Stony Brook University

CSE 361: Web Security

Basic Client-Side Technologies/Security

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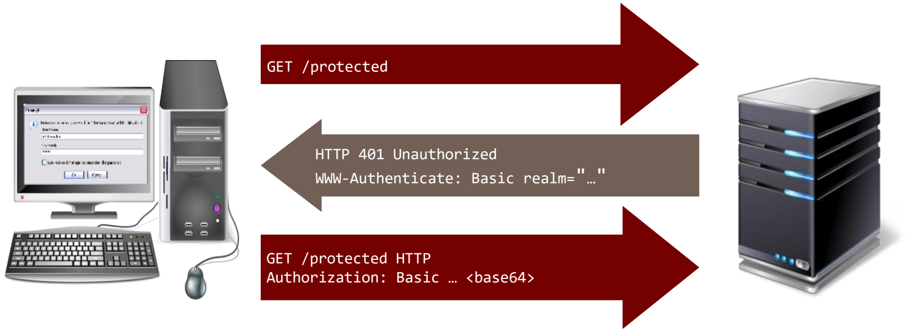
Adding State to HTTP

- Recall: no inherent state in HTTP
  - server does not keep any state after TCP connection is closed
- For static content sites, no problem
  - developing "applications" is impossible though
  - e.g., shopping cart on Amazon
- Need to introduce state in HTTP
  - in the form of "sessions"

Option 1: HTTP Authentication



```
GET /protected
```

```
HTTP 401 Unauthorized
WWW-Authenticate: Basic realm="…"
```

```
GET /protected HTTP
Authorization: Basic … <base64>
```

- Associate user with state on server
  - unclear when the "sessions" ends
- Authentication done by Web server
  - Not by the application served via the server
- Implements "pulling" of credentials
  - User: "Please give me resource X"
  - Server: "No, please tell me who you are"
  - User: "Ok, I am *alice* and my password is *nu7^yjUtasw* "
- Logout non-trivial
  - browser always sends along authentication header

Option 2: Session Identifier in URL

- Generate random token on first page visit
- Ensure that session ID is in all links

```
http://example.org/
cart.html?sess=9b2dac168331
```

- Potential for accidental leakage is high
  - "Here is the link to the product on Amazon"
- URL is transmitted in Referer header
  - Session leaked to all included third-party sites

Option 3: Cookies

- Generate random token on first page visit
- Sent to client via `Set-Cookie` header
- Client always sends along cookies in every request to the server
  - important: regardless of initiating site
- Cookies are persisted in the browser
  - controllable by Expires option in cookie
  - default: delete on session end (when browser is closed)
- Ending session: delete cookie

Cookie directives

- `<name>=<value>`
- `Expires=<Date>`, determines when cookie should be deleted
- `Max-Age=<Seconds>`, determines when cookie should be deleted
- `Domain=<domain>`, defaults to current host
  - Can be set for parent domains (and their subdomains)
  - If nothing is specifically set, cookie is only set for current domain without subdomains
  - `Domain=example.com` on `websec.example.com` sets cookie for `*.example.com and example.com`
- `Path=<path>`, only set cookie for this path (and sub-paths)

Cookie directives

- `HttpOnly`, disallows access from JavaScript via document.cookie
- `Secure`, only transmit cookie over secure connection
  - Can only be set from HTTPS connections
- `SameSite=None/Strict/Lax`
  - `Strict:` do not transmit cookies on **any** cross-site request
  - `Lax:` only transmit cookies on "safe" top-level navigation
    - Safe methods (per RFC 7231): GET, HEAD, OPTIONS, (TRACE)
  - `None:` explicit opt-in for cross-site requests, requires `Secure`
  - Browsers will default to `SameSite=Lax` soon (Chrome already does so, FF and Edge warn)

