Cross-Site Scripting (XSS)

Web Application Security, shown in OWASP Juice Shop

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INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

What Is XSS? (1/4)

Cross-Site Scripting: an attacker's script runs in *another user's* browser.



What Is XSS? (2/4)

Cross-Site Scripting: an attacker's script runs in *another user's* browser.



What Is XSS? (3/4)

Cross-Site Scripting: an attacker's script runs in *another user's* browser.



What Is XSS? (4/4)

Cross-Site Scripting: an attacker's script runs in *another user's* browser.



The browser trusts the page's code. The attacker **slipped code into the page**, so it runs with the victim's **cookies and session**.

Why Attackers Need XSS (1/3)

The same origin policy stops `attacker.com` from reading `bank.com`.



blocked: different origin

Why Attackers Need XSS (2/3)

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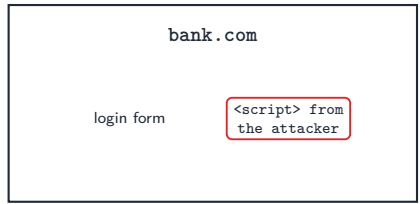

runs *as* bank.com

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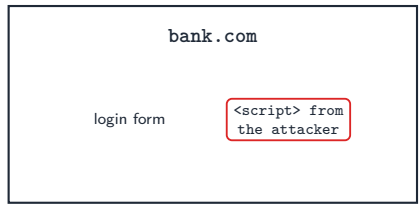

runs *as* bank.com

XSS = get JavaScript to run **inside the target's own page**, with its origin.

XSS Is a Code Injection Vulnerability (1/4)

Untrusted data unexpectedly becomes code. Sounds familiar?

	SQL injection (S3)
the command	an SQL query
the interpreter	the database
the unexpected code	extra SQL

XSS Is a Code Injection Vulnerability (2/4)

Untrusted data unexpectedly becomes code. Sounds familiar?

	SQL injection (S3)	**cross-site scripting**
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the interpreter	the database	the **browser**
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XSS Is a Code Injection Vulnerability (3/4)

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the unexpected code	extra SQL	**JavaScript**
runs with	the database account	the **user's session**

The attacker can do **anything the user can do** in that site: read cookies, send requests with them.

Session Hijacking with XSS (1/4)

What can the injected script do with the user's session?





Stanford CS253, L06 Cross Site Scripting; RFC 6265: HTTP State Management Mechanism

Session Hijacking with XSS (2/4)

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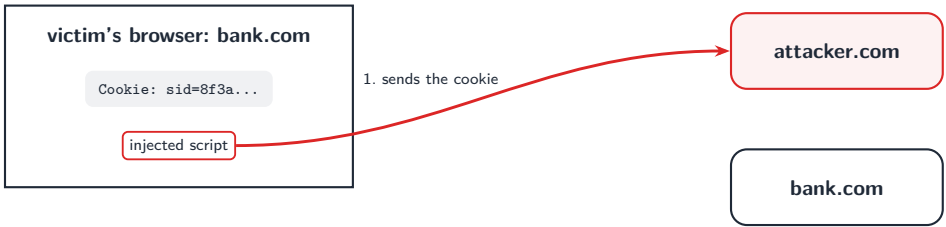

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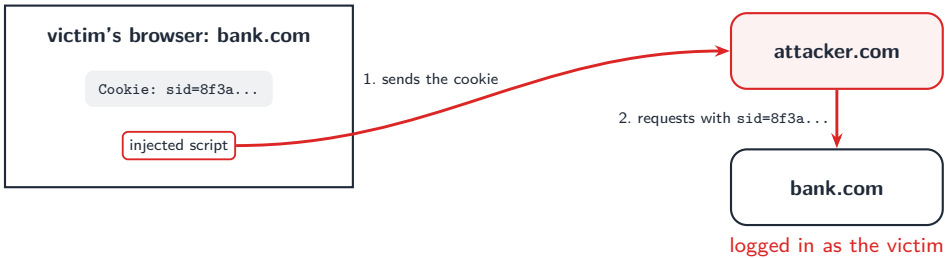

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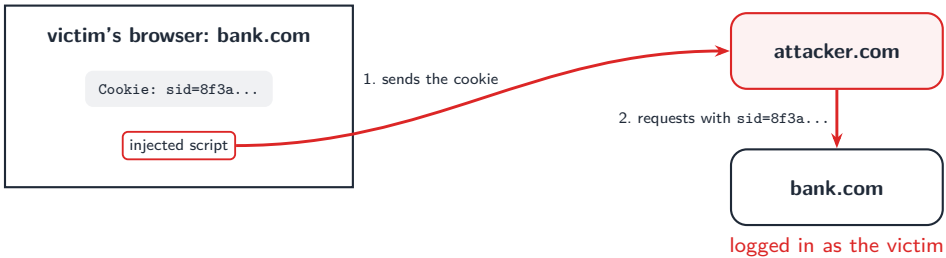

Defences next session: **HttpOnly** cookies, escaping, Content Security Policy.

