Web Application Architecture

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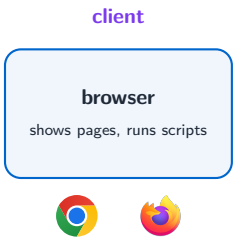
ভাৰতীয় প্ৰযুক্তিবিদ্যা প্ৰতিষ্ঠান গুৱাহাটী
भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Web Application (1/3)

What is running when you use a web application?



CERN: A Short History of the Web; Stanford CS253, L01 What is Web Security?

Web Application (2/3)

What is running when you use a web application?

client

browser

shows pages, runs scripts



server

web server

runs the program,
keeps the data



CERN: A Short History of the Web; Stanford CS253, L01 What is Web Security?

Web Application (3/3)

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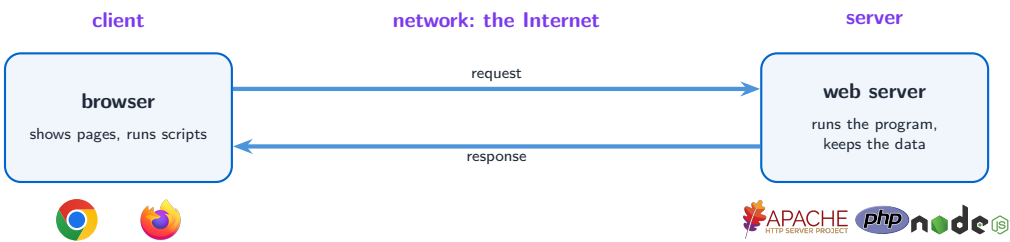

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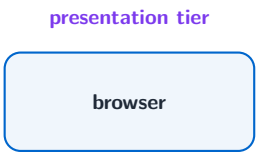
Three-Tier Architecture (1/4)

Where does the program keep its data?



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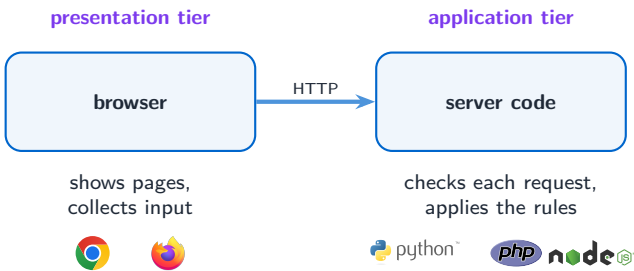

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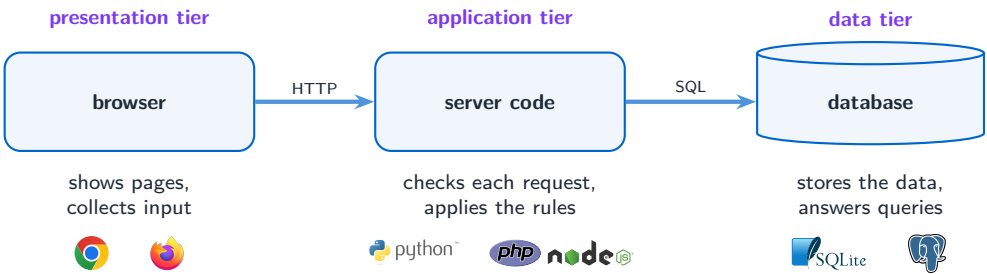

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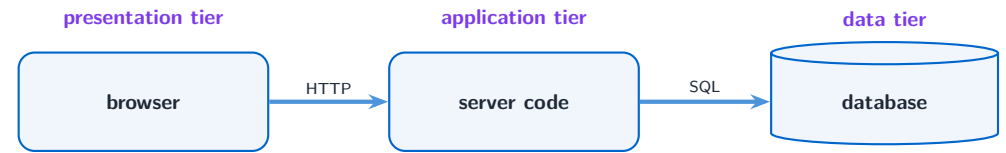


in Juice Shop

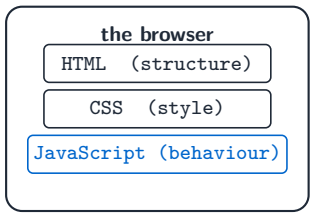
`Angular single-page app`

`Node.js + Express`

`SQLite: Users, Products, Baskets`

Client-Side Scripting (1/3)

The server sends it, but *your browser* runs it.



runs on the user's machine

MDN: JavaScript

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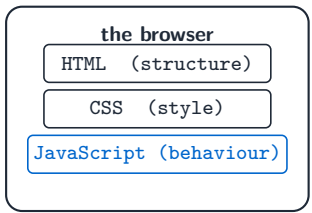

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- change the page without reloading
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- call APIs in the background (AJAX)
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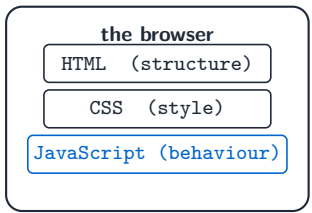

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What it does

- change the page without reloading
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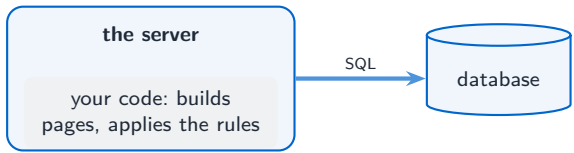
Because it runs on the client, the user can **read and change** it. Never trust it.

