Browser history re:visited

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Fraser Brown[*] *Deian Stefan*[†]

[†]*UC San Diego* [*]*Stanford University*

Web Content


Web Content
sandboxing


Web Content
history data
sandboxing

- https://www.google.com
- https://www.google.com/search?q=usenix+woot+2018
- https://bulkcheesewhizdelivery.com
- https://ashleymadison.com

- https://www.google.com
- https://www.google.com/search?q=usenix+woot+2018
- https://bulkcheesewhizdelivery.com
- https://ashleymadison.com

Click here

"This points to something new!"

- https://www.google.com
- https://www.google.com/search?q=usenix+woot+2018
- https://bulkcheesewhizdelivery.com
- https://ashleymadison.com

Click here

"I've been there before!"

2002

CSS visited pages disclosure

This message: [Message body] [Respond] [More options]
Related messages: [Next message] [Previous message]

From: Andrew Clover <and@doxdesk.com>
Date: Thu, 14 Feb 2002 12:17:54 +0000
To: bugtraq@securityfocus.com
Message-ID: <20020214121754.B11742@doxdesk.com>

https://www.usenix.org/conference/woot18

https://www.usenix.org/conference/woot18

Click here

https://www.usenix.org/conference/woot18

Click here

visited = true

https://www.usenix.org/conference/woot18

Click here

visited = false

global_rank	domain_name	rank_country	rank_value	categories	demog_male	demog_female	site_title	keywords	owner_name	own
1	google.com	United States	1	Computers/Internet/Searching /Search_Engines/Google...	49	50	Google	Mountain View	aa	dns-
2	facebook.com	United States	2	Society/Activism /We_Are_The_99_Percent, Computers/...	47.5	52.5	Facebook		TheFacebook, Inc.	dom
3	youtube.com	United States	3	Computers/Internet /On_the_Web /Web_Applications/Vid...	50	49	YouTube - Broadcast yourself			
4	yahoo.com	United States	5	Computers/Internet /On_the_Web/Web_Portals, Compute...	49	51	Yahoo!	On the Web, Web Portals		
5	baidu.com	China	1	World/Chinese_Simplified_CN /计算机/互联网络/搜寻/搜索引擎	31.5	75.5	Baidu.com	Chinese Simplified	2009 Baidu	baid
6	wikipedia.org	United States	6	Computers/Open_Source /Open_Content /Encyclopedias/W...	51.5	49	Wikipedia	On the Web, Tracking	Wikimedia Foundation, Inc.	info-
7	twitter.com	United States	7	Computers/Internet /On_the_Web /Online_Communities/S...	46	54	Twitter		Obvious Corp	twitt
8	amazon.com	United States	4	Shopping/Entertainment, Shopping/General_Merchandi...	40.5	61.5	Amazon.com	General Interest	Amazon.com	www
9	qq.com	China	2	World/Chinese_Simplified_CN /计算机/互联网络/门户网站, World/C...						bn

Source: Alexa Top Sites

bandwidth = URLs / second

global_rank	domain_name	rank_country	rank_value	categories	demog_male	demog_female	site_title	keywords	owner_name	own
1	google.com	United States	1	Computers/Internet/Searching /Search_Engines/Google...	49	50	Google	Mountain View	aa	dns-
2	facebook.com	United States	2	Society/Activism /We_Are_The_99_Percent, Computers/...	47.5	52.5	Facebook		TheFacebook, Inc.	dom
3	youtube.com	United States	3	Computers/Internet /On_the_Web /Web_Applications/Vid...	50	49	YouTube - Broadcast yourself			
4	yahoo.com	United States	5	Computers/Internet /On_the_Web/Web_Portals, Compute...	49	51	Yahoo!	On the Web, Web Portals		
5	baidu.com	China	1	World/Chinese_Simplified_CN /计算机/互联网络/搜寻/搜索引擎	31.5	75.5	Baidu.com	Chinese Simplified	2009 Baidu	baid
6	wikipedia.org	United States	6	Computers/Open_Source /Open_Content /Encyclopedias/W...	51.5	49	Wikipedia	On the Web, Tracking	Wikimedia Foundation, Inc.	info-
7	twitter.com	United States	7	Computers/Internet /On_the_Web /Online_Communities/S...	46	54	Twitter		Obvious Corp	twitt
8	amazon.com	United States	4	Shopping/Entertainment, Shopping/General_Merchandi...	40.5	61.5	Amazon.com	General Interest	Amazon.com	www
9	qq.com	China	2	World/Chinese_Simplified_CN /计算机/互联网络/门户网站, World/C...						br

Source: Alexa Top Sites

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2010 - ~3,000 URLs/sec

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Plugging the CSS History Leak

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2018 (CR deadline) – CVE-2018-6137 (~3,000)

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2011 – `MozAfterPaint` leak (~100 URLs/sec)

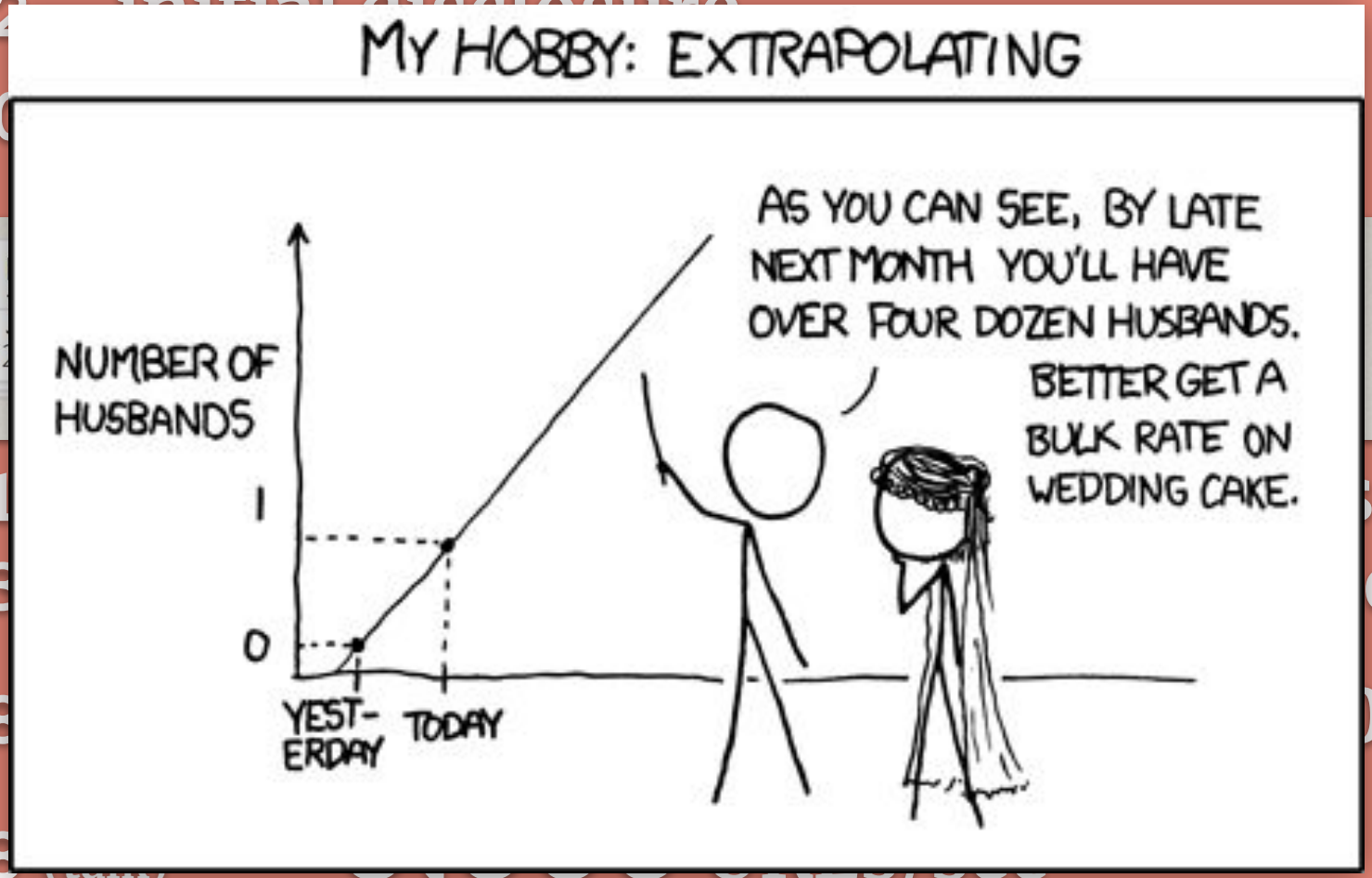
2013 – 'Pixel Perfect' attack (~60 URLs/sec)

2018 (CR deadline) – CVE-2018-6137 (~3,000)

2018 (talk) – ~6,000 URLs/sec

2002 initial disclosure

2010



2011 sec)

2013 ec)

2018 0))

2018 (talk)

4 APIs, 4 attacks

- CSS Paint API
- CSS 3D transforms
- SVG `fill`-coloring
- JavaScript bytecode cache

Security-focused browsers affected

Chrome + Site Isolation

Chrome + ChromeZero add-on

DeterFox

FuzzyFox

Brave

Unaffected

Tor Browser

historySniffer()

input: target URLs

output: visited URLs

TODO

- ☐ find vulnerable feature
- ☐ leak visited bit for a URL
- ☐ exfiltrate visited bit
- ☐ amplify bandwidth

CSS Painting API Level 1

W3C Working Draft, 10 April 2018

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CSS Pai
W3C Working Draft, 10 April 2018
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N20904
JS


CSS Pai
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SUSPEND
MiniMed
B
ESC
ACT


UNITED
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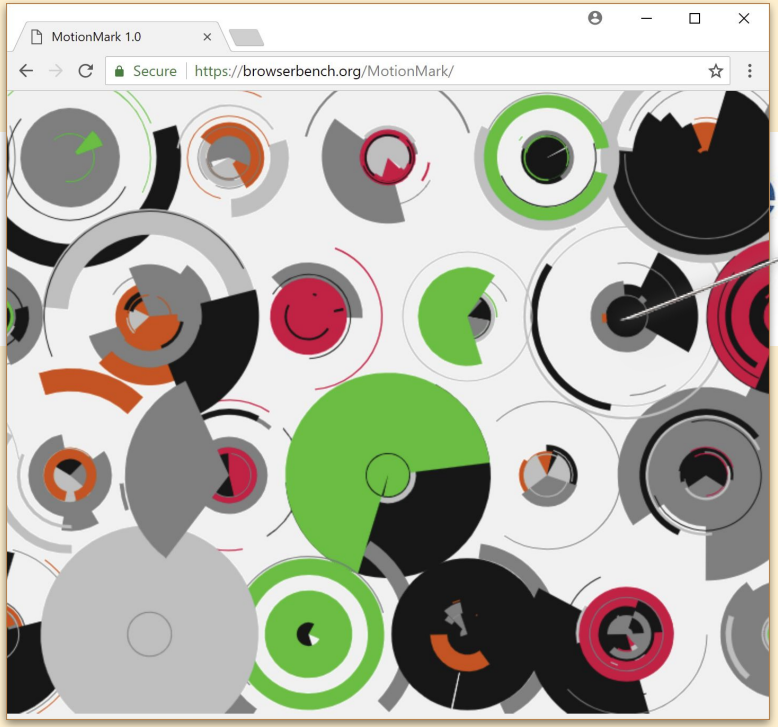
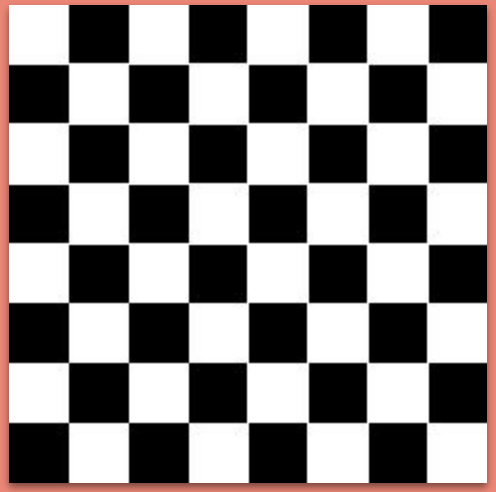
CSS
W3C Wor
1:31 THRESH
SUSPEND
Medtronic
MiniMed
B
ESC
ACT

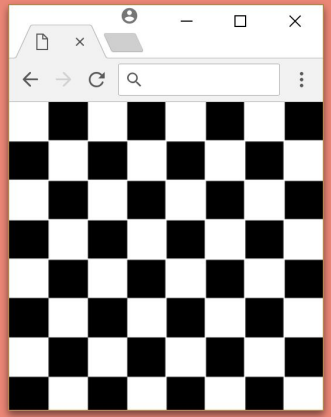
CSS Painting API Level 1

W3C Working Draft, 10 April 2018


MotionMark 1.0
Secure
https://browserbench.org/MotionMark/

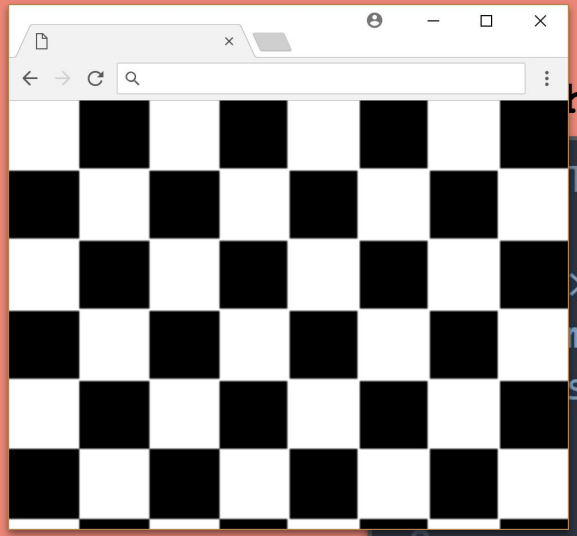

JS





index.html

```html
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="utf-8"/>
    <style>
        body {
            background: url(chessboard.png) top left / cover;
        }
    </style>
</head>
<body>
</body>
</html>
```