XSS in Juice Shop (1/5)



Our target for today: the **XSS** category of the score board.

stars	challenge	kind	where
★	DOM XSS	DOM	product search
★	Bonus Payload	DOM	product search
★★	Reflected XSS	reflected	order tracking
★★★	API-only XSS	stored	product description
★★★	Client-side XSS Protection	stored	past a client-side check
★★★★	HTTP-Header XSS	stored	an HTTP header
★★★★	Server-side XSS Protection	stored	past a server-side check
★★★★	CSP Bypass	stored	a legacy page
★★★★★★	Video XSS	stored	the promo video

Juice Shop: challenges.yml, category XSS

XSS in Juice Shop (2/5)



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★	Bonus Payload	DOM	product search
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★★★	API-only XSS	stored	product description
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Juice Shop: challenges.yml, category XSS

XSS in Juice Shop (5/5)



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Most ask for the same harmless proof: `alert(‘xss‘)` must run.

Juice Shop: challenges.yml, category XSS

Three Kinds of XSS (1/3)



Where does the code come from, and who puts it into the page?

reflected: the server copies the request into the page



Juice Shop: order tracking

Stanford CS253, L06 Cross Site Scripting; OWASP: DOM Based XSS

Three Kinds of XSS (2/3)



Where does the code come from, and who puts it into the page?

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Juice Shop: order tracking

stored: the code waits in the database



Juice Shop: product description

Stanford CS253, L06 Cross Site Scripting; OWASP: DOM Based XSS

Three Kinds of XSS (3/3)



Where does the code come from, and who puts it into the page?

reflected: the server copies the request into the page



Juice Shop: order tracking

stored: the code waits in the database



Juice Shop: product description

DOM: the page's own JavaScript writes the URL into the page

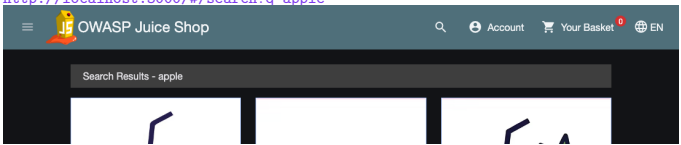


Juice Shop: product search

the server may never see the code

Stanford CS253, L06 Cross Site Scripting; OWASP: DOM Based XSS

DOM XSS in Juice Shop's Search (1/4)

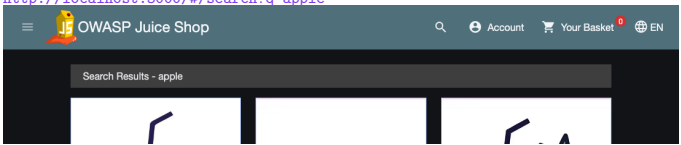


Juice Shop v20.4 on 127.0.0.1

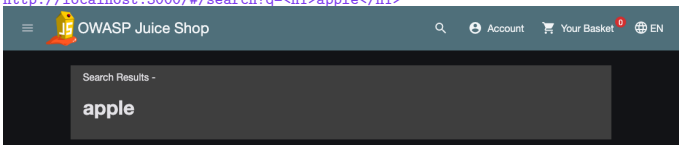
DOM XSS in Juice Shop's Search (2/4)



http://localhost:3000/#/search?q=apple



http://localhost:3000/#/search?q=<h1>apple</h1>



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DOM XSS in Juice Shop's Search (3/4)



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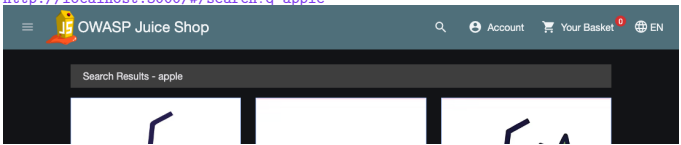

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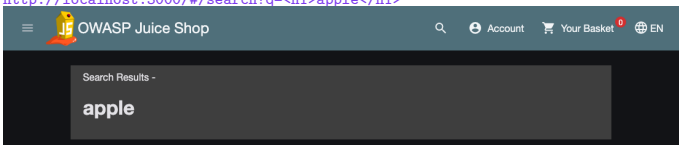