MDN: JavaScript

Server-Side Scripting (1/3)

Code that runs on the server, out of the user's reach.



MDN: Server-side website programming

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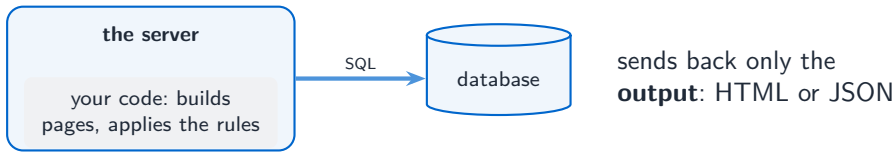

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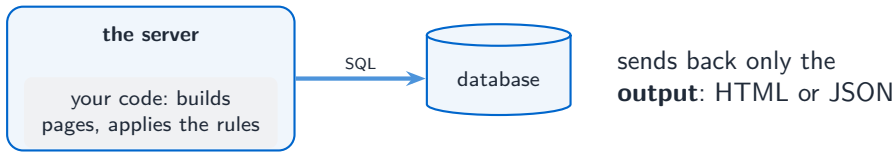

Languages: PHP, Python, Node.js, Java, Ruby. The user sees the **output**, never the code. So this is where real checks live: the server decides who may do what.

MDN: Server-side website programming

Servers and Frameworks (1/6)

You do not build all this from scratch. What is available?

Web servers	Apache · Nginx · IIS

MDN: Web frameworks

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Juice Shop, our target today, is **Node.js + Express + Angular + SQLite**.

MDN: Web frameworks

What Is Web Security? (1/5)

Where in this picture can things go wrong?



Stanford CS253, L01 What is Web Security?; MDN: Same-origin policy

What Is Web Security? (2/5)

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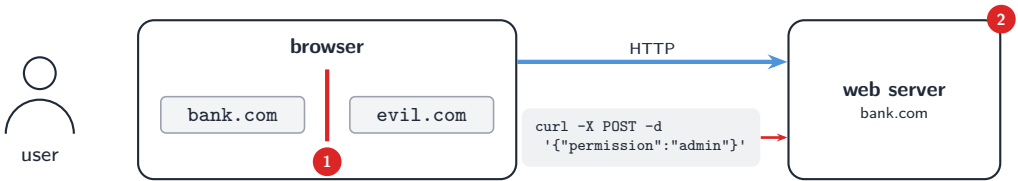

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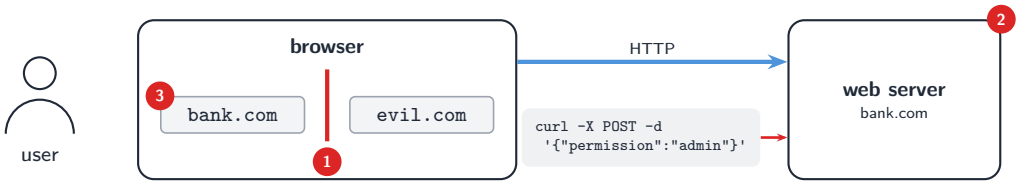

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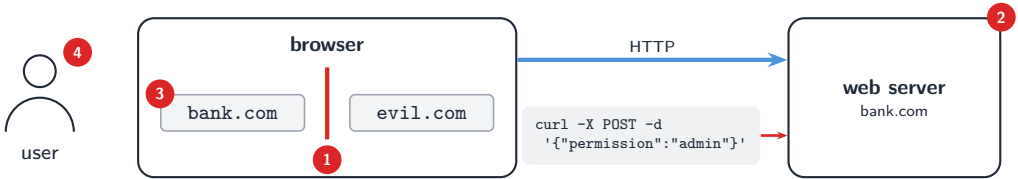

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3. Client-side security
the user is attacked inside the app's own page

4. Protect the user
from tricks (social engineering) and from trackers

Stanford CS253, L01 What is Web Security?; MDN: Same-origin policy

Why Is Web Security Hard? (1/3)

Why do web applications have so many security bugs?