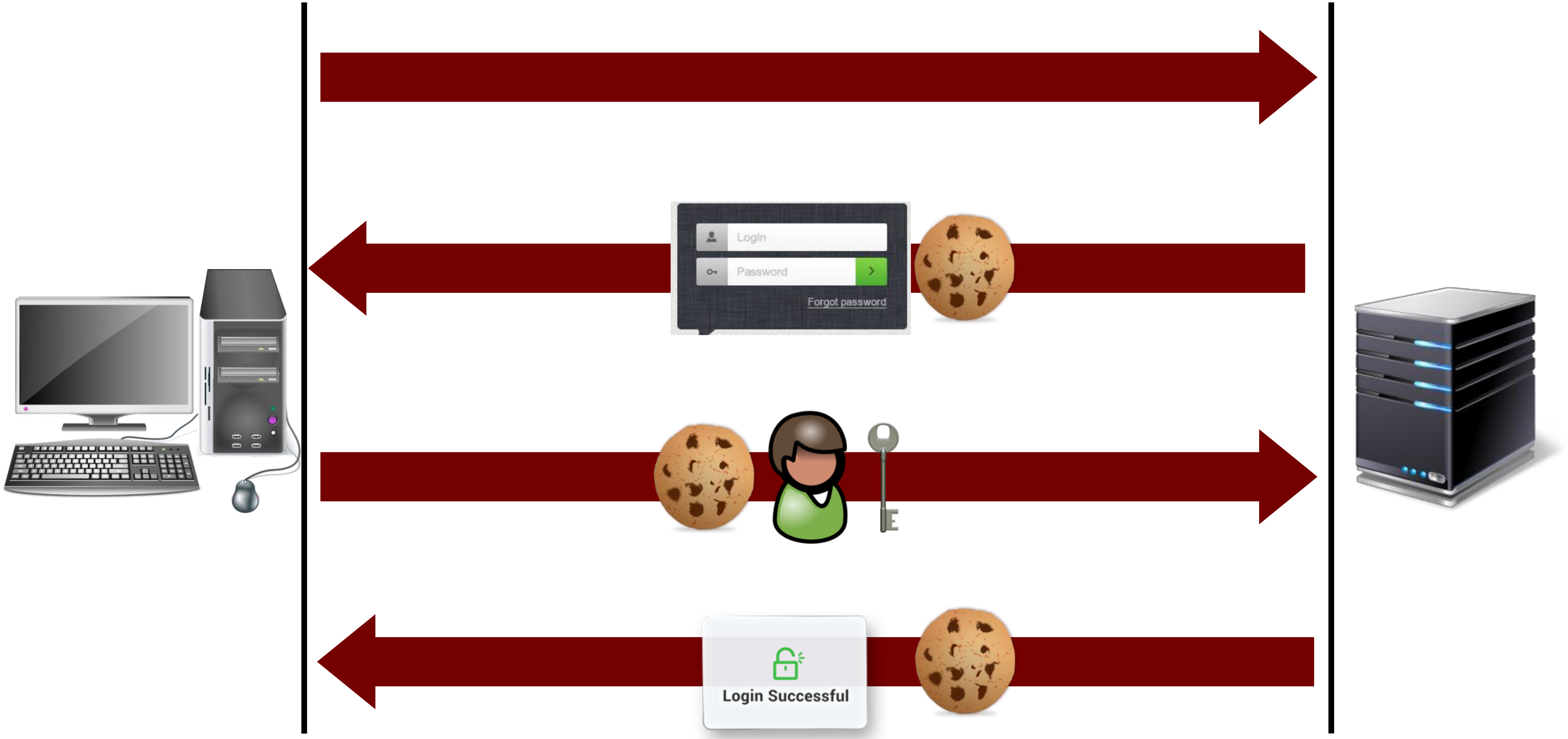
Cookie examples

- `Set-Cookie: test=1; Domain=.example.com; Secure; HttpOnly; SameSite=none`
  - Sets a cookie with name "test" to the value "1"
  - Cookie will be sent to any HTTPS request made to example.com and any subdomain
  - Cookie is not accessible from JavaScript
  - Cookie will be sent on cross-site requests as well
  - Cookie will be deleted on browser close (no explicit expiry date)
- `Set-Cookie: test=1; Domain=.example.com; HttpOnly; SameSite=none`
  - Recent versions of Chrome and Firefox will not accept this (SameSite=None requires Secure)