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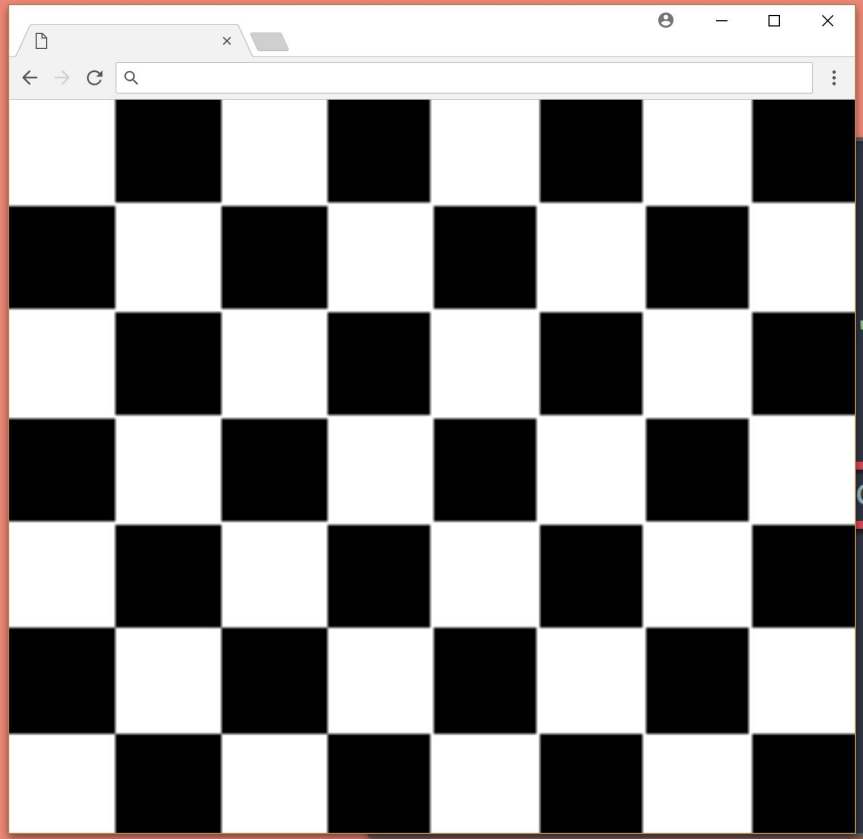
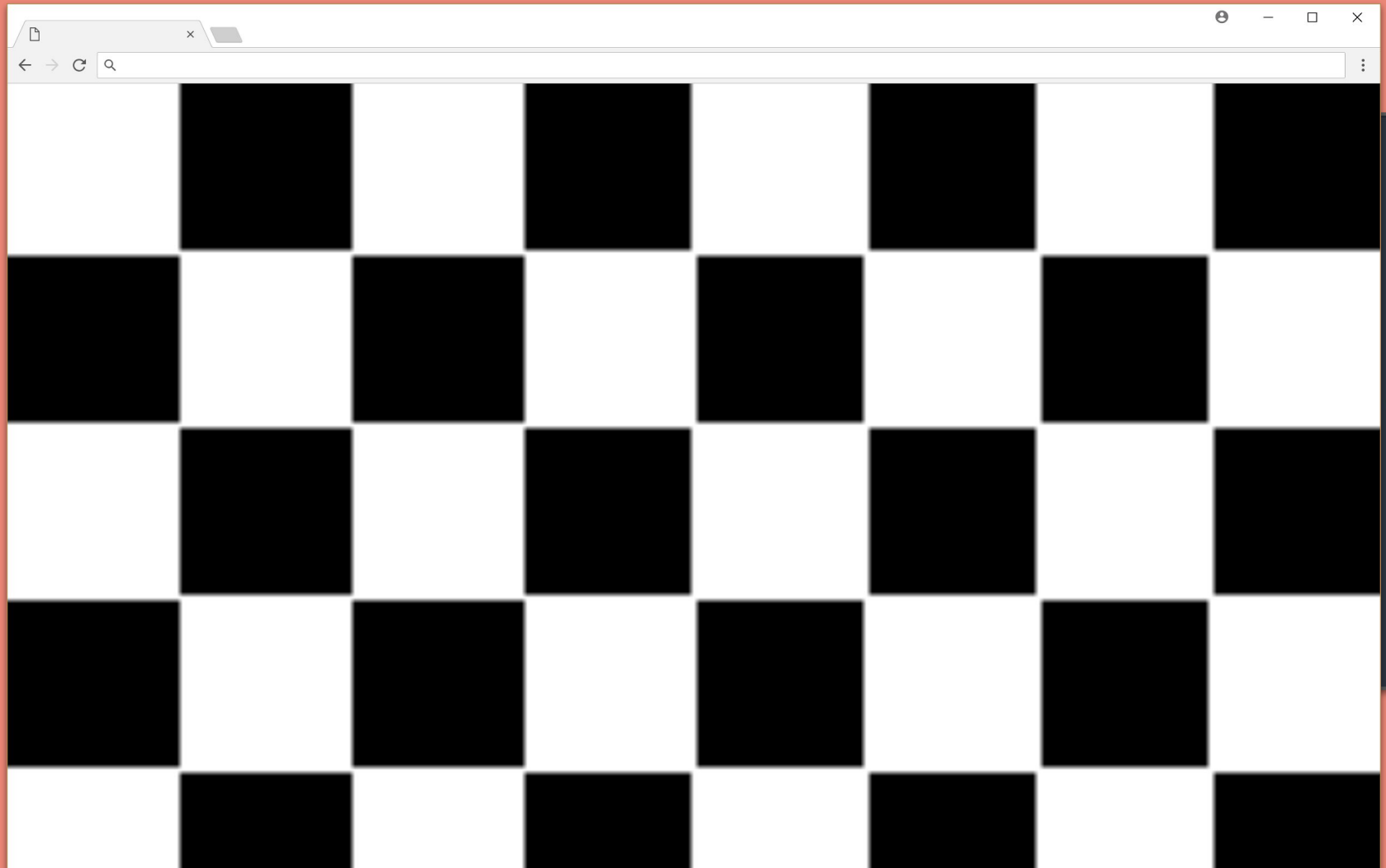


```
"utf-8"/>

ound: url(chessboard.png) top left / cover;
```



```
cover;
```

CSS Painting API Level 1

W3C Working Draft, 10 April 2018

paintlet.js

```
1 class ChessboardPainter {
2     paint (canvas, geometry, properties) {
3         // ... draw chessboard pattern ...
4     }
5 }
6
7 registerPaint('chessboard', ChessboardPainter);
```