- Goal: run **untrusted code** safely
- Many sites mixed in one tab
- Low-level features, hardware access
- It must also be fast
- APIs grew; never designed as a whole
- Old pages must work: "don't break the web"

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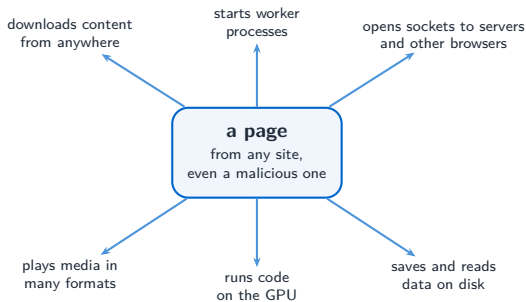

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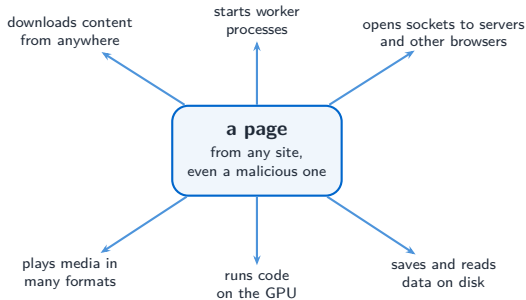

The browser must allow all of this, and still keep **each site and the user** safe.

URL (1/7)

What does each part of a web address mean?

`https://shop.example.com:8443/search?q=shoes#reviews`

RFC 3986: URI Generic Syntax; Stanford CS253, L01 What is Web Security?

URL (2/7)

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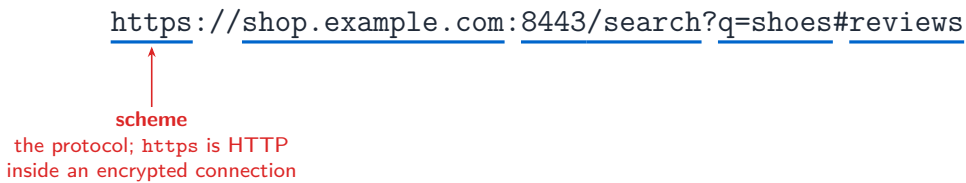

URL (3/7)

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URL (4/7)

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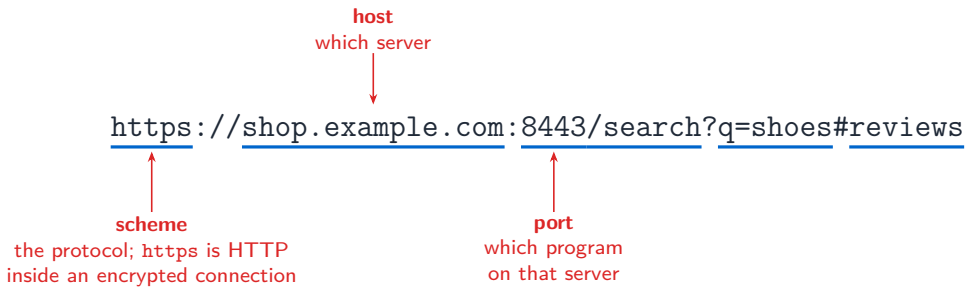

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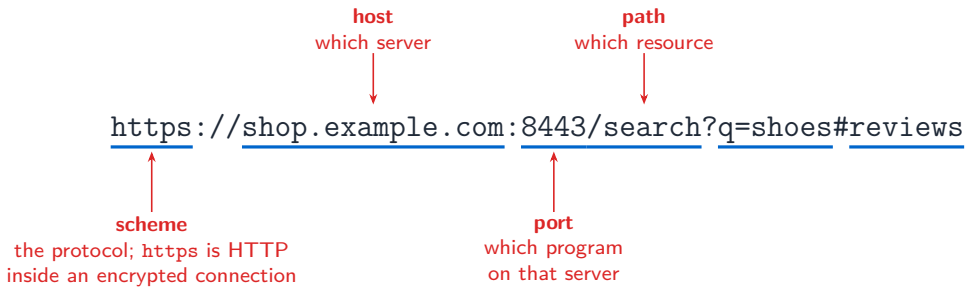

URL (6/7)

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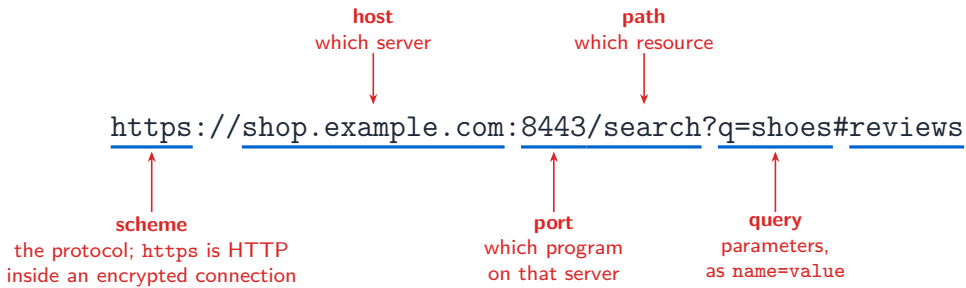