Form-based authentication

- Default today: HTML forms
  - Server provides form with username and password fields
  - User fills and submits form
  - Server decides if credentials were correct, and "upgrades" session
    - actually better: create new session (more on that later)
- Password fields hide input with ***
  - besides this, not different than any other input field
  - accessible via JavaScript
  - sent in clear text via GET or POST to server
  - can be sent cross-domain (a.com can send data to b.com)

Form-based authentication



Authentication with cookies - caveats

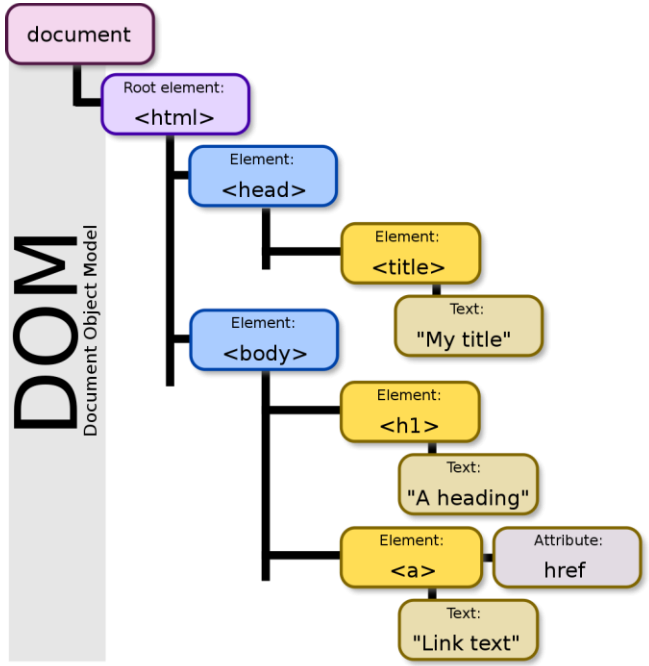
- Cookies were not designed with security in mind
  - cookies readable and writeable from JavaScript (unless HttpOnly is used)
  - if set for a given domain, valid for all sub-domains
  - added to all requests, regardless of the origin of requesting site
- Several security problems from this (which we cover later)
  - Session Hijacking
  - Session Fixation
  - Cross-Site Request Forgery
  - Cross-Site Script Inclusion

JavaScript

```
HILD :
  var simple = typ
      forward = type.slice(
      ofType = what === "of-type";

  return first === 1 && last === 0 ?

      // Shortcut for :nth-*(n)
      function( elem ) {
          return !!elem.parentNode;
      } :

      function( elem, context, xml ) {
          var cache, outerCache, node, diff, nodeIndex, start,
              dir = simple !== forward ? "nextSibling" : "
                  previousSibling",
              parent = elem.parentNode,
              name = ofType && elem.nodeName.toLowerCase(),
              useCache = !xml && !ofType;

          if ( parent ) {
                                        only)-(child|of-type)
```

What is JavaScript in the browser?

- JavaScript core
  - ECMAScript specified language
  - initially developed for Netscape in 1995 as LiveScript/JavaScript
- The Document Object Model (DOM)
  - provides access to the rendered HTML document
  - allows controlling the browsing window via JavaScript
- Browser-based standard APIs
  - Math, WebStorage, XMLHttpRequest, …



JavaScript Core

- Functional programming language
  - object model is prototype-based
  - no class hierarchy
  - allows for closures and anonymous functions
- No native concurrency model
  - JavaScript in an execution context (e.g., a Web document) is single-threaded
  - Concurrency is event-driven
    - Do something, yield process, wait for wake-up
    - e.g., implemented by setTimeout with (potentially anonymous) callback function
    - loading the same page twice might not execute instructions in the same order