Juice Shop search

```
q = apple
  #searchValue innerHTML:
     apple
q = <h1>apple</h1>
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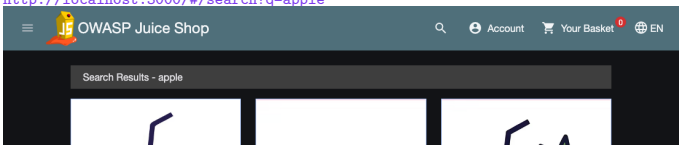
Juice Shop v20.4 on 127.0.0.1

DOM XSS in Juice Shop's Search (4/4)



http://localhost:3000/#/search?q=apple



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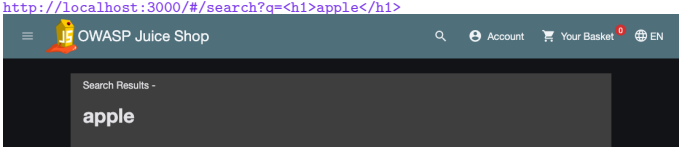

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The search text is **parsed as HTML**. The challenge: do the same with Juice Shop's `<iframe src="javascript:...">`.

Juice Shop v20.4 on 127.0.0.1

Where the Search Goes Wrong (1/4)



search-result.component.html, Juice Shop (Angular)

```
11 <span id="searchValue" [innerHTML]="searchValue"></span>
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Juice Shop: search-result.component.ts, challenge *DOM XSS*; Angular: Security

Where the Search Goes Wrong (2/4)



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search-result.component.ts

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145 this.dataSource.filter = queryParam.toLowerCase()
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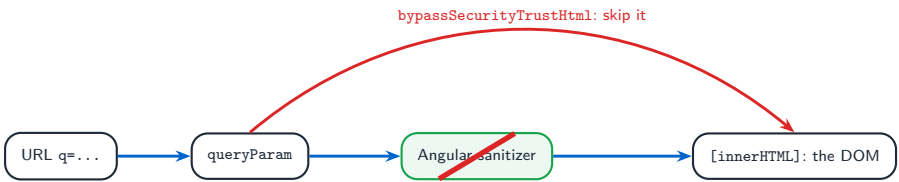

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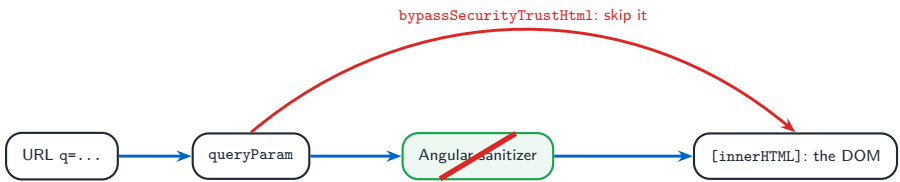

Frameworks **escape by default**. XSS often comes from code that **switches it off**.

Juice Shop: search-result.component.ts, challenge *DOM XSS*; Angular: Security

Stored XSS: Product Descriptions (1/4)



The same component, another field. Who writes the descriptions?

search-result.component.ts, Juice Shop

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Juice Shop: search-result.component.ts, challenge *API-only XSS*; codefix restfulXssChallenge

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- The descriptions come from the **database**: shown to **every** visitor

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- The REST API let users **change** them: **broken access control**
- Juice Shop's fix: **remove the bypass**; and stop users editing products

Juice Shop: search-result.component.ts, challenge *API-only XSS*; codefix restfulXssChallenge

Reflected XSS: Order Tracking (1/4)



The server copies the order id from the URL into its answer.

routes/trackOrder.ts, Juice Shop

```
14 // Truncate id to avoid unintentional RCE
15 const id = !utils.isChallengeEnabled(challenges.reflectedXssChallenge) ? String(req.params
       .id).replace(/[^\w-]+/g, '') : utils.trunc(req.params.id, 60)
```

what happens to the id

Juice Shop: routes/trackOrder.ts, challenge *Reflected XSS*

Reflected XSS: Order Tracking (2/4)



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An order id has a known shape: **validate it**. Where text is free, **escape it**.