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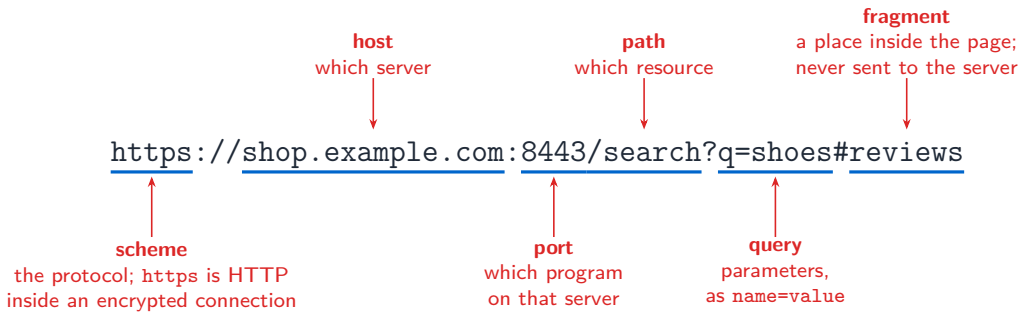

HTTP: Request and Response (1/6)

Request: browser to server

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GET /index.html HTTP/1.1
Host: 127.0.0.1:8000
User-Agent: curl/8.7.1
Accept: */*
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RFC 9110: HTTP Semantics; Stanford CS253, L02 DNS, HTTP

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HTTP/1.0 200 OK
Content-type: text/html
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← status code

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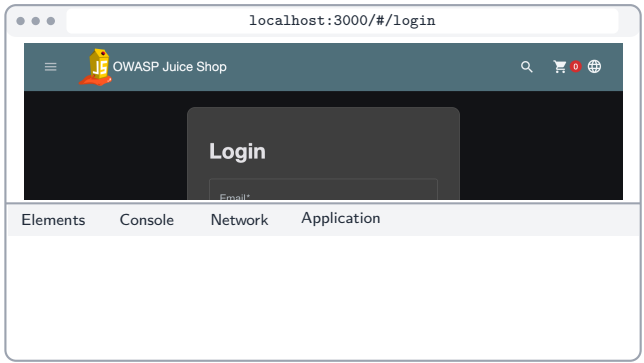
Status codes: **2xx** success, **3xx** go elsewhere, **4xx** client error, **5xx** server error.

Browser Developer Tools (1/5)

Can we see this HTTP traffic in a normal browser?



Chrome, Firefox: same tools

Chrome DevTools: Open; Stanford CS253, L02 DNS, HTTP

Browser Developer Tools (2/5)

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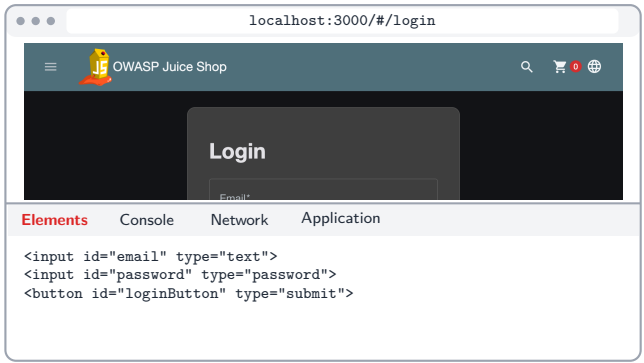

Elements: the page as a tree (DOM)

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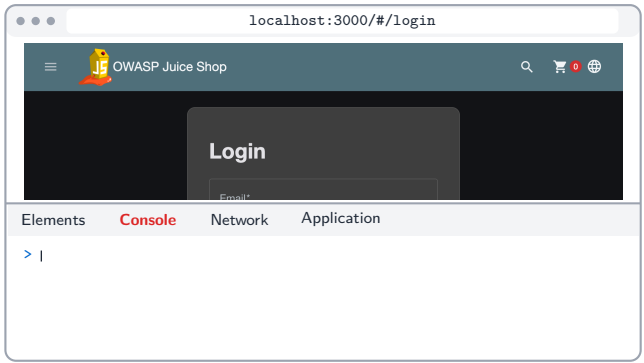

Elements: the page as a tree (DOM)

Console: run JavaScript in the page

Chrome, Firefox: same tools

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Browser Developer Tools (4/5)