JavaScript in Web documents

- JavaScript can be included in script tags or event handlers
  - `<script>var hello="world";</script>`
  - `<script src="http://hello.world"></script>`
  - `<a onclick='var hello="world";'>Click me</a>`
- Each script tag or event handler is separate parsing block
  - code not executed when parsing error occurs
  - other scripts’ execution is not interrupted
- Rendering of document stops until script is executed
  - especially important when HTML is written by JavaScript
- **All scripts run in same global space (of including page)**

JavaScript Objects

- JavaScript is highly flexible
  - Dynamic typing at its best
  - Lots of implicit type casting
    - `"a" + 1 => "a1"`
    - `"a" + undefined => "aundefined"`
    - `alert(42) => alert(42.toString())`
- Primitives types (strings, numerical, ..) and Object types
- New properties can be added to existing objects

```
var myObj = new myObject();
myObj.a = 1;
```

JavaScript Prototype-based Object Model

- All objects have a *prototype*
  - Prototype can have prototype as well
  - so-called prototype chaining
- Function call is propagated along chain until either
  - corresponding function is found
  - prototype is null (for Object)

```
var a = "a";
a.__proto__
// > String {length: 0, constructor: function,…}
a.__proto__.__proto__
// > Object {__defineGetter__: function, …}
a.__proto__.__proto__.__proto__
// > null
```

JavaScript Prototype-based Object Model

- Prototypes can be set and manipulated during runtime

```
Number.prototype.toString = function() {
  return "Gotcha";
};

// This will display "Gotcha" instead of 42
alert(new Number(42));
```

- Prototype changes also affect existing objects

```
var fortytwo = new Number(42);
// This will display "42"
alert(fortytwo);
Number.prototype.toString = function() {
  return "Gotcha again";
};

// This will display "Gotcha again"
alert(fortytwo);
```

JavaScript Objects

- Objects are instances of functions

```
function myObj(p1, p2) {
this.m1 = p1;
this.m2 = p2;
}
var x = new myObj(1,2);
// > myObj {m1: 1, m2: 2}
```

- Also true for built-in objects

```
Number
// > function Number() { [native code] }
Number.constructor
// > function Function() { [native code] }
```

- Almost everything has a `toString()`

```
myObj.toString()
"function myObj(p1, p2) {
this.m1 = p1;
this.m2 = p2;
}"
```

JavaScript Variable Scoping

- Variables without *var* keyword always in global scope
- Variables with *var* keyword as specified in current scope (function-level)
  - Gotcha: in top-level script code, that is the global scope
- Public members of object use `this` keyword, private members `var`

```
function Container(param) {
    var member = param;
}


var a = new Container(1);
a.member
// > undefined
```

```
function Container(param) {
    this.member = param;
}


var a = new Container(1);
a.member
// > 1
```

```
function Container(param) {
 var member = param;
 this.getmember = function() {
  return member; }
}

var a = new Container(1);
a.getmember()
// > 1
```

Getters, Setters, and Freezing

- ECMAScript introduced the Object.defineProperty method
  - get and set to allow read/write access to properties
  - configurable to prevent redefinition for the property

```
var obj = new Container(1);
var mValue = 42;

Object.defineProperty(obj, "member", {
   get: function() { return mValue; },
   set: function(newValue) { mValue = newValue; },
   configurable: false});

obj.member
// > 42
obj.member = 43
mValue
// > 43
Object.defineProperty(obj, "member", {get: function() { return 1; }});
// > Uncaught TypeError: Cannot redefine property: member
```

(Almost) everything in JavaScript can be overwritten/deleted

```
eval("var a='hello'")
a
// > "hello"

eval = alert;

eval("var a='hello');
// opens alert box
```

```
var oAlert = alert;
alert = function(x) {
    console.log(x);
    oAlert(x);
}
alert(1);
// log 1 to console
// opens alert box
```

```
var oAlert = alert;
delete alert;

alert(1);
// Uncaught ReferenceError: alert is not defined

oAlert(1)
// opens alert box
```