Juice Shop: routes/trackOrder.ts, challenge *Reflected XSS*

Quiz: Reflected, Stored or DOM? (1/4)

1. An error page prints the bad `?page=` value from the URL
2. A product review shows HTML from its author to every buyer
3. Page JavaScript writes `location.hash` into `innerHTML`

Stanford CS253, L06 Cross Site Scripting; OWASP: DOM Based XSS

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Why Is XSS So Common? (1/3)

One page, several languages. Each has its own control characters.

```
<p>Hi DATA</p>
 <img alt='DATA'>
 <a href='DATA'>link</a>
 <div onclick='go(DATA)'>
 <script>let n = 'DATA'</script>
```

Stanford CS253, L06 Cross Site Scripting; OWASP XSS Prevention Cheat Sheet

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element: < &

attribute: ' " &

URL: the scheme itself

event handler: JavaScript, then HTML

script: ' \ and </script>

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event handler: JavaScript, then HTML

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Slip up in **one** place, and the whole page is vulnerable.

Stanford CS253, L06 Cross Site Scripting; OWASP XSS Prevention Cheat Sheet

Attributes with Special Meanings (1/3)

Escaping keeps data in the attribute. But what does the attribute *do*?

what data: and javascript: URLs are for

```
<a href='javascript:alert("hi")'>Say hi</a>       run JavaScript on click
<img src='...' />  an image inside the page
```

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```

let the user choose a URL ...

```
<a href='USER_URL'>my homepage</a>          javascript: runs on click
<iframe src='USER_URL'></iframe>            data:text/html makes a page
<script src='USER_URL'></script>            never safe, even escaped
```

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```

the fix: an allow-list of schemes

```
22 def safe_url(u):                        # allow-list of URL schemes
23     return u if urlparse(u).scheme in ("http", "https") else "#"
```

Parsers, Parsers, Everywhere (1/4)

Data inside a <script>. Why is escaping quotes not enough?

```
<script>
  let username = '</script><script>alert(1)//'
</script>
```

the page as sent

Parsers, Parsers, Everywhere (2/4)

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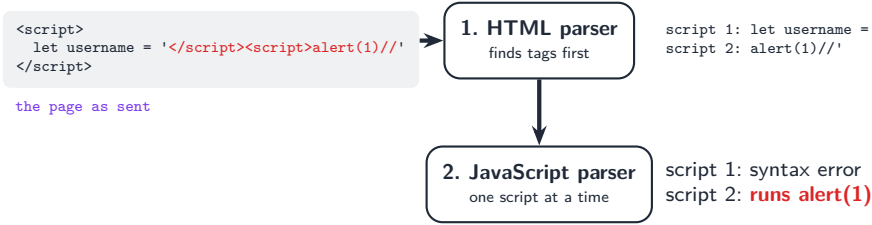
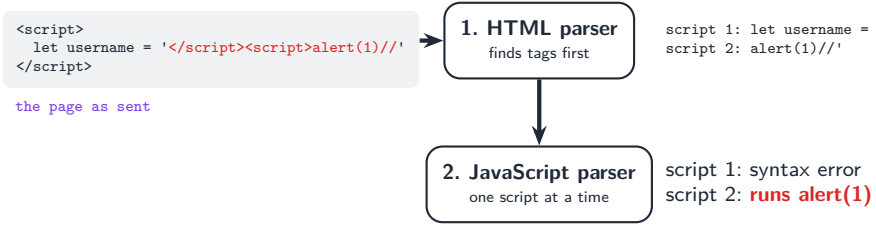
Parsers, Parsers, Everywhere (3/4)

Data inside a <script>. Why is escaping quotes not enough?



Parsers, Parsers, Everywhere (4/4)

Data inside a <script>. Why is escaping quotes not enough?



Fixes: **hex encode** the data and decode it in JavaScript, or put it in a <template> element.

Contexts Which Are Never Safe (1/3)

```
<script>USER_DATA_HERE</script>
<!-- USER_DATA_HERE -->
<USER_DATA_HERE href='/'>Link</USER_DATA_HERE>
<div USER_DATA_HERE='some value'></div>
<style>USER_DATA_HERE</style>
```

Contexts Which Are Never Safe (2/3)

```
<script>USER_DATA_HERE</script>
<!-- USER_DATA_HERE -->
<USER_DATA_HERE href='/'>Link</USER_DATA_HERE>
<div USER_DATA_HERE='some value'></div>
<style>USER_DATA_HERE</style>
```

HTML parsers are **lax**: they accept and repair broken markup.