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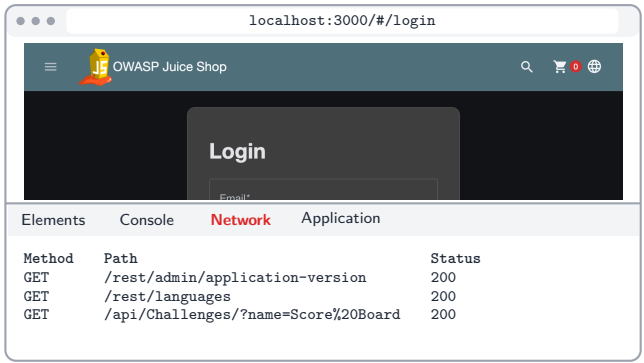

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Network: every request and response

Chrome, Firefox: same tools

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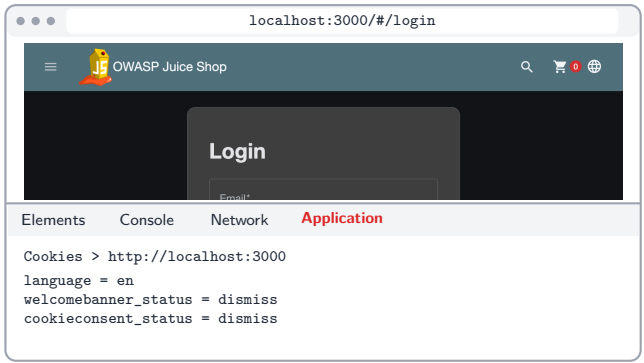

Elements: the page as a tree (DOM)

Console: run JavaScript in the page

Network: every request and response

Application: cookies and storage

Chrome, Firefox: same tools

Chrome DevTools: Open; Stanford CS253, L02 DNS, HTTP

HTTP Is Stateless (1/5)

Each request stands alone. How does a site remember who you are?



RFC 6265: HTTP State Management Mechanism; Stanford CS253, L04 Cookies and Sessions

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HTTP Is Stateless (4/5)

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HTTP Is Stateless (5/5)

Each request stands alone. How does a site remember who you are?



Whoever sends this session id **is** alice for the server.

Cookies: Uses and Attributes (1/5)

🍪 A cookie: **small data** the browser keeps and sends back.

```
Set-Cookie: sid=a3fWa; Max-Age=2592000; Secure; HttpOnly; SameSite=Strict
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MDN: Using HTTP cookies; RFC 6265: HTTP State Management Mechanism; Stanford CS253, L04 Cookies and Sessions

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kept **30 days**
without it: gone when the browser closes

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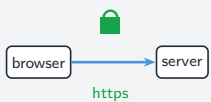

sent **only over HTTPS**
nobody on the
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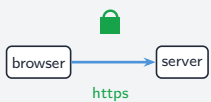

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HttpOnly



JavaScript cannot read it
so XSS cannot steal it

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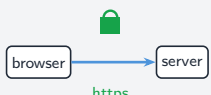
without it: gone when the browser closes

Secure



sent **only over HTTPS**
nobody on the network reads it

HttpOnly



JavaScript cannot read it
so XSS cannot steal it

SameSite=Strict



not sent when the request comes from another site

MDN: Using HTTP cookies; RFC 6265: HTTP State Management Mechanism; Stanford CS253, L04 Cookies and Sessions

Quiz: Requests and Sessions (1/4)

Fill in each answer.

1. Which part of `http://a.com/p?x=1#top` does the server never see?

2. A server answers `404`. Who made the mistake?

3. After login, what tells the server who you are?

RFC 9110: HTTP Semantics

Quiz: Requests and Sessions (2/4)

Fill in each answer.

1. Which part of `http://a.com/p?x=1#top` does the server never see?

`#top`

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RFC 9110: HTTP Semantics

Quiz: Requests and Sessions (3/4)

Fill in each answer.

1. Which part of `http://a.com/p?x=1#top` does the server never see? `#top`

2. A server answers `404`. Who made the mistake? `the client`

3. After login, what tells the server who you are? _____

RFC 9110: HTTP Semantics

Quiz: Requests and Sessions (4/4)

Fill in each answer.

1. Which part of `http://a.com/p?x=1#top` does the server never see? `#top`

2. A server answers `404`. Who made the mistake? `the client`

3. After login, what tells the server who you are? `the cookie`

RFC 9110: HTTP Semantics

JavaScript and the DOM (1/4)

What if a page carries its own program?

```
<h1 id="t">Hello</h1>
<script>
  let h = document.getElementById("t");
  h.textContent = "Hi, alice";
</script>
```

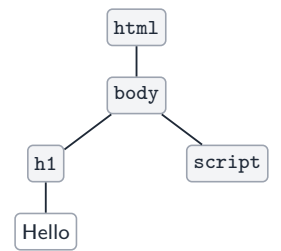
MDN: JavaScript; Stanford CS253, L01 What is Web Security?

JavaScript and the DOM (2/4)

What if a page carries its own program?