Document Object Model (DOM) and Browser APIs

- Exposed to JavaScript through global objects
  - `document`: Access to the document (e.g., cookies, head/body)
  - `navigator`: Information about the browser (e.g., UA, plugins)
  - `screen`: Information about the screen (e.g., dimension, color depth)
  - `location`: Access to the URL (read and modify)
  - `history`: Navigation
- Global object is called `window`, current object is `self`

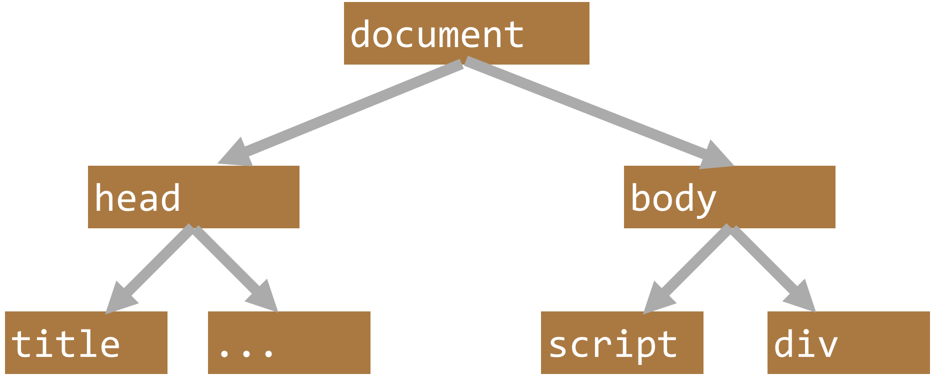
```
a = "Hello";
a === window.a;
> true
```

```
document.location === location;
> true
```

```
self === window;
> true
```

Manipulating the rendered document

- HTML represented by a tree of `HTMLElement` objects
- Element attributes of HTML nodes map to properties of HTMLElement object
    - `document.body.children[1].style.color = "red"`
- Several methods/properties to change document
    - `document.write`
    - `element.innerHTML/element.outerHTML`
    - `element.attribute`
    - `element.appendChild`



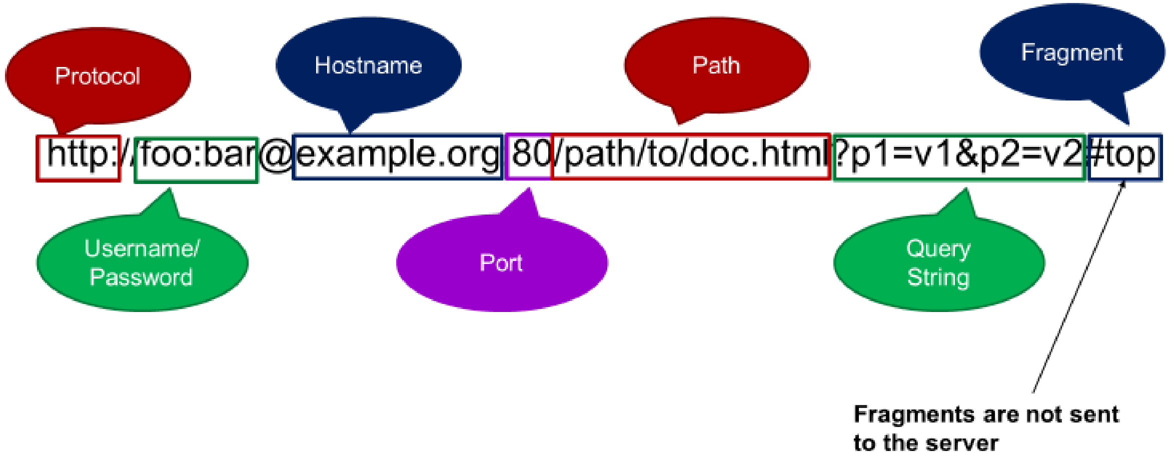
- Elements with id automatically in global scope