index.html

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<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="utf-8"/>
    <script>
        CSS.paintWorklet.addModule('paintlet.js');
    </script>
    <style>
        body {
            background: paint(chessboard);
        }
    </style>
</head>
<body>
</body>
</html>
```

index.html

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<html lang="en">
<head>
    <meta charset="utf-8"/>
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        }
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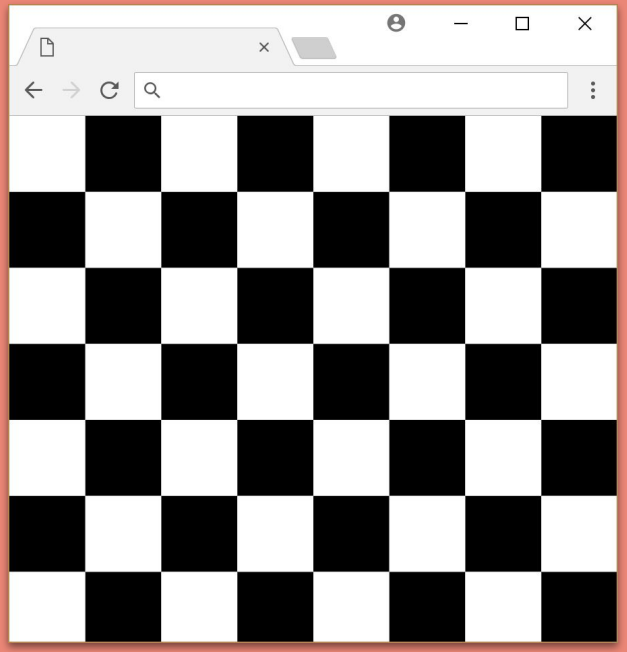
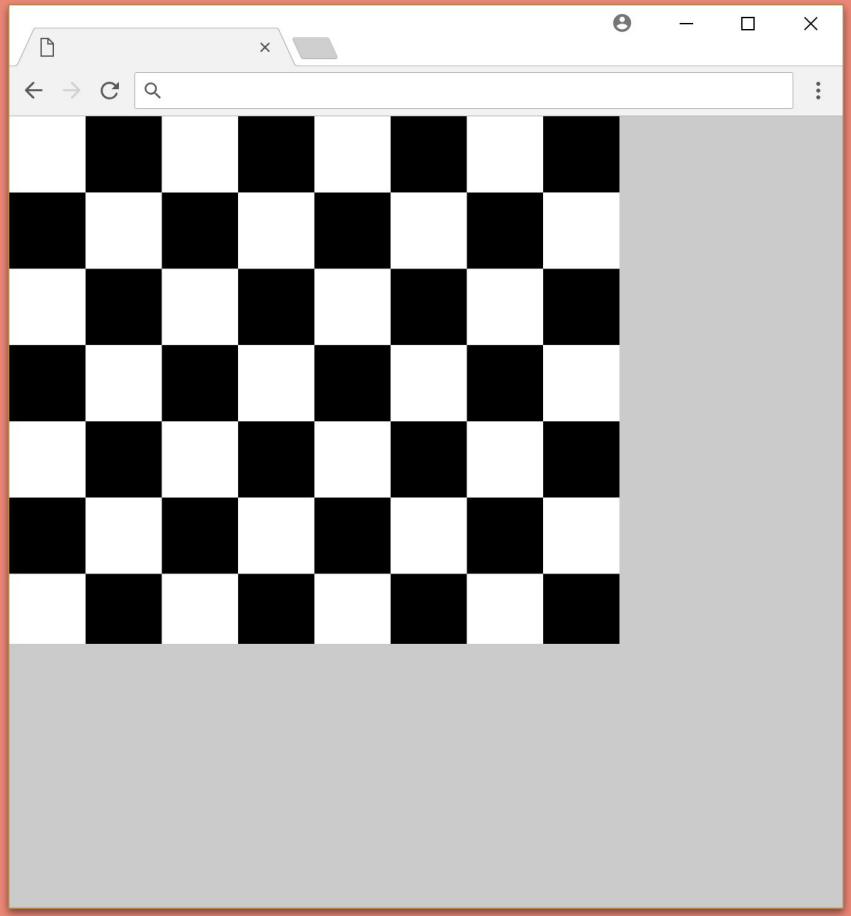
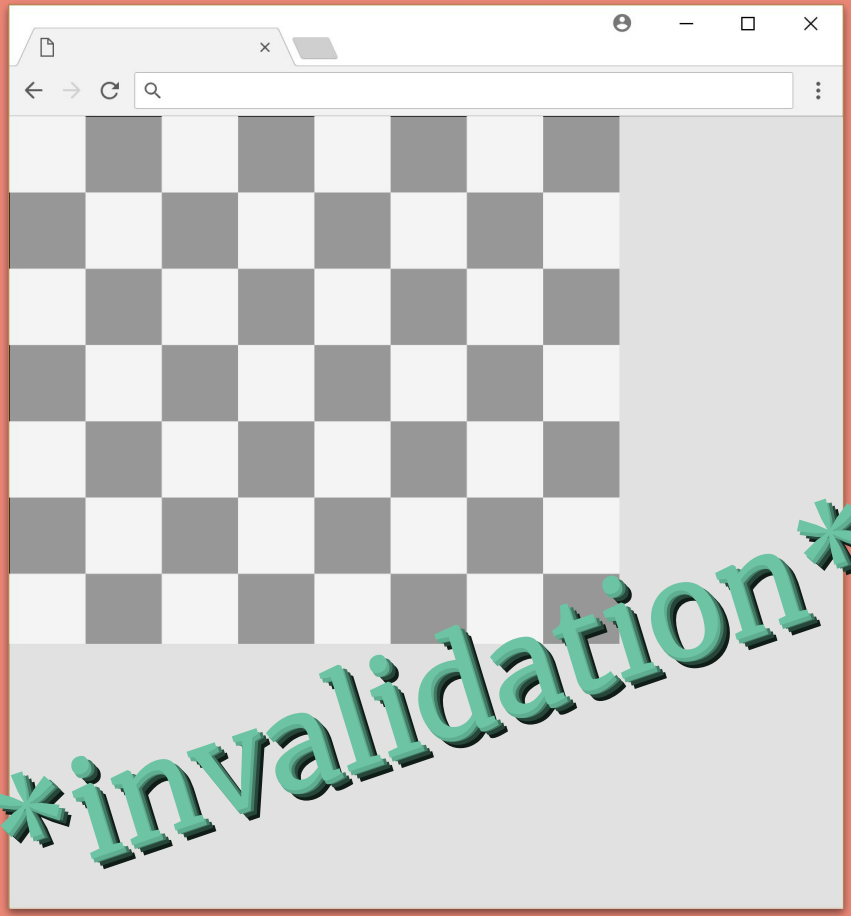
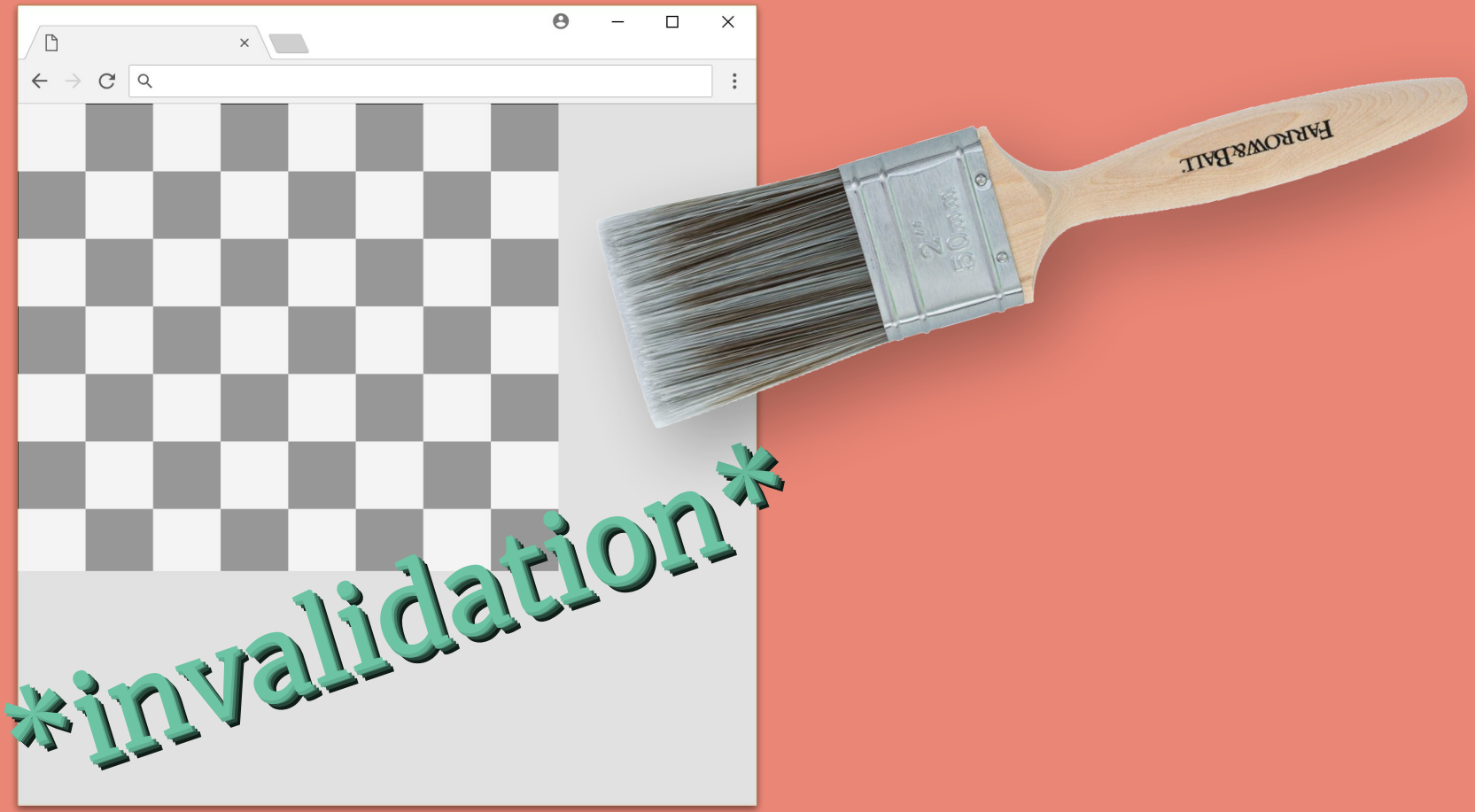
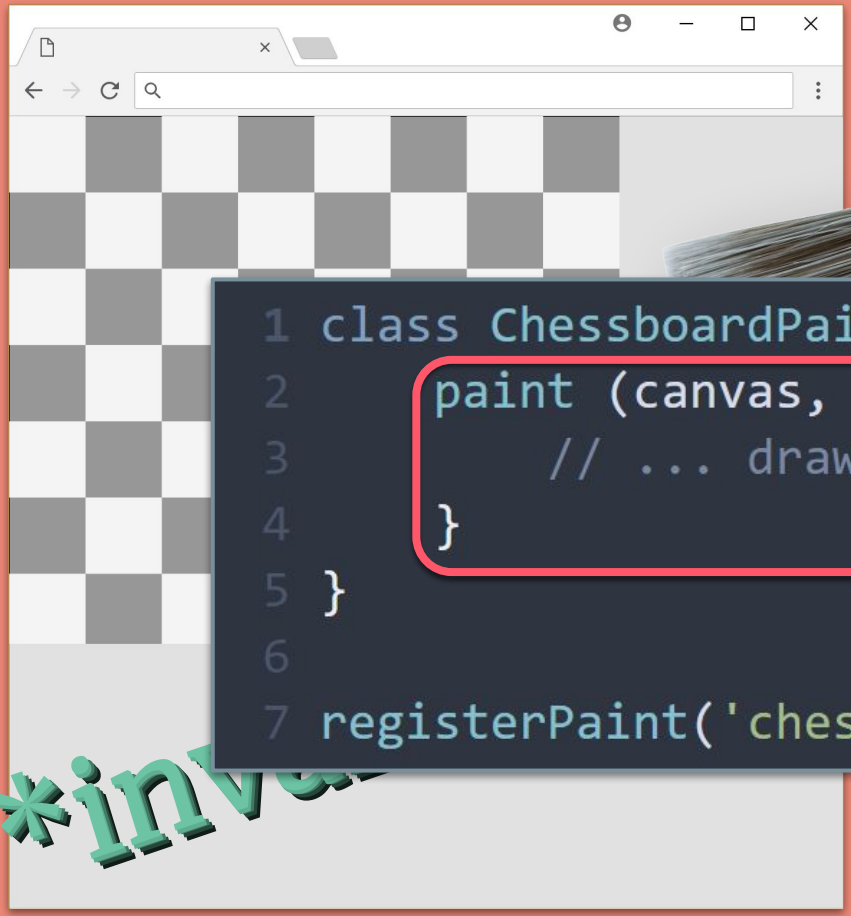





invalidation


FARROW&BALL
2"
50mm
invalidation

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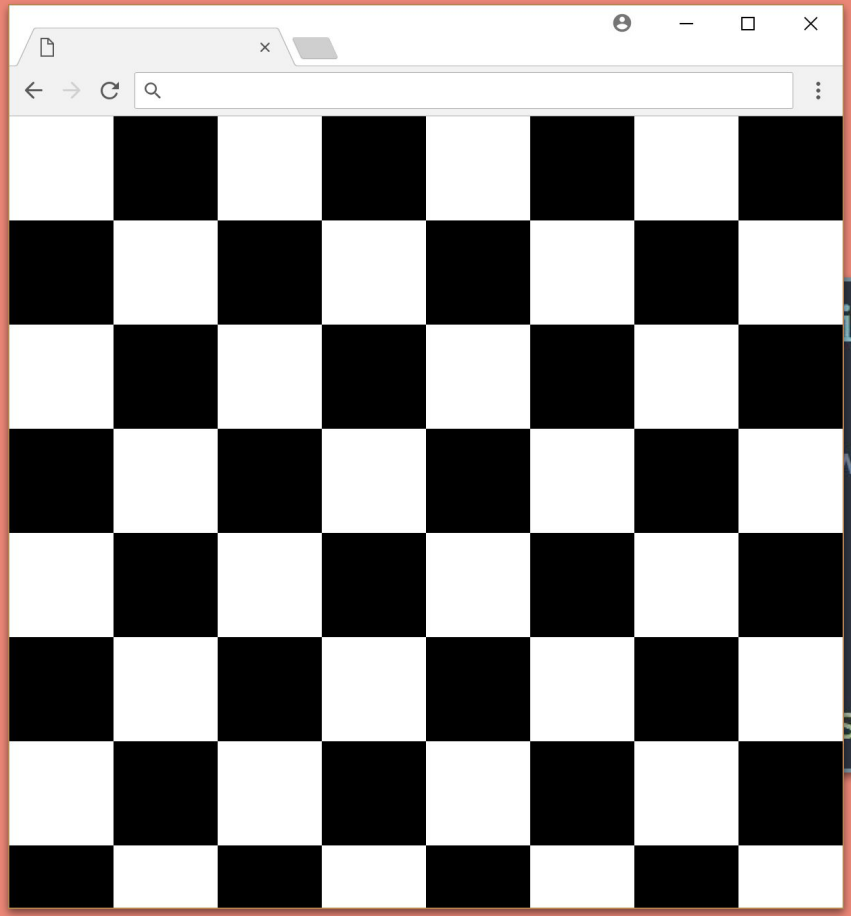
*inva



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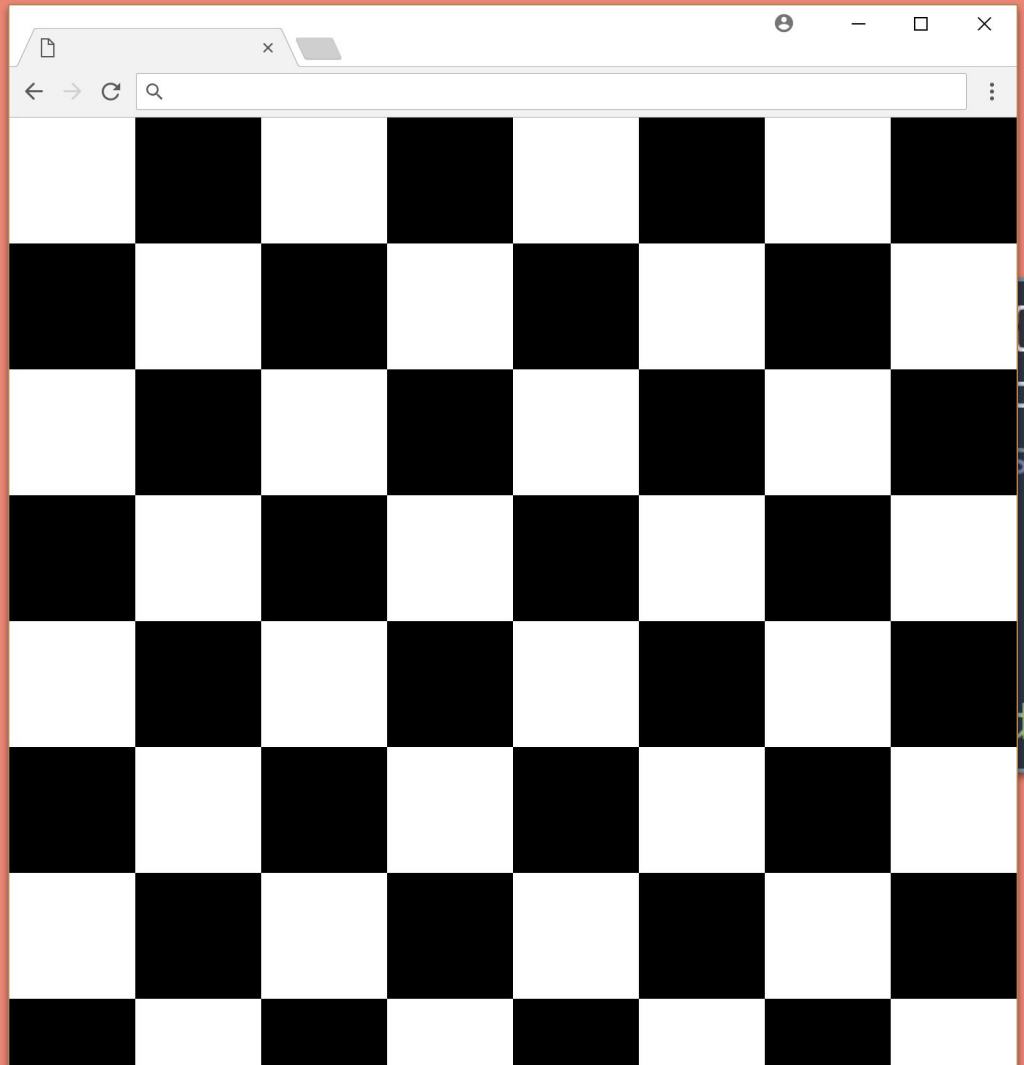

```
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sboard pattern ...

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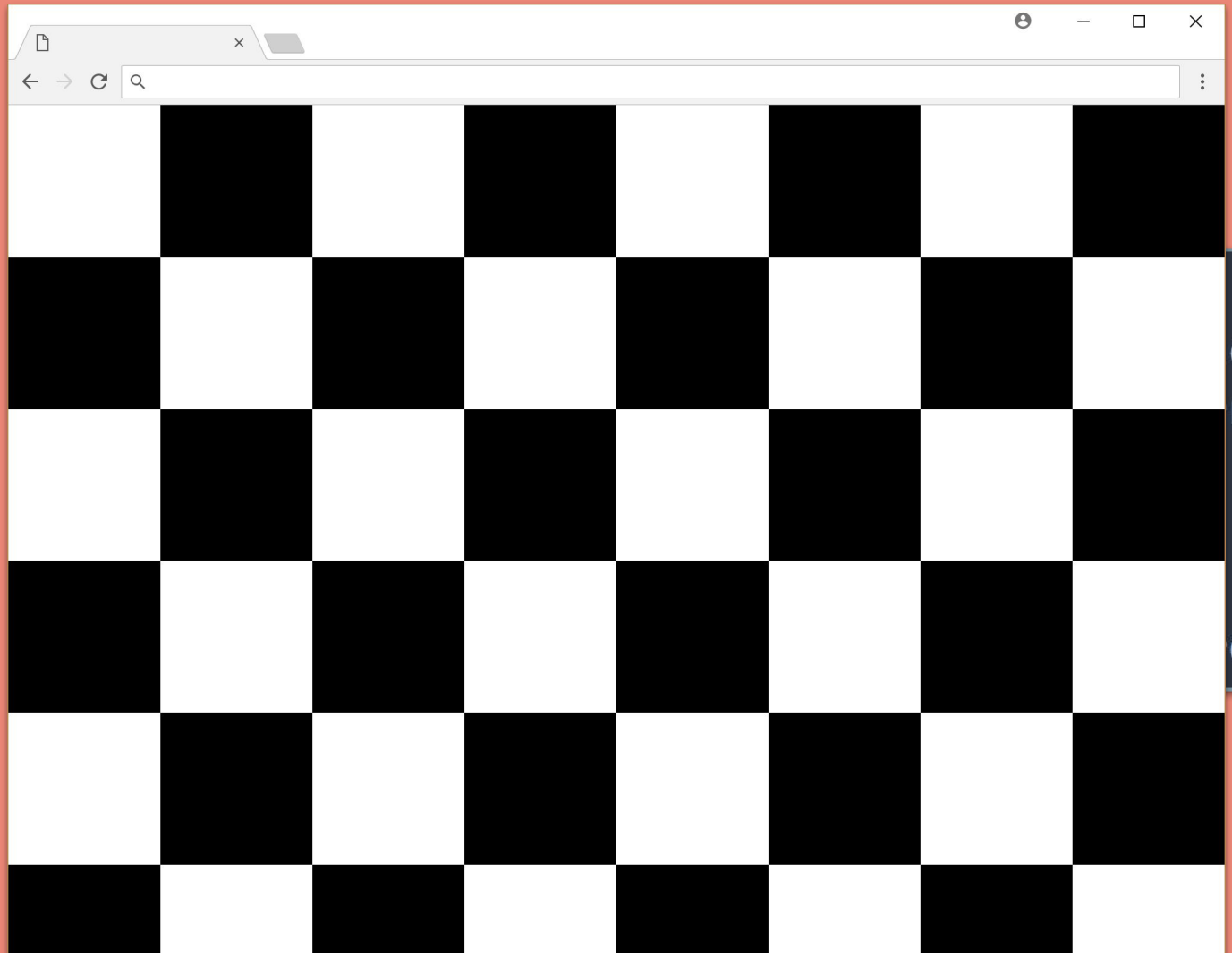
```



```
es) {
n ...

dPainter);
```

CSS Painting API Level 1

W3C Working Draft, 10 April 2018

§ 9. Security Considerations

There are no known security issues introduced by these features.

§ 10. Privacy Considerations

There are no known privacy issues introduced by these features.

