for the media type specified in the `Content-Type` header are:
  - `application/x-www-form-urlencoded`
  - `multipart/form-data`
  - `text/plain`
- If the request is made using an `XMLHttpRequest` object, no event listeners are registered on the object returned by the `XMLHttpRequest.upload` property used in the request; that is, given an `XMLHttpRequest` instance `xhr`, no code has called `xhr.upload.addEventListener()` to add an event listener to monitor the upload.
- No `ReadableStream` object is used in the request.

From https://developer.mozilla.org/en-US/docs/Web/HTTP/CORS

When CORS is Needed



What requests use CORS?

This cross-origin sharing standard can enable cross-origin HTTP requests for:

- Invocations of the `XMLHttpRequest` or Fetch APIs, as discussed above.
- Web Fonts (for cross-domain font usage in `@font-face` within CSS), so that servers can deploy TrueType fonts that can only be loaded cross-origin and used by web sites that are permitted to do so.
- WebGL textures.
- Images/video frames drawn to a canvas using `drawImage()`.
- CSS Shapes from images.

This is a general article about Cross-Origin Resource Sharing and includes a discussion of the necessary HTTP headers.

From https://developer.mozilla.org/en-US/docs/Web/HTTP/CORS

Revisiting SRI Relative to Crossing Origins

- <script src=https://example.com/example-framework.js integrity="sha384-oqVuAfXRKap7fdgcCY5uykM6+R9GqQ8K/uxy9rx7HNQlGYl1kPzQho1wx4JwY8wC“ crossorigin="anonymous"></script>
  - anonymous = No credentials (e.g., cookies)
  - use-credentials

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