Access to other documents

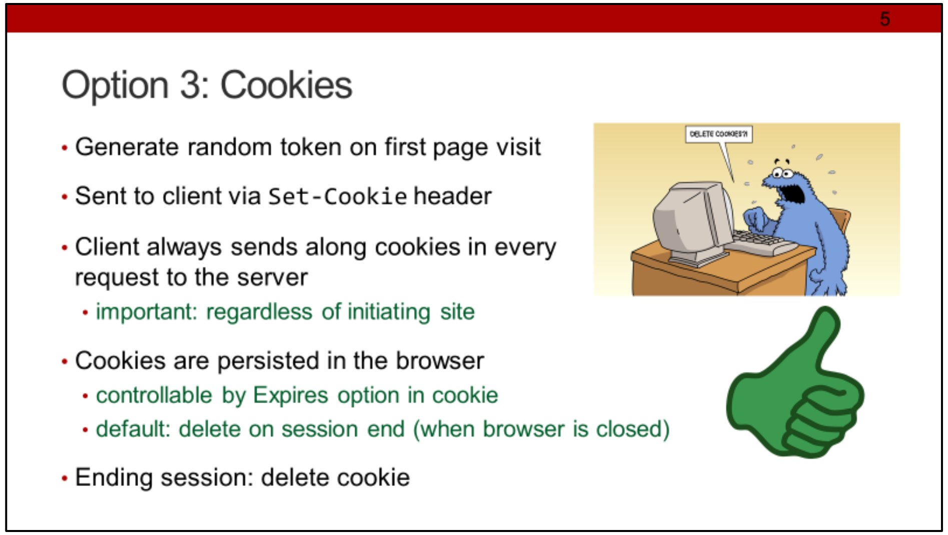
- Handles to other frames in same browsing window
  - `parent`
  - `top`
  - `frames[]`
- Handles to popup windows
  - `var handle = window.open("http://example.org")`
  - `window.opener`
- Initially no security considerations...

The location object

- `location.href`: complete URL including fragment
- `location.host`: HTTP host, including port (if any)
  `location.hostname`: only HTTP host
  `location.port`: only the port (if non-standard)
- `location.protocol`: protocol
- `location.pathname`: path
- `location.search`: URL query
- `location.hash`: URL fragment


Protocol
Hostname
Path
Fragment
http://foo:bar@example.org:80/path/to/doc.html?p1=v1&p2=v2#top
Username/ Password
Port
Query String
Fragments are not sent to the server

Summary



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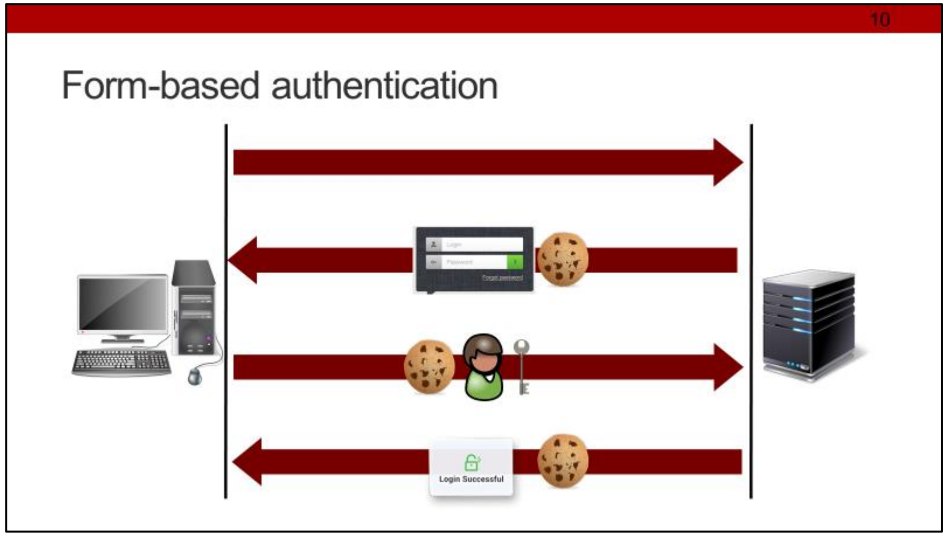