```
a {
    background-image: paint(chessboard);
}
```

Click here

TODO

- ☑ find vulnerable feature
- ☐ leak visited bit for a URL
- ☐ exfiltrate visited bit
- ☐ amplify bandwidth

If https://ashleymadison.com is...

...unvisited

...visited

If https://ashleymadison.com is...

...unvisited

Attacker creates link pointing to https://dummy.com; visited = `false`

```
<a href="https://dummy.com">
    Click here
</a>
```

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Paintlets can’t communicate

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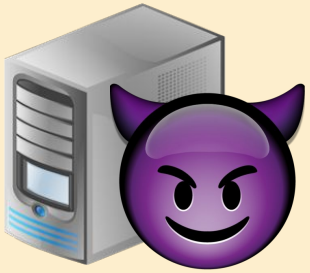

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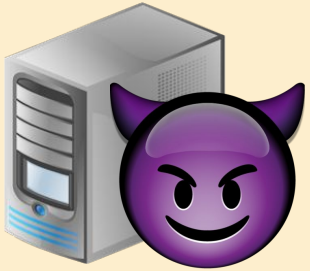
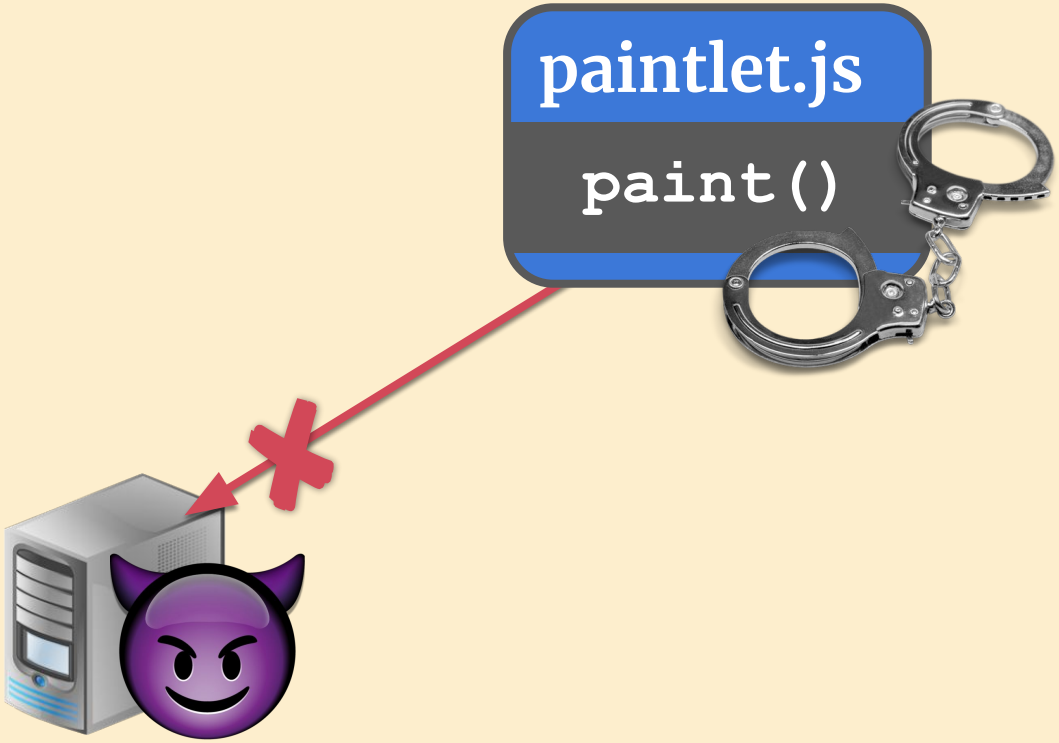


Paintlets can't communicate



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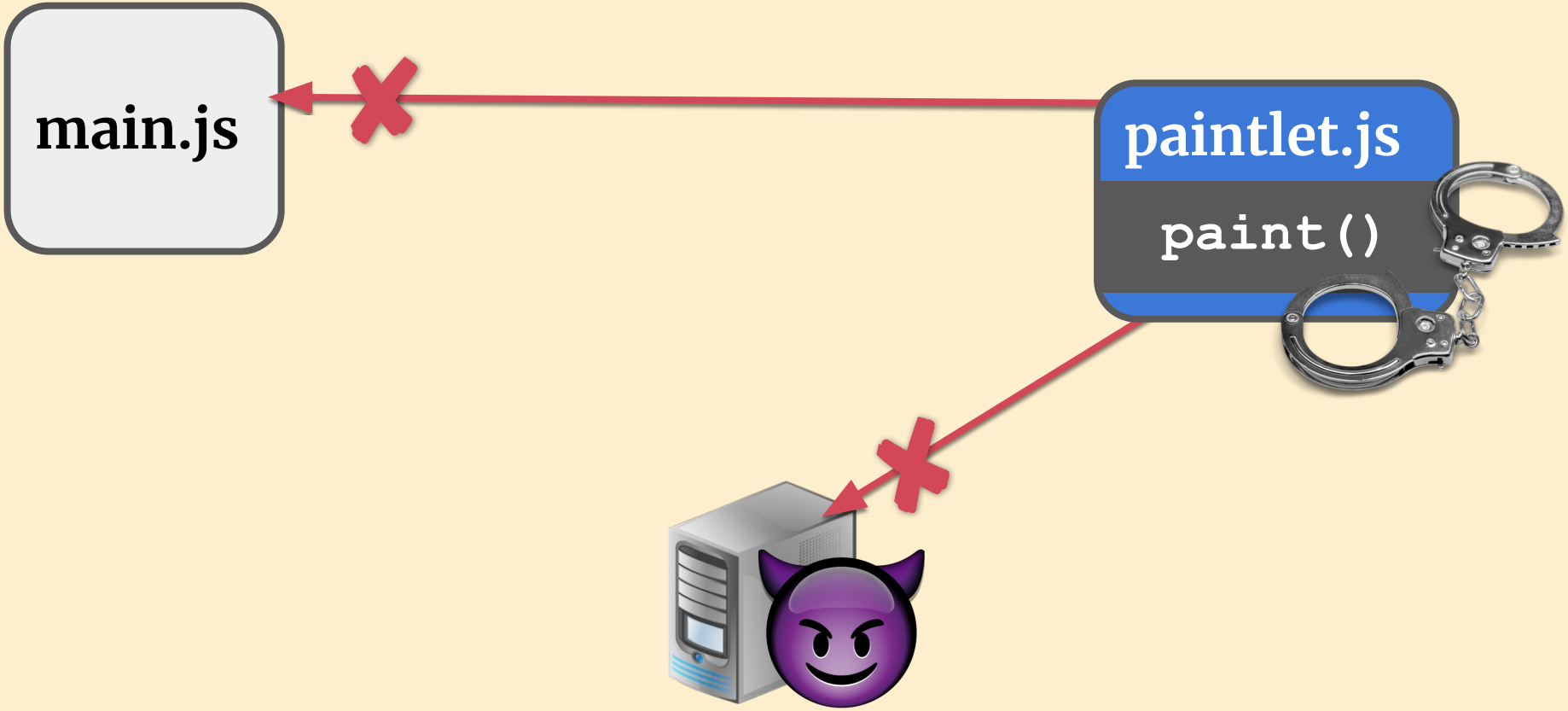

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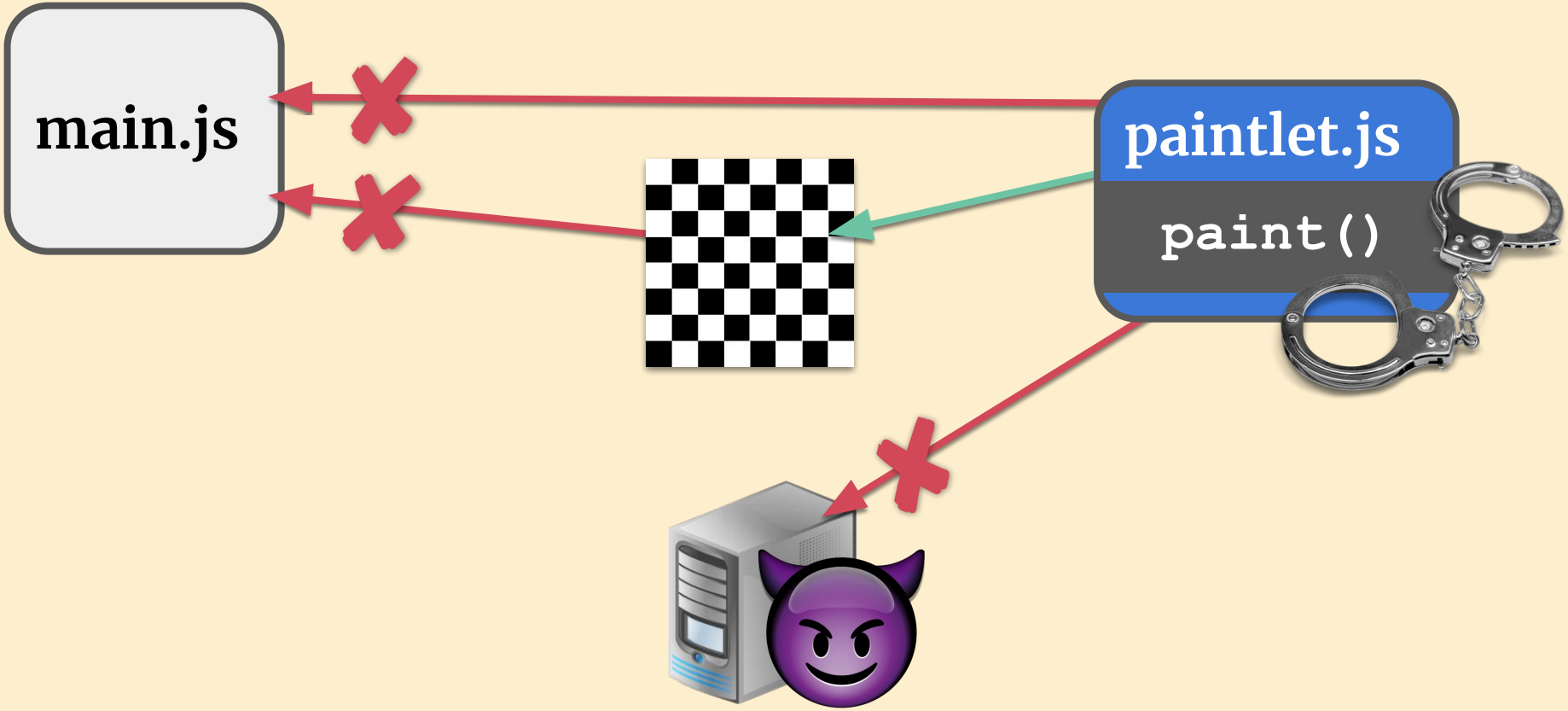
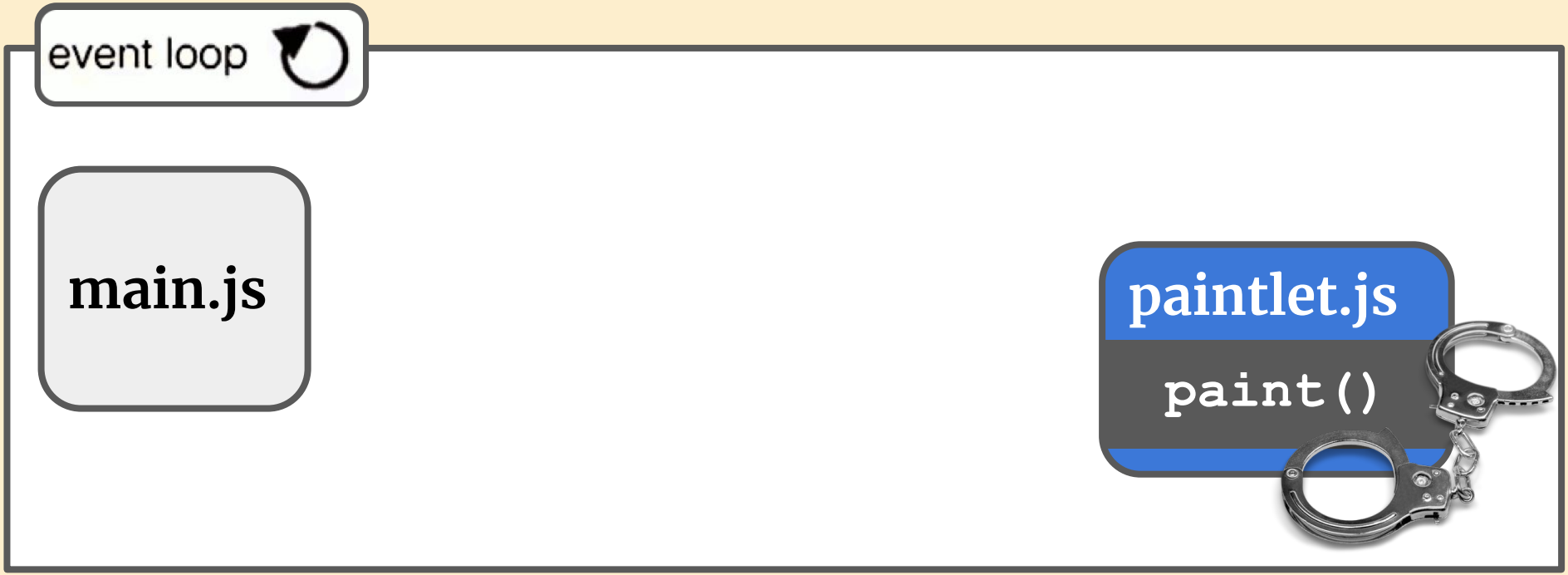
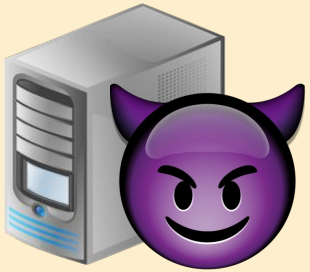



event loop
main.js
paintlet.js
paint()



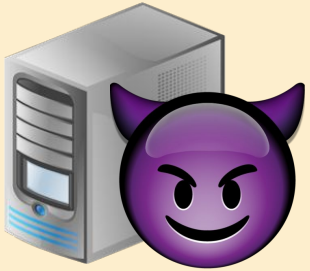
event loop

main.js