Contexts Which Are Never Safe (3/3)

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<style>USER_DATA_HERE</style>
```

HTML parsers are **lax**: they accept and repair broken markup.

Postel's robustness principle: "be liberal in what you accept".
Good for compatibility, **bad for security**.

Where Escaped Data Is Safe (1/3)

context	safe with	
HTML element body	HTML escaping	**yes**
HTML attribute	HTML escaping, **in quotes**	**yes**
JavaScript string		**yes**

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Where Escaped Data Is Safe (2/3)

context	safe with	
HTML element body	HTML escaping	**yes**
HTML attribute	HTML escaping, **in quotes**	**yes**
JavaScript string	hex, or `<template>`	**yes**

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Where Escaped Data Is Safe (3/3)

context	safe with	
HTML element body	HTML escaping	**yes**
HTML attribute	HTML escaping, **in quotes**	**yes**
JavaScript string	hex, or `<template>`	**yes**
URL attribute	a scheme allow-list	**with care**
nested: `onclick="setTimeout(...)"`	JS twice, then HTML	**avoid**

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Quiz: Which Escaping? (1/5)

`DATA` comes from the user. What is needed?

1. `<td>DATA</td>`
2. `<input value=DATA>`
3. `<a href='DATA'>profile</a>`
4. `<script>var q = 'DATA'</script>`

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Quiz: Which Escaping? (2/5)

DATA comes from the user. What is needed?

1. `<td>DATA</td>` — escape < and &
2. `<input value=DATA>`
3. `<a href='DATA'>profile</a>`
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1. `<td>DATA</td>` — escape < and &
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3. `<a href='DATA'>profile</a>` — http(s) allow-list, escape
4. `<script>var q = 'DATA'</script>`

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Quiz: Which Escaping? (5/5)

`DATA` comes from the user. What is needed?

1. `<td>DATA</td>`	escape < and &
2. `<input value=DATA>`	add quotes, then escape
3. `<a href='DATA'>profile</a>`	http(s) allow-list, escape
4. `<script>var q = 'DATA'</script>`	hex, or a <template>

Stanford CS253, L06 Cross Site Scripting; OWASP XSS Prevention Cheat Sheet

Hands-On: Juice Shop XSS (1/5)



On your own Juice Shop (`http://localhost:3000`), 25 minutes:

1. Search for `<h1>apple</h1>`. Inspect the element: text or HTML?

OWASP Juice Shop; Pwning OWASP Juice Shop

Hands-On: Juice Shop XSS (2/5)



On your own Juice Shop (`http://localhost:3000`), 25 minutes:

1. Search for `<h1>apple</h1>`. Inspect the element: text or HTML?
2. Solve **DOM XSS** with the input given in its description

OWASP Juice Shop; Pwning OWASP Juice Shop

Hands-On: Juice Shop XSS (3/5)



On your own Juice Shop (`http://localhost:3000`), 25 minutes:

1. Search for `<h1>apple</h1>`. Inspect the element: text or HTML?
2. Solve **DOM XSS** with the input given in its description
3. Open its code <>: mark line 146, pick the fix

OWASP Juice Shop; Pwning OWASP Juice Shop

Hands-On: Juice Shop XSS (4/5)



On your own Juice Shop (`http://localhost:3000`), 25 minutes:

1. Search for `<h1>apple</h1>`. Inspect the element: text or HTML?
2. Solve **DOM XSS** with the input given in its description
3. Open its code <>: mark line 146, pick the fix
4. Same for **Bonus Payload** and **API-only XSS**

OWASP Juice Shop; Pwning OWASP Juice Shop

Hands-On: Juice Shop XSS (5/5)



On your own Juice Shop (`http://localhost:3000`), 25 minutes:

1. Search for `<h1>apple</h1>`. Inspect the element: text or HTML?
2. Solve **DOM XSS** with the input given in its description
3. Open its code <>: mark line 146, pick the fix
4. Same for **Bonus Payload** and **API-only XSS**
5. Search the frontend code for `bypassSecurityTrust`: how many?

Only on your own copy, bound to 127.0.0.1. Never on a real site.

OWASP Juice Shop; Pwning OWASP Juice Shop

Summary (1/5)

- XSS: data becomes **JavaScript in the target's page**, with the user's session

Summary (2/5)

- XSS: data becomes **JavaScript in the target's page**, with the user's session
- **Reflected**, **stored**, **DOM**: who writes the code into the page
- Juice Shop: frameworks protect by default; **bypasses** cause the bugs

Summary (3/5)

- XSS: data becomes **JavaScript in the target's page**, with the user's session
- **Reflected**, **stored**, **DOM**: who writes the code into the page
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- Every **context** has its own control characters and escaping

Summary (4/5)

- XSS: data becomes **JavaScript in the target's page**, with the user's session
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Summary (5/5)

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