```
1 <h1 id="t">Hello</h1>
2 <script>
3   let h = document.getElementById("t");
4   h.textContent = "Hi, alice";
5 </script>
```

the DOM: the page as a tree



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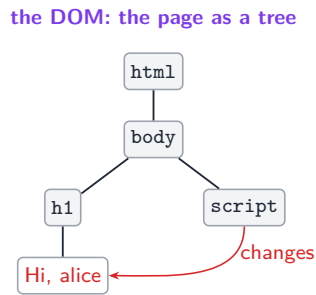

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JavaScript and the DOM (4/4)

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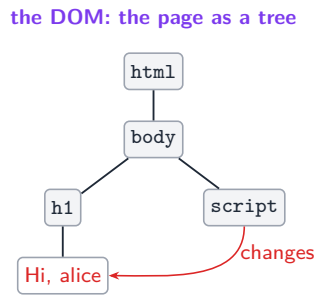


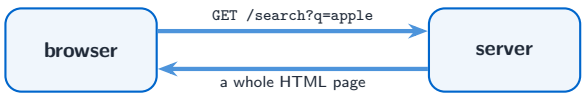
A script can read and change **everything in its page**, and read its cookies: `document.cookie`.

MDN: JavaScript; Stanford CS253, L01 What is Web Security?

AJAX and Single-Page Applications (1/3)

Every click loads a whole new page. Can a page ask for data only?

classic: one page per click



response body

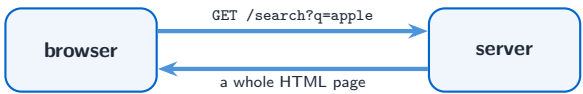
```
<h1>Results for apple</h1>
<li>Apple Juice (1000ml)</li>
```

Garrett, *Ajax: A New Approach to Web Applications*, 2005

AJAX and Single-Page Applications (2/3)

Every click loads a whole new page. Can a page ask for data only?

classic: one page per click



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<h1>Results for apple</h1>
<li>Apple Juice (1000ml)</li>
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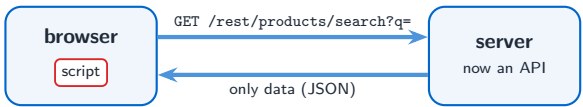
AJAX: the script asks in the background



response body

```
{"status":"success","data":[
 {"id":1,"name":"Apple Juice (1000ml)",
  ...}, ...]}
```

Garrett, *Ajax: A New Approach to Web Applications*, 2005

AJAX and Single-Page Applications (3/3)

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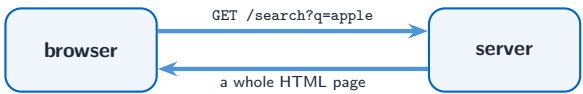

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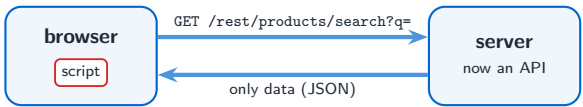


response body