```
class ChessboardPainter {
    paint (canvas, geometry, properties) {
        sleep(20); // milliseconds
    }
}
```

paintlet.js

paint()



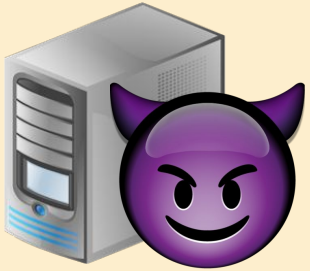
event loop

main.js

```
class ChessboardPainter {
    paint (canvas, geometry, properties) {
        sleep(20); // milliseconds
    }
}
```

paintlet.js

paint()



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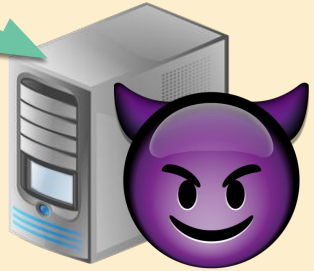

TODO

- ☑ find vulnerable feature
- ☑ leak visited bit for a URL
- ☑ exfiltrate visited bit
- ☐ amplify bandwidth

Timing attacks are slow :(

Timing attacks are slow :(

Click here

[max bandwidth: 60 URLs/sec]

Timing attacks are slow :(

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Timing attacks are slow :(

Other covert channels are fast :)

Timing attacks are slow :(

Other covert channels are fast :)

`registerPaint()` *covert channel*

`registerPaint()` *covert channel*

- `registerPaint()` function can be called *inside* paintlet sandbox
- Unintended behavior: can use `registerPaint()` to control width of element *outside* paintlet sandbox

`registerPaint()` covert channel

1) create weird HTML element outside paintlet

```
<!-- in web page HTML: -->
<div id="weirdElement"> </div>
<style>
    #weirdElement { display: inline; }
    #weirdElement::after {
        content: paint(myPainterIdentifier);
    }
</style>
```

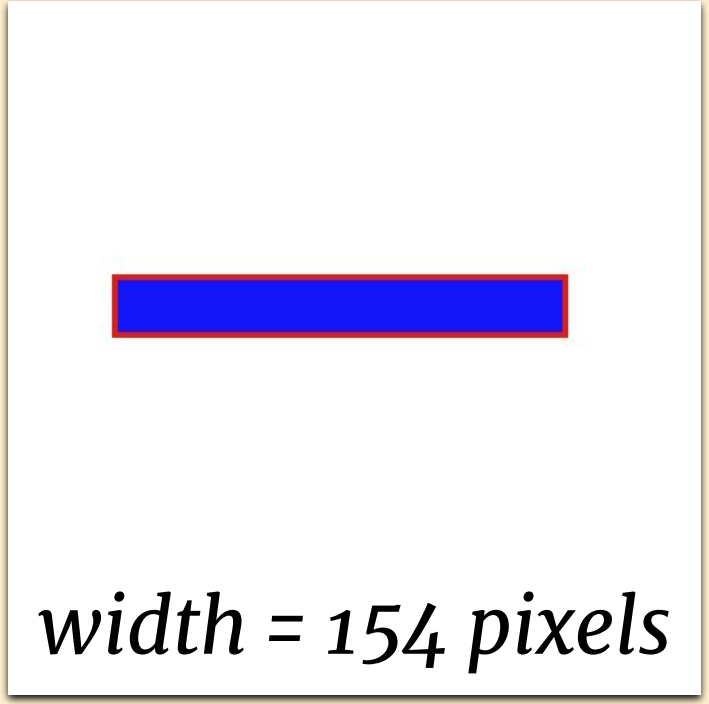
`registerPaint()` covert channel

2) call `registerPaint()` inside paintlet