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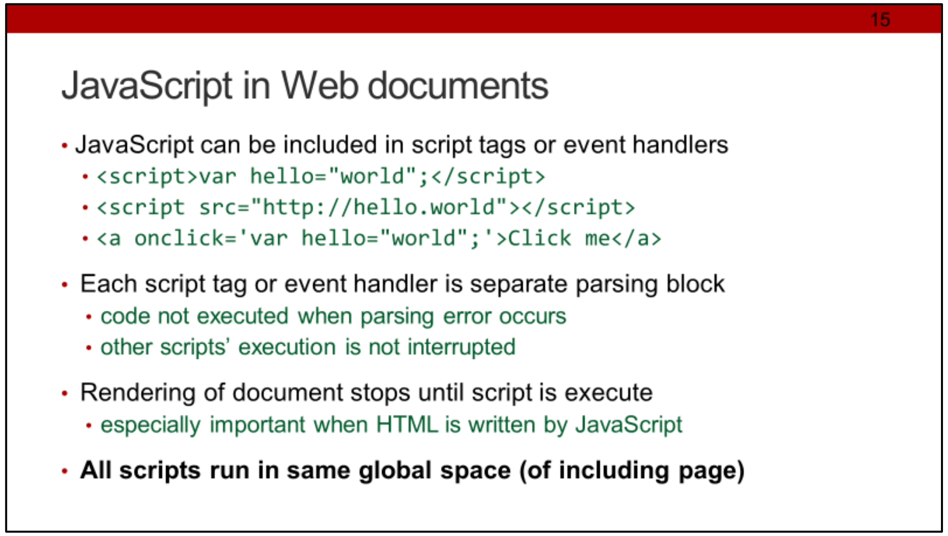

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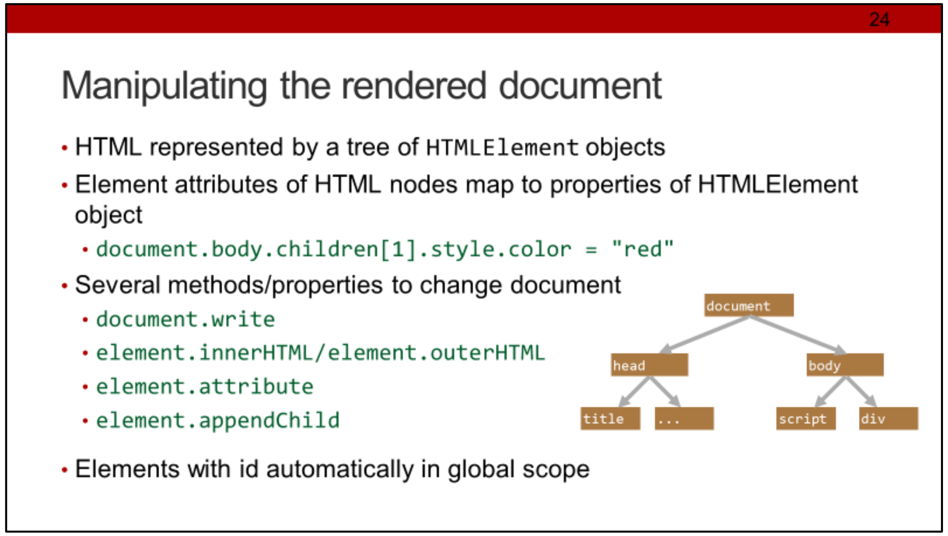

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Credits

- Original slide deck by Ben Stock
- Modified by Nick Nikiforakis