```
{"status":"success","data":[
 {"id":1,"name":"Apple Juice (1000ml)",
  ...}, ...]}
```

Single-page application: one HTML page, then only data from an API.

Garrett, *Ajax: A New Approach to Web Applications*, 2005

Trust Boundaries (1/5)

Which side of the picture can you trust?

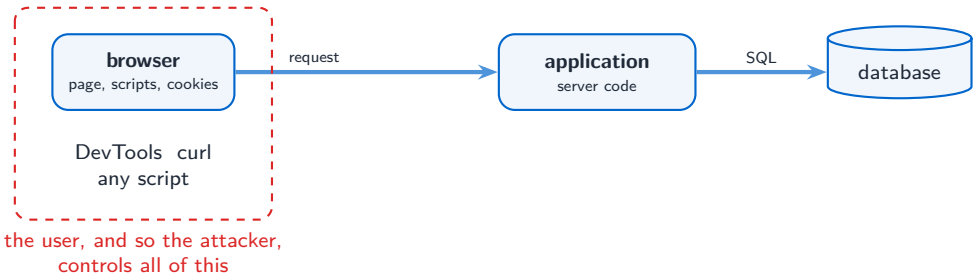


DevTools curl
any script

OWASP: Attack Surface Analysis Cheat Sheet; Stanford CS253, L01 What is Web Security?

Trust Boundaries (2/5)

Which side of the picture can you trust?



OWASP: Attack Surface Analysis Cheat Sheet; Stanford CS253, L01 What is Web Security?

Trust Boundaries (3/5)

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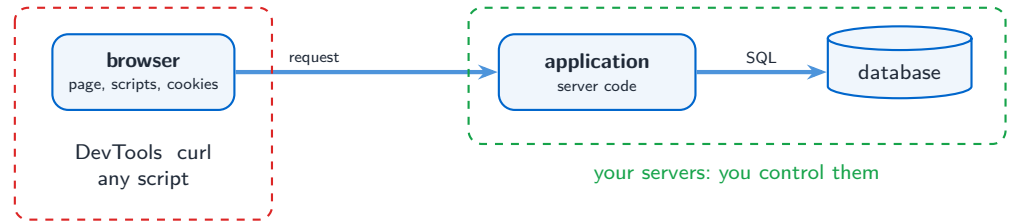
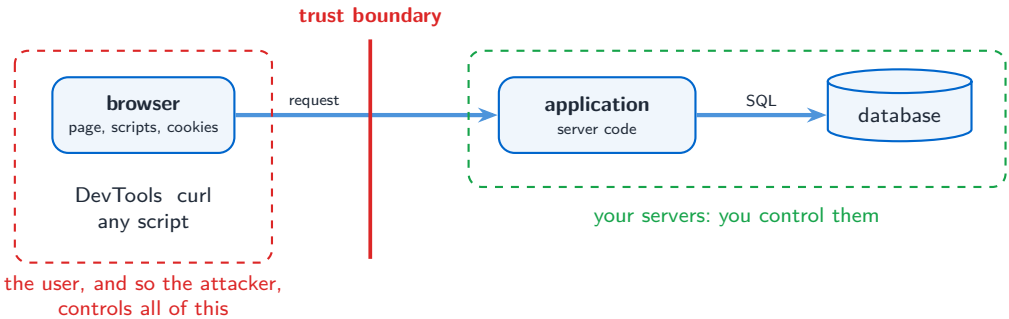


OWASP: Attack Surface Analysis Cheat Sheet; Stanford CS253, L01 What is Web Security?

Trust Boundaries (4/5)

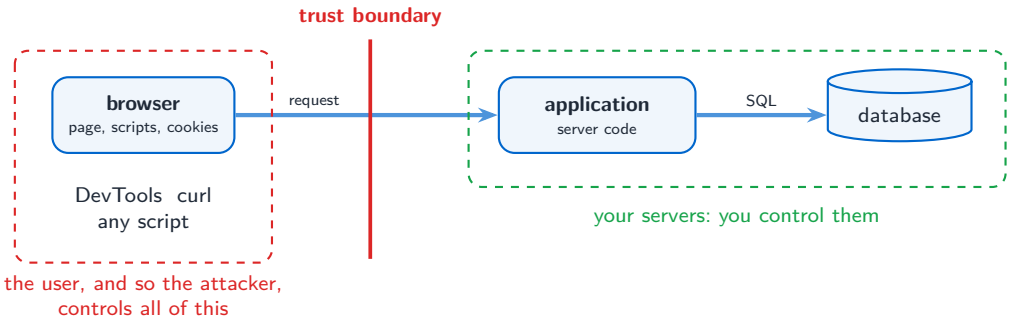
Which side of the picture can you trust?



OWASP: Attack Surface Analysis Cheat Sheet; Stanford CS253, L01 What is Web Security?

Trust Boundaries (5/5)

Which side of the picture can you trust?

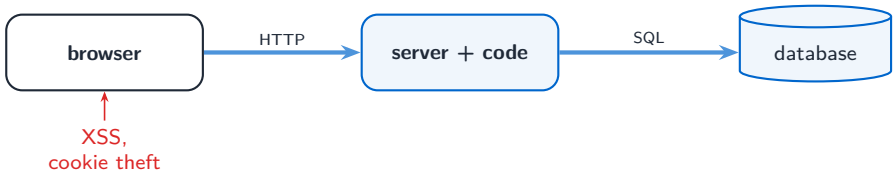


Rule: **check all data where it crosses the boundary**, on the server side.

OWASP: Attack Surface Analysis Cheat Sheet; Stanford CS253, L01 What is Web Security?

Attack Surface: Where Each Part Breaks (1/5)

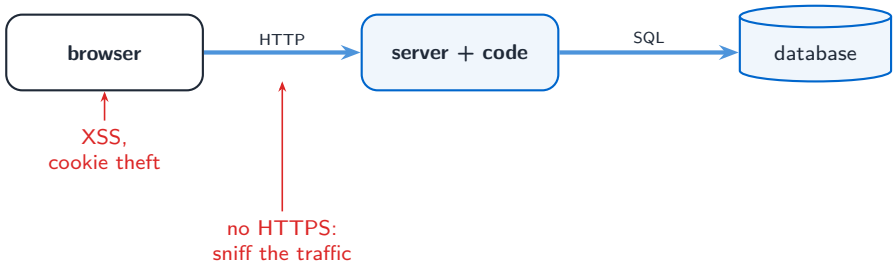
Every component we just saw is also a place to attack.



OWASP: Attack Surface Analysis

Attack Surface: Where Each Part Breaks (2/5)

Every component we just saw is also a place to attack.



OWASP: Attack Surface Analysis

Attack Surface: Where Each Part Breaks (3/5)

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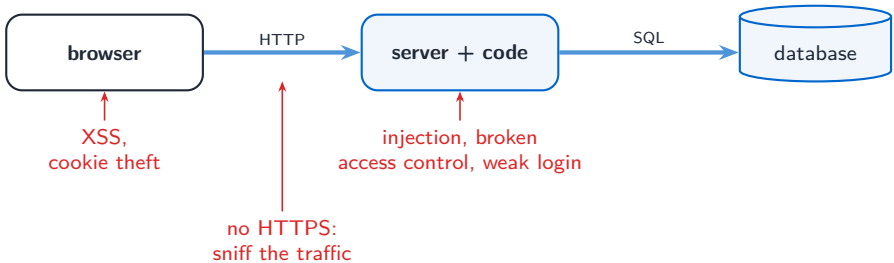
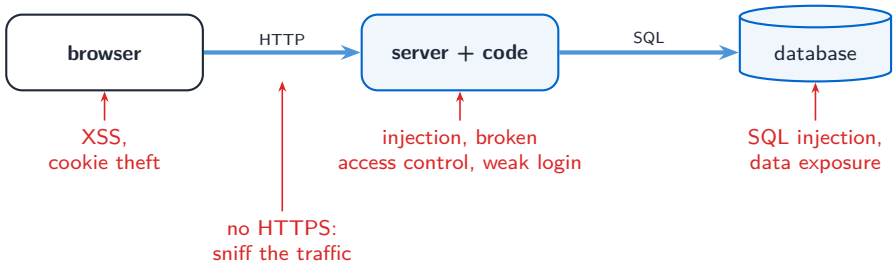


OWASP: Attack Surface Analysis

Attack Surface: Where Each Part Breaks (4/5)

Every component we just saw is also a place to attack.



OWASP: Attack Surface Analysis

Attack Surface: Where Each Part Breaks (5/5)