```
// inside paintlet script:
registerPaint('myPainterIdentifier', PainterClass);
```

`registerPaint()` covert channel

3) weird element gets big width value



`registerPaint()` covert channel

3) weird element gets big width value

width = 154 pixels

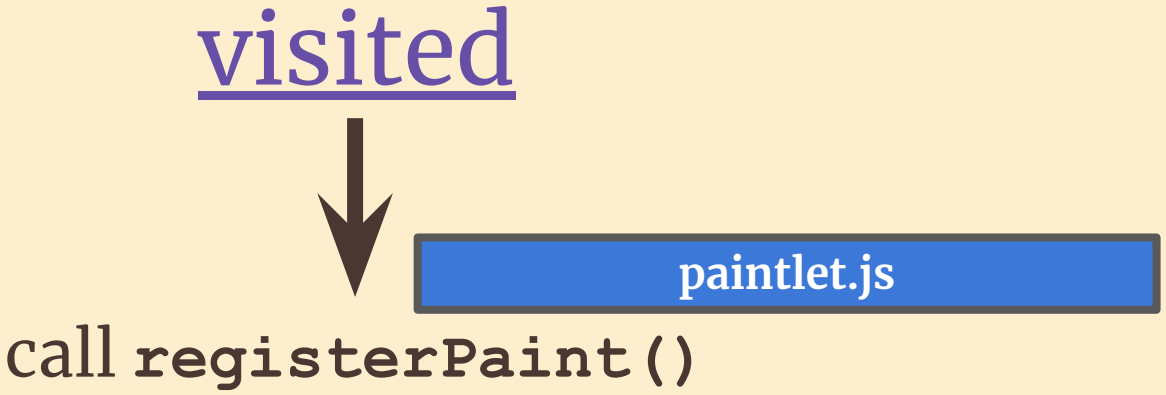
vs

width = 4 pixels

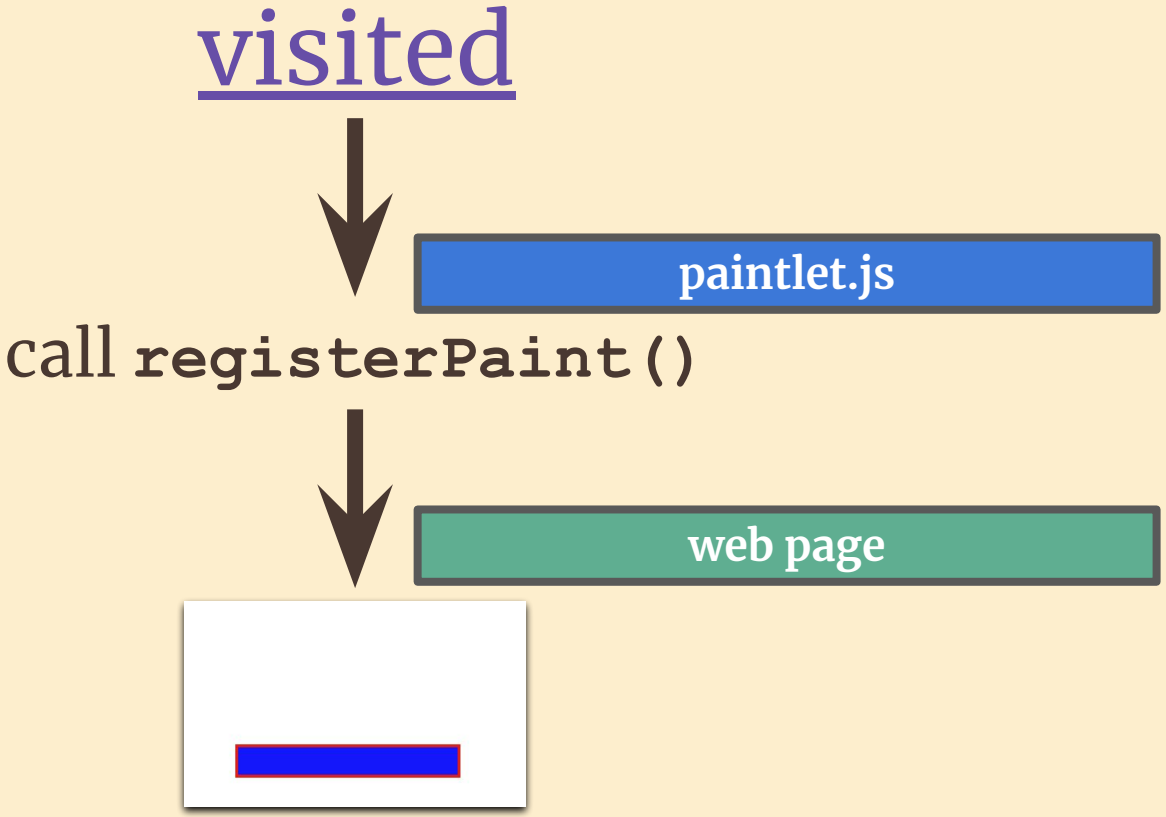
`registerPaint()` covert channel

visited

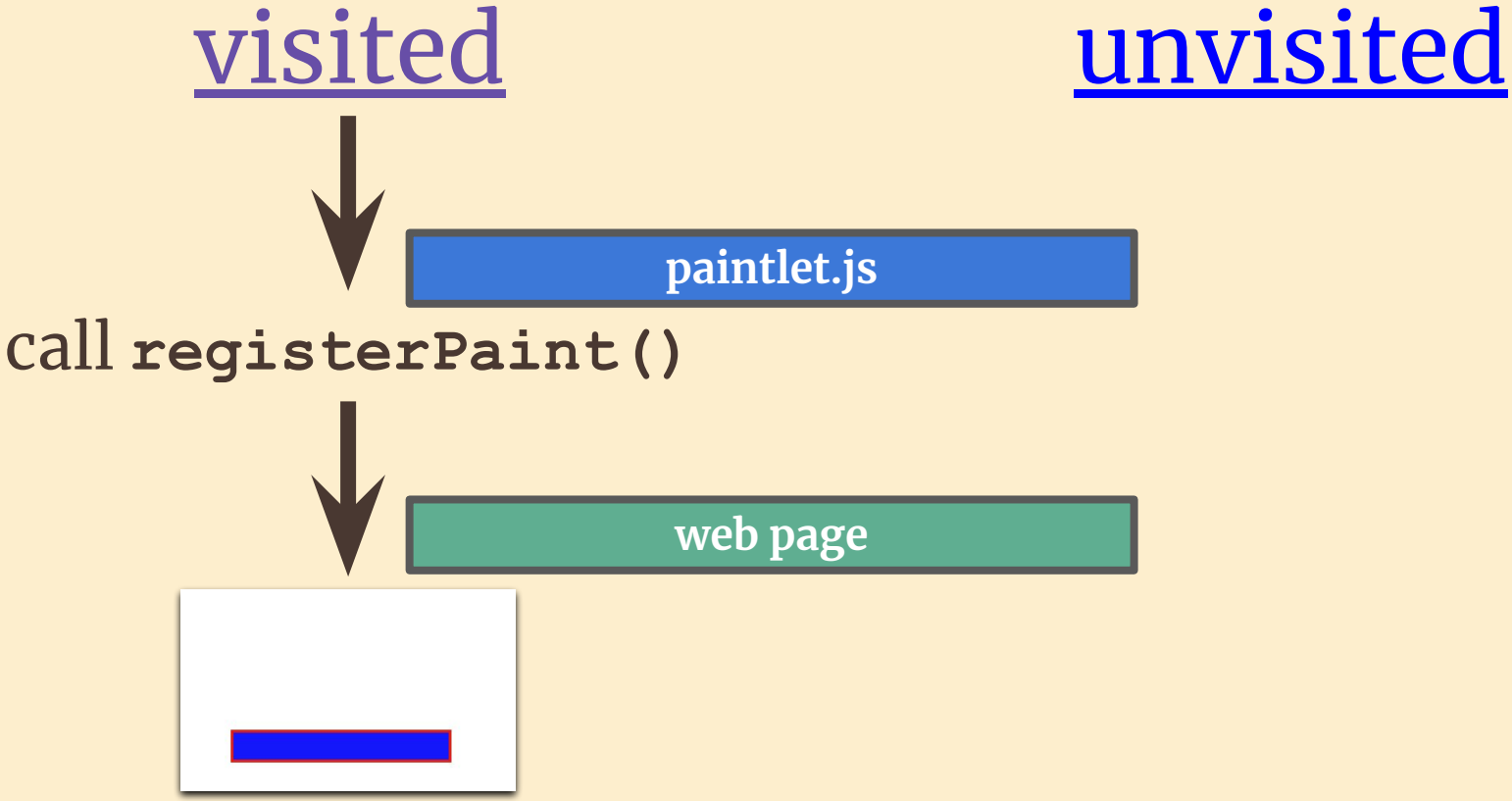
`registerPaint()` covert channel



`registerPaint()` covert channel



`registerPaint()` covert channel



`registerPaint()` covert channel

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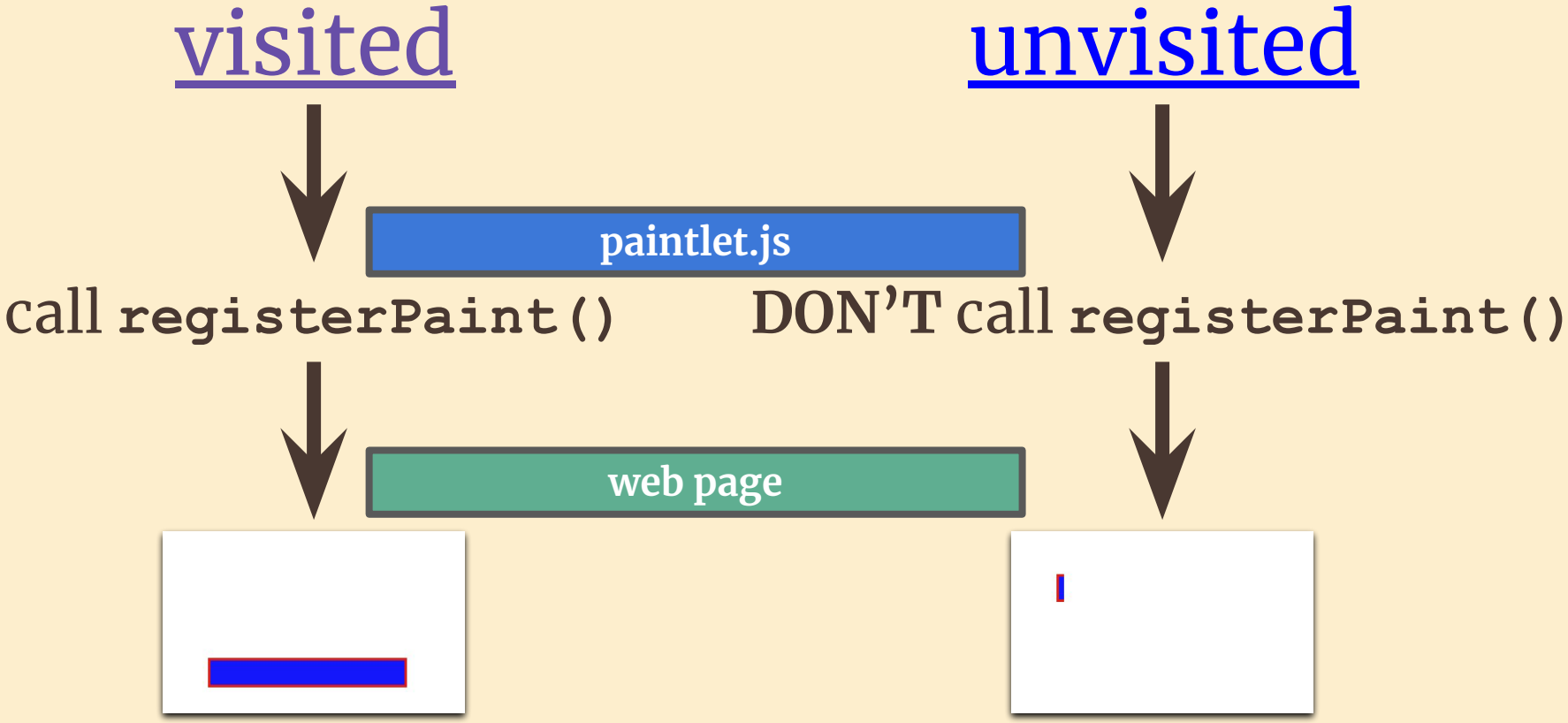
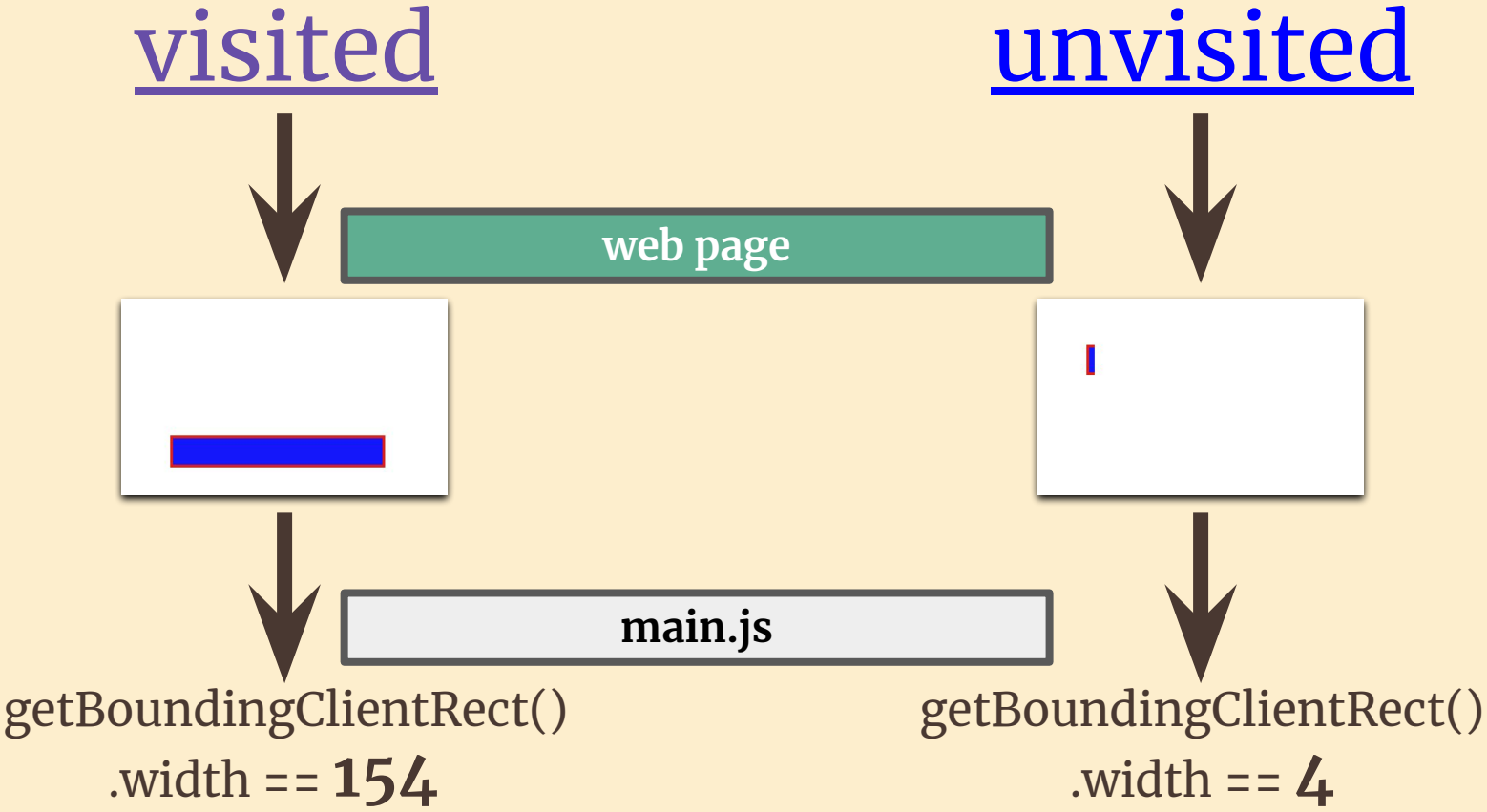


`registerPaint()` covert channel



`registerPaint()` covert channel

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Demo!

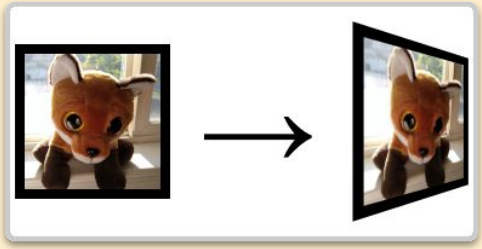
TODO

- ☑ find vulnerable feature
- ☑ leak visited bit for a URL
- ☑ exfiltrate visited bit
- ☑ amplify bandwidth

4 APIs, 4 attacks

- CSS Paint API
- CSS 3D transforms
- SVG `fill`-coloring
- JavaScript bytecode cache

Attack: CSS 3D transforms



Attacker makes a link expensive to render with CSS 3D transforms

Attacker rapidly toggles the link's destination between a *dummy URL* and a *target URL*

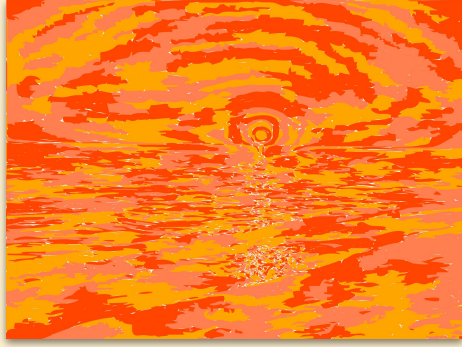
Browser doesn't need to re-render the link
→ paint performance is FAST

Browser does lots of expensive re-renders for the link
→ paint performance is SLOW

unvisited

visited

Attack: SVG `fill`-coloring



Attacker puts a complex SVG image inside a link