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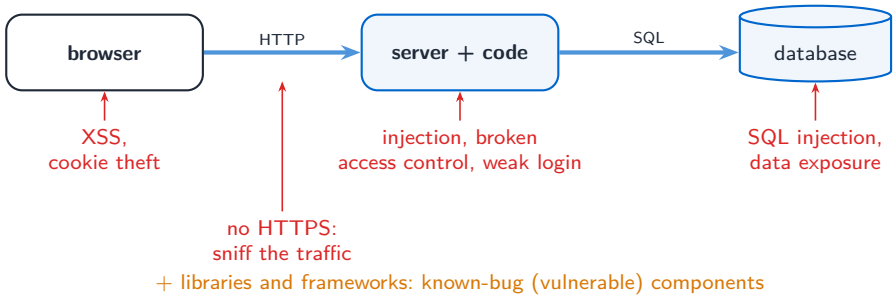

The rest of today attacks each one: the server, the database, the browser, the session.

OWASP: Attack Surface Analysis

Quiz: Who Controls It? (1/4)

Can the attacker change it?

1. A hidden form field, `price=499`
2. The `User-Agent` header of a request
3. The session table on the server

OWASP: Attack Surface Analysis Cheat Sheet

Quiz: Who Controls It? (2/4)

Can the attacker change it?

1. A hidden form field, `price=499` **YES**
2. The `User-Agent` header of a request
3. The session table on the server

OWASP: Attack Surface Analysis Cheat Sheet

Quiz: Who Controls It? (3/4)

Can the attacker change it?

1. A hidden form field, `price=499` **YES**
2. The `User-Agent` header of a request **YES**
3. The session table on the server

OWASP: Attack Surface Analysis Cheat Sheet

Quiz: Who Controls It? (4/4)

Can the attacker change it?

1. A hidden form field, `price=499` **YES**
2. The `User-Agent` header of a request **YES**
3. The session table on the server **NO**

OWASP: Attack Surface Analysis Cheat Sheet

Responsible Disclosure (1/3)

You can now read and change any request. What may you test?

- Test only systems you **own**, or have permission to test
- Never destroy or change other people's data

Responsible Disclosure (2/3)

You can now read and change any request. What may you test?

- Test only systems you **own**, or have permission to test
- Never destroy or change other people's data
- Found a bug? Tell the **owner** privately, for example through its bug bounty program
- Give the owner time to fix it before you talk about it

Stanford CS253, L01 What is Web Security?; CERT-In: Responsible Vulnerability Disclosure and Coordination Policy

Responsible Disclosure (3/3)

You can now read and change any request. What may you test?

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Stanford CS253, L01 What is Web Security?; CERT-In: Responsible Vulnerability Disclosure and Coordination Policy