Attacker sets `fill`-styles to change SVG image's colors if link is visited

Attacker rapidly toggles the link's destination between a *dummy URL* and a *target URL*

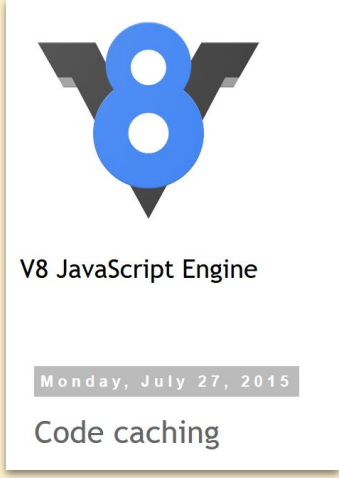
Browser doesn't need to re-render the link
→ paint performance is FAST

→ ***unvisited***

Browser does lots of expensive re-renders for the link
→ paint performance is SLOW

→ ***visited***

Attack: JavaScript bytecode cache



Attacker injects script from target site into their own page

Attacker measures script's compilation time

Browser has to compile script from scratch
→ compilation time is LONG

unvisited

Browser has script's bytecode in cache, skips most of compilation
→ compilation time is SHORT

visited

4 APIs, 4 attacks

- CSS Paint API
- CSS 3D transforms
- SVG `fill`-coloring
- JavaScript bytecode cache

2002 – initial disclosure

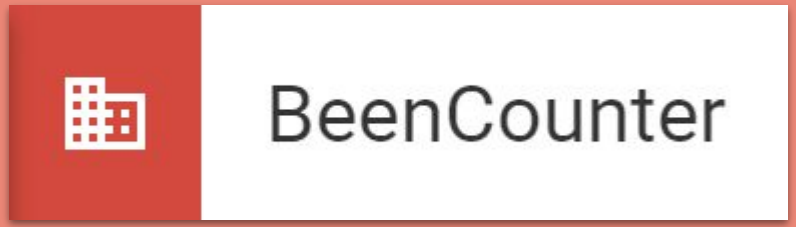
2010 – ~3,000 URLs/sec

An Empirical Study of Privacy-Violating Information Flows in JavaScript Web Applications

Dongseok Jang Ranjit Jhala Sorin Lerner Hovav Shacham

"Our survey shows that several popular sites, *including Alexa global top-100 sites*, use privacy-violating flows to exfiltrate information about users' browsing behavior."

SaaS = Sniffing as a Service

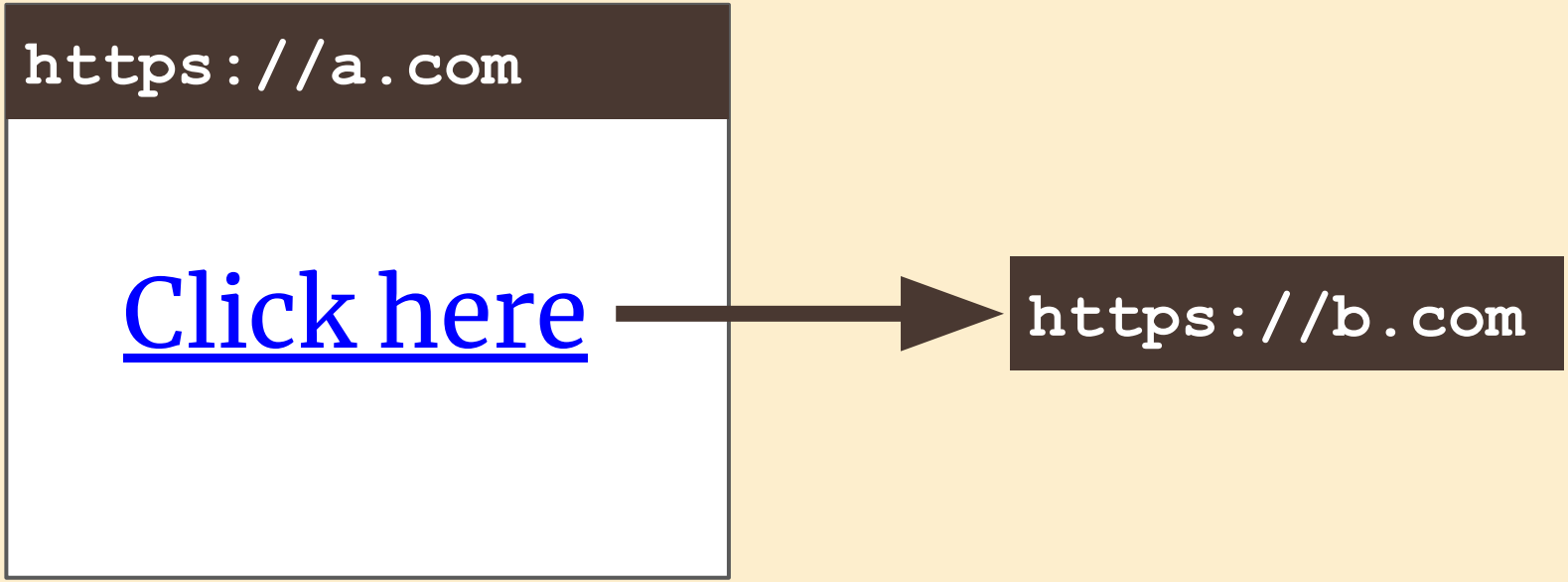


"Track which sites your visitors visit. Learn how many of them have been to your competitor's site or your advertising partner's site."

"Tealium's *patent-pending technology* lets you see the view-through traffic to your site by those who've been exposed to your press, or blog or video coverage."

Defense: “referrer-origin labels”

Defense: "referrer-origin labels"



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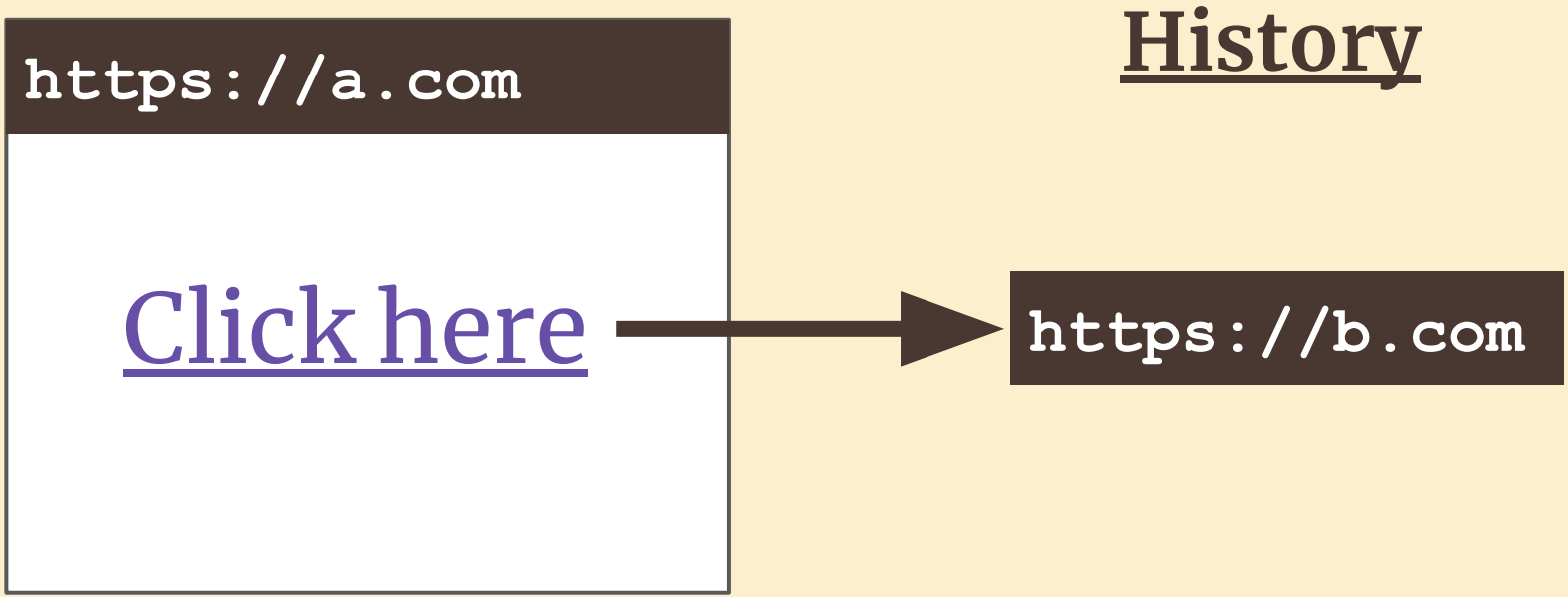

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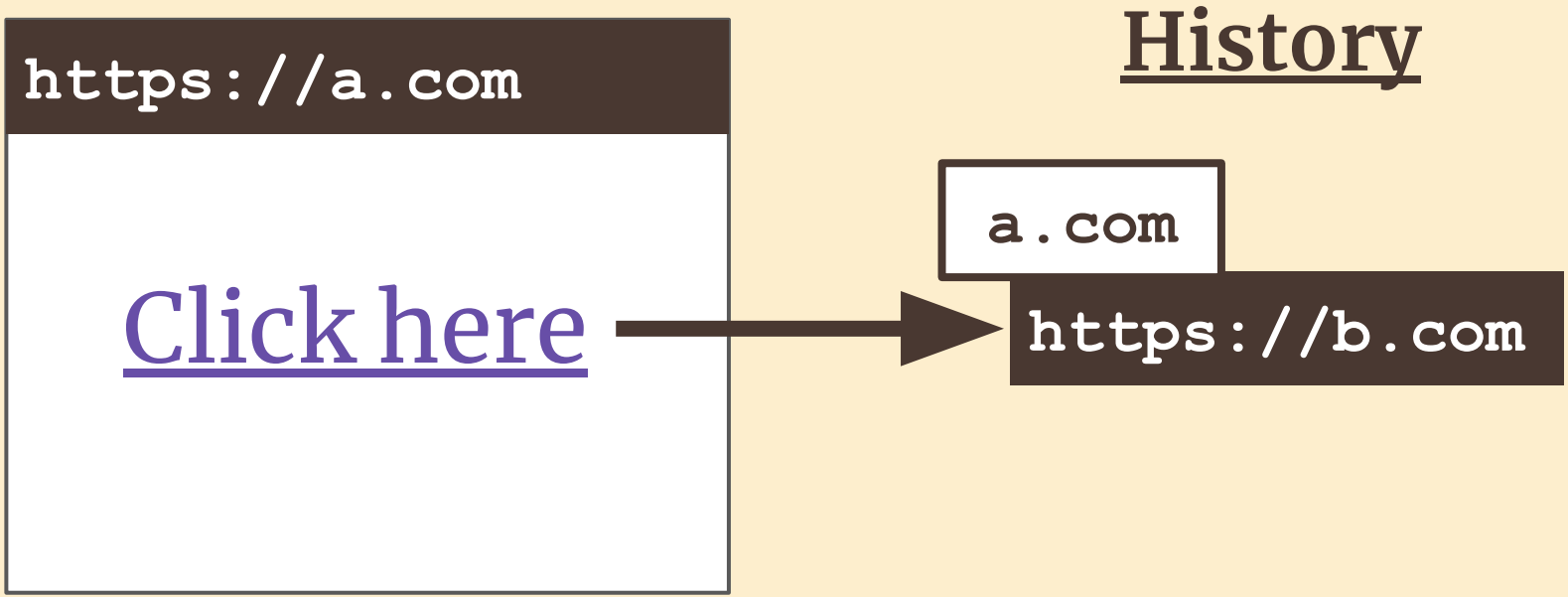

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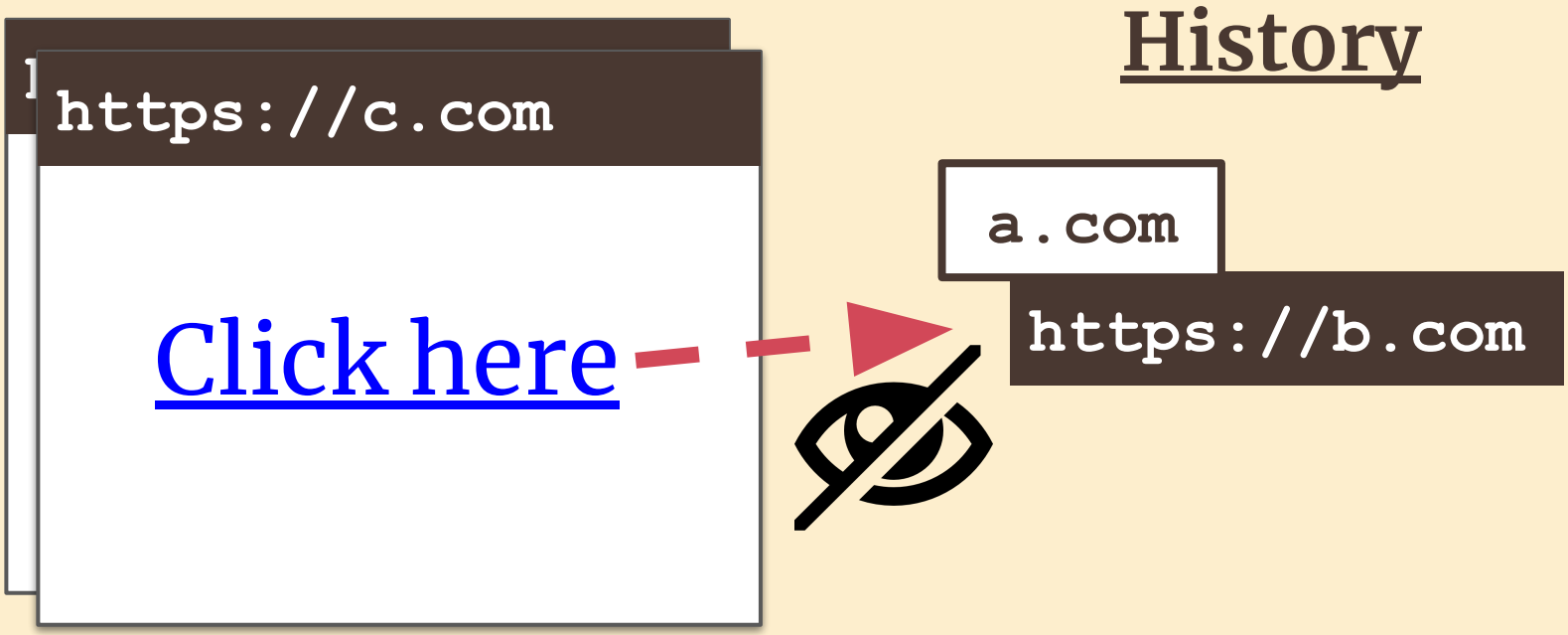

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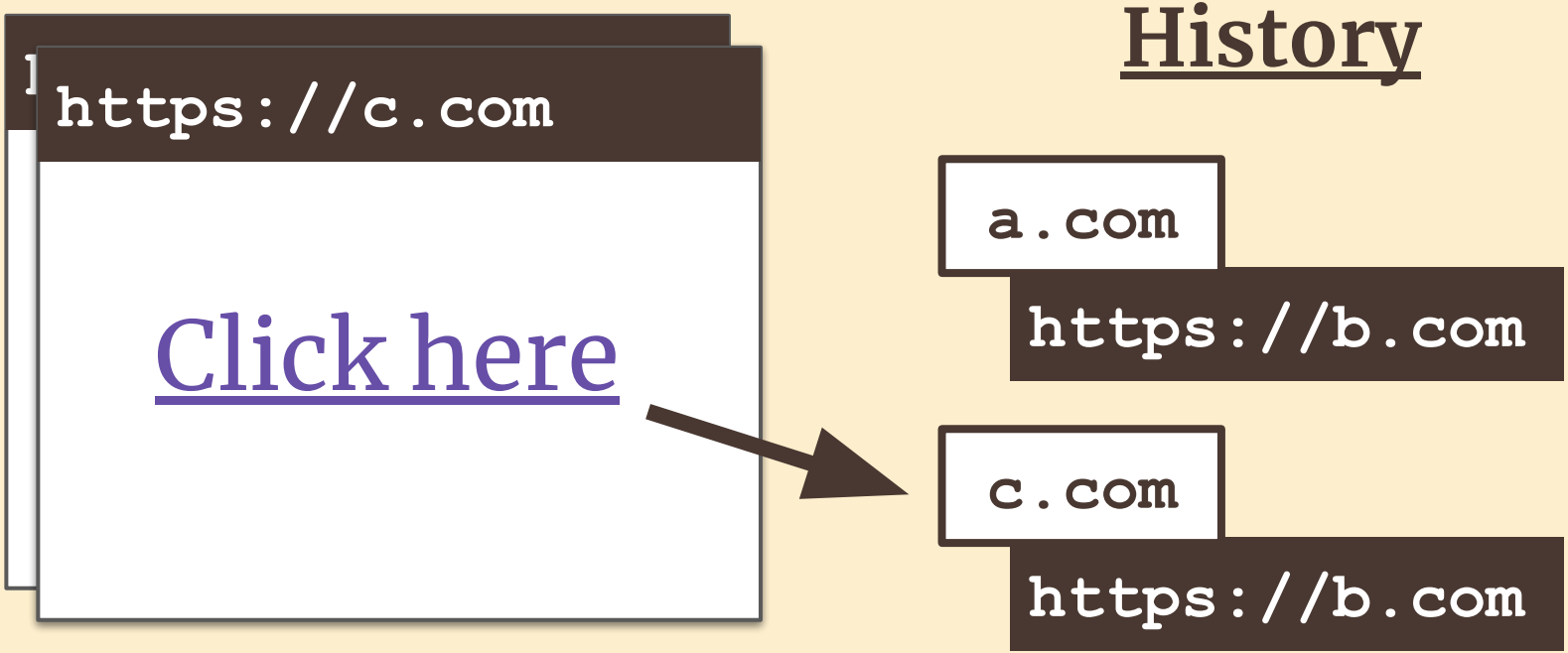
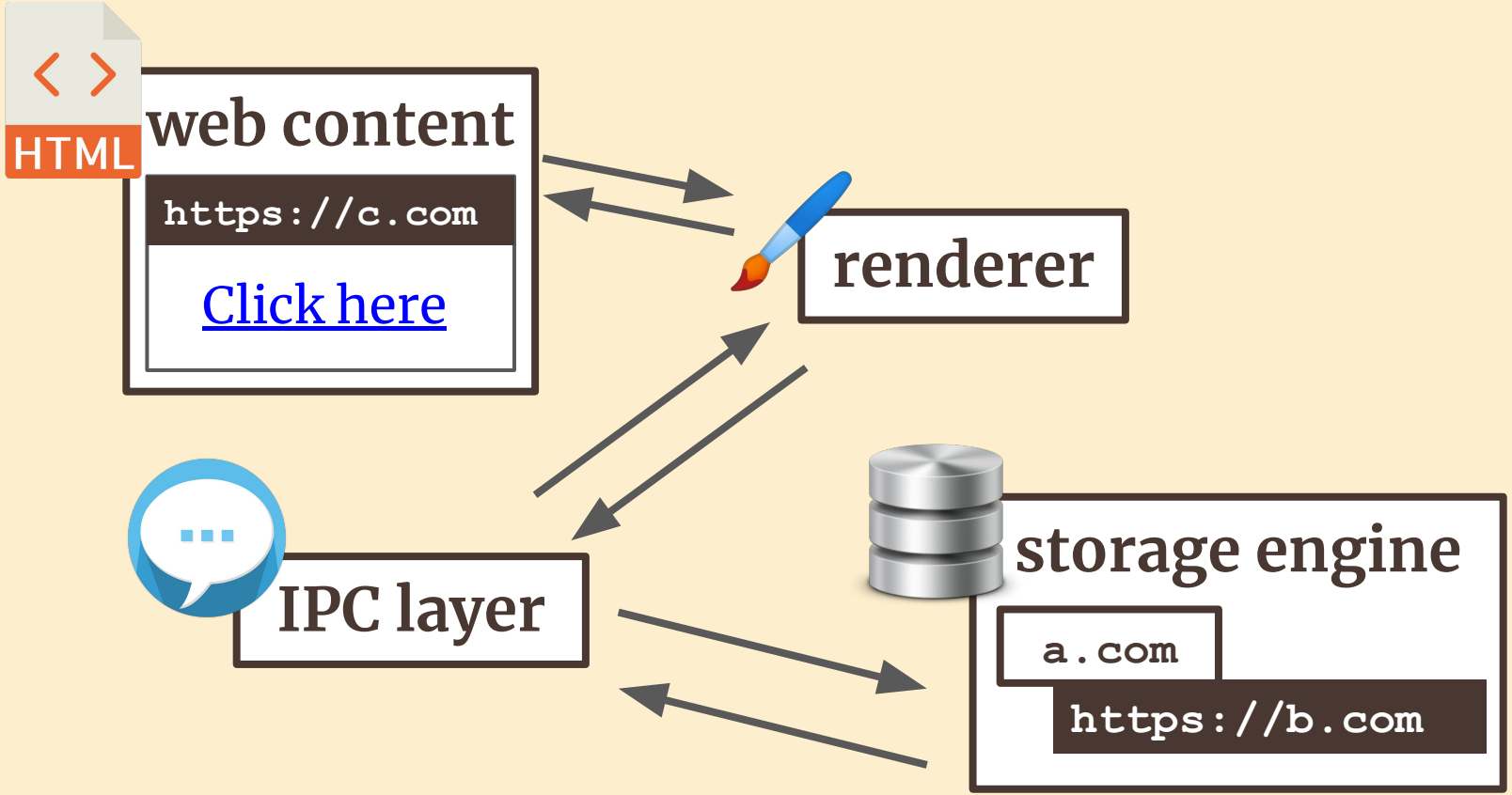


“Is https://b.com visited?”



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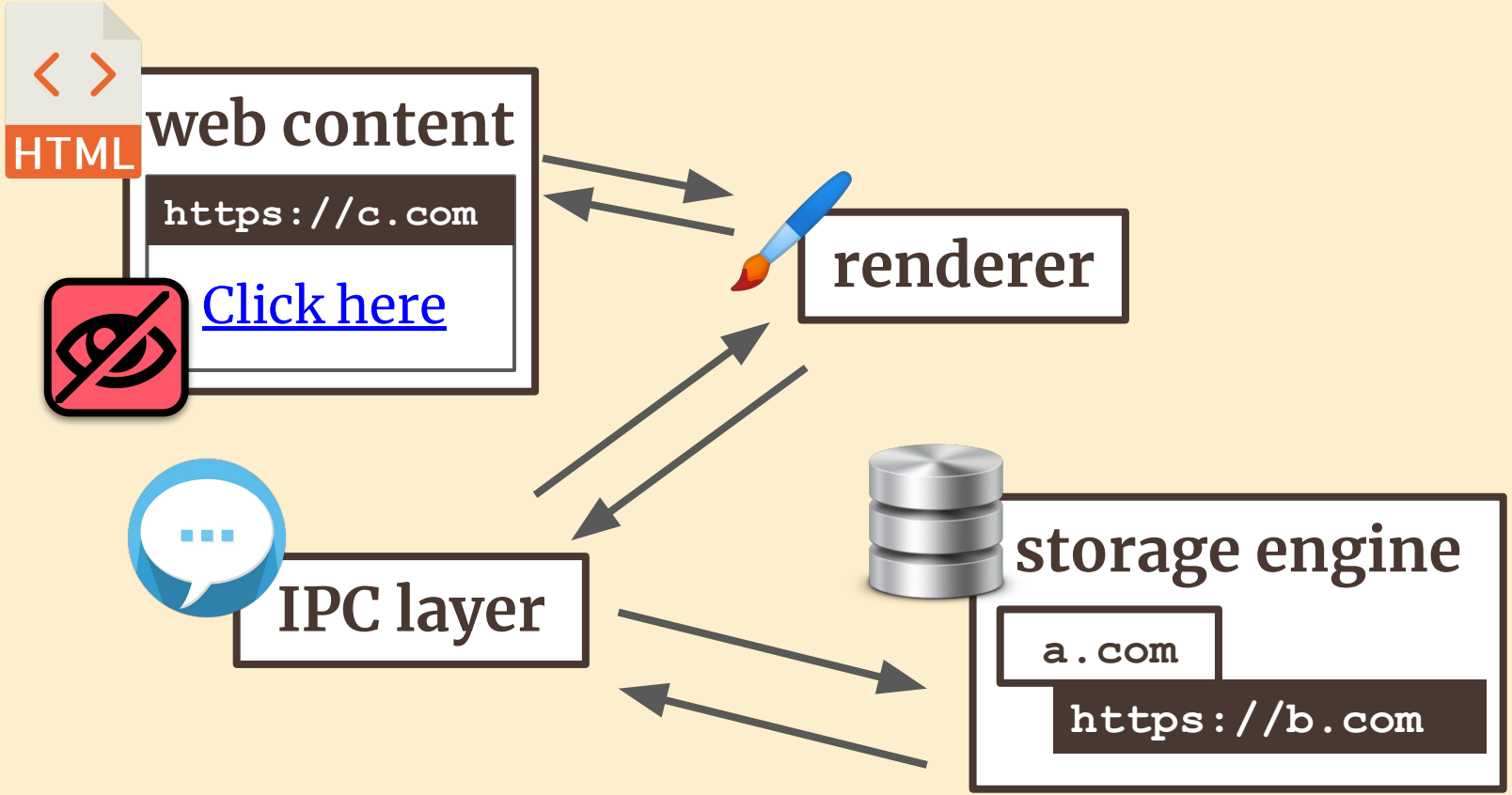

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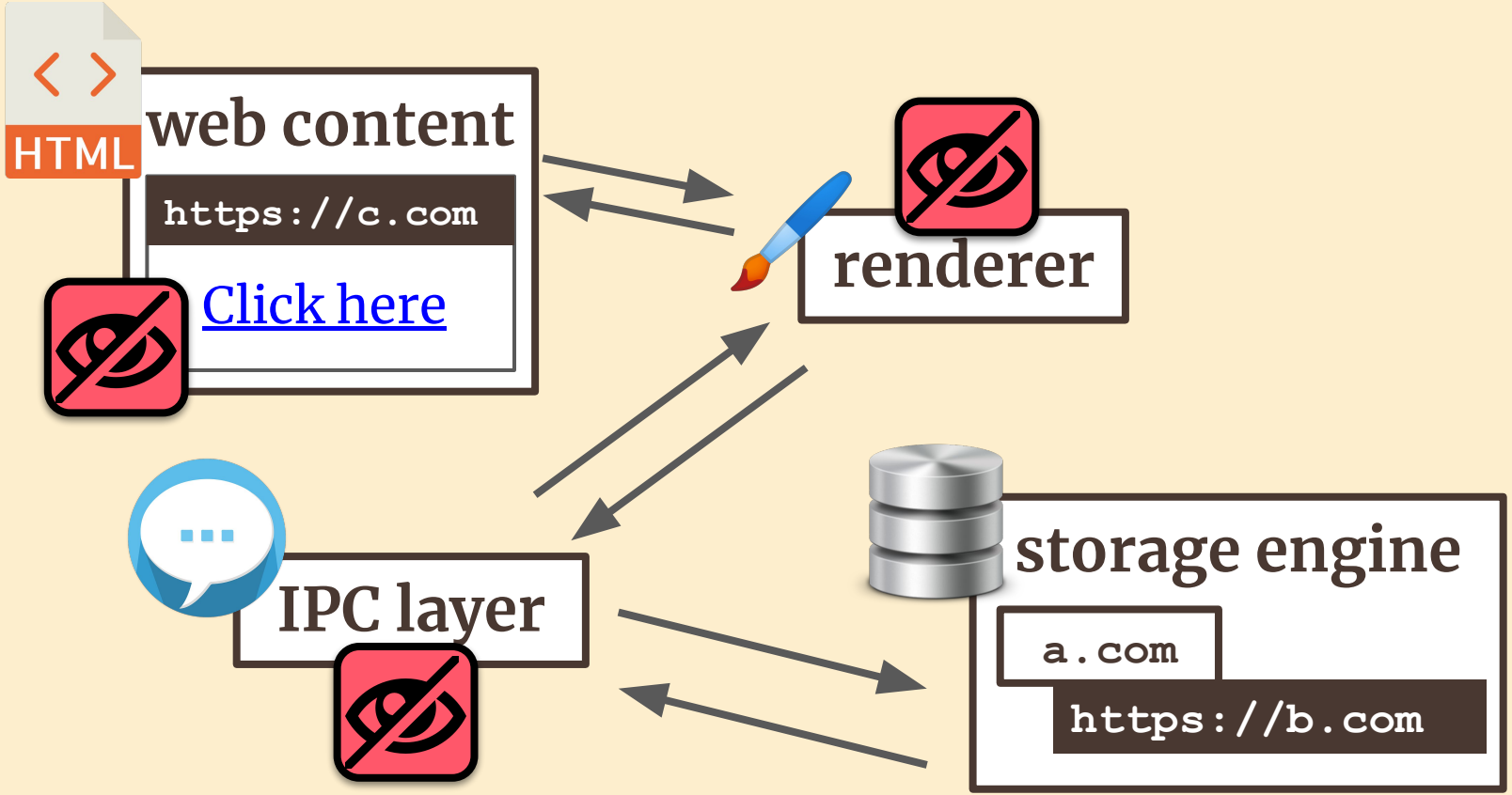

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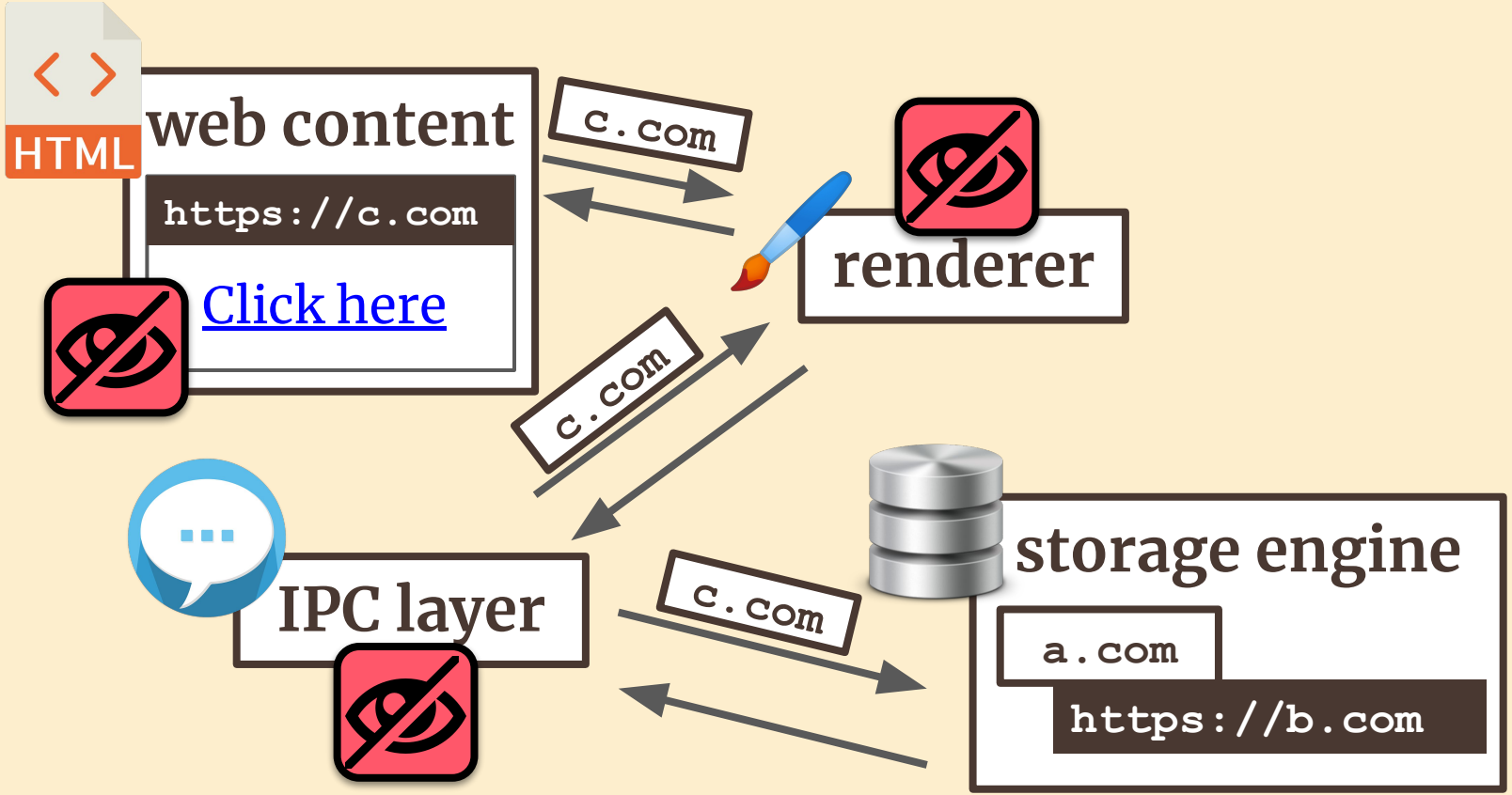

Defense: “referrer-origin labels”

1) Applies to:
   history data + cache data

2) Replaces prior mitigations

AmeliaBR commented

The Paint API vulnerability was unique because of its high-throughput. But the fundamental problem is that rendering of a web page relies on information that the web page authors should not be able to access. **And adding mitigations for each rendering pathway seems like trying to patch leaks with duct tape when you could just turn off the water at the faucet.**

And all that duct tape just makes a sticky tangle of so many language features. E.g., Other open bugs for `:visited` include #2263 #2844 #2884 #2037

- Attack: invisibly determine whether exact URLs are visited
  - 4 APIs, 4 attacks
  - Major browsers affected
  - CVE-2018-6137:
    our highest bandwidth (~6,000 URLs/sec)
- Defense: “referrer-origin labels”