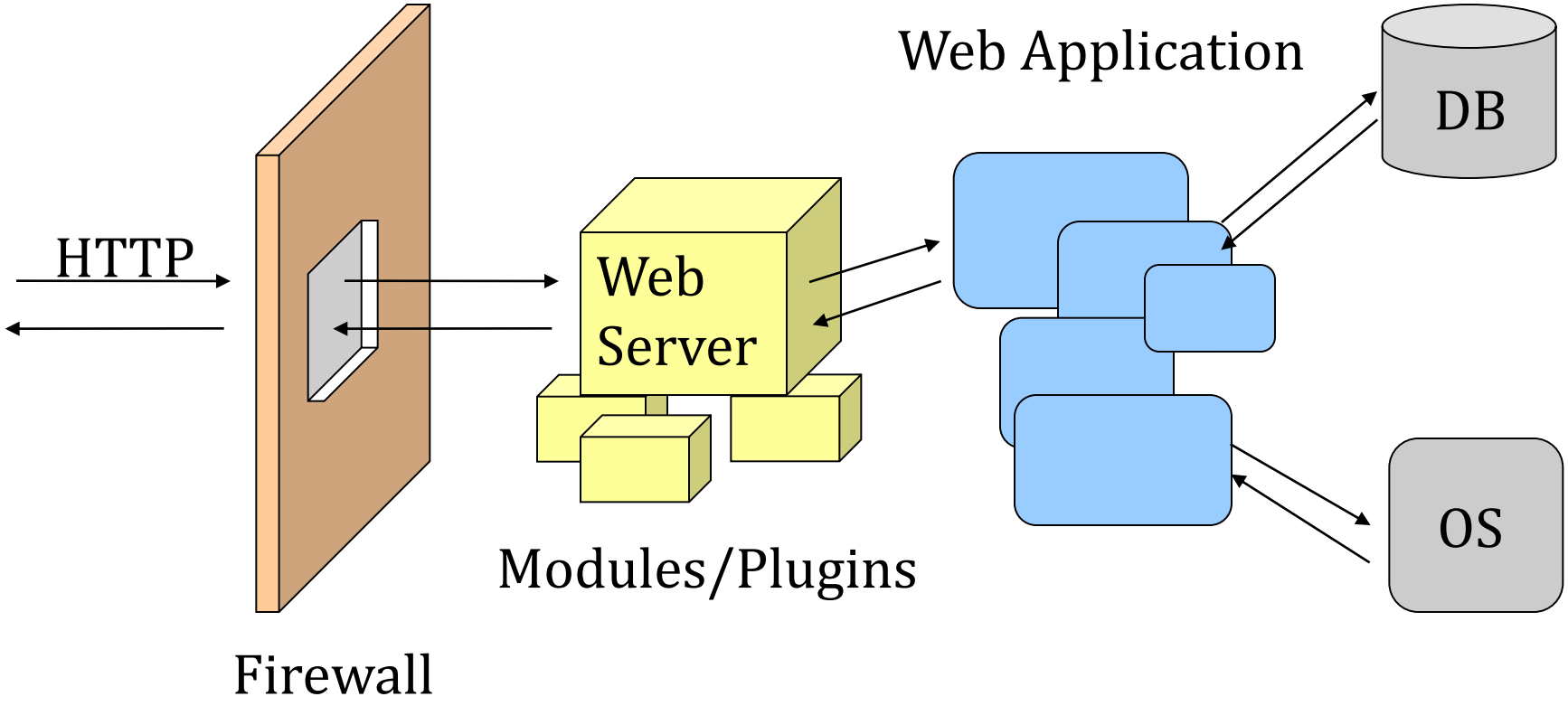
On a Typical Web Server



Web Server Scripting

- Allows easy implementation of functionality (also for non-programmers – Think: Is this good?)
- Example scripting languages are Perl, Python, ASP, JSP, PHP
- Scripts are installed on the Web server and return HTML as output that is then sent to the client
- Template engines are often used to power web sites
  - E.g., Cold Fusion, Cocoon, Zope
  - These engines often support/use scripting languages

Web Application Example

Objective: Write an application that accepts username and password and displays them

- First, we write HTML code and use forms

```
<html><body>
<form action="/scripts/login.pl" method="post">
Username: <input type="text" name="username"> <br>
Password: <input type="password" name="password"> <br>
<input type="submit" value="Login" name="login">
</form>
</body></html>
```

Web Application Example

Second, here is the corresponding Perl script that prints the username and password passed to it:

```
#!/usr/local/bin/perl
uses CGI;
$query = new CGI;
$username = $query->param("username");
$password = $query->param("password");
…
print "<html><body> Username: $username <br>
Password: $password <br>
</body></html>";
```

OWASP

The Open Web Application Security Project (www.owasp.org)

- OWASP is dedicated to helping organizations understand and improve the security of their web applications and web services.
- The Top Ten vulnerability list was created to point corporations and government agencies to the most serious of these vulnerabilities.
- Web application security has become a hot topic as companies race to make content and services accessible though the web. At the same time, attackers are turning their attention to the common weaknesses created by application developers.

OWASP Top 10 (2007)

1 Injection Flaws **(1) (1 in 2013, and still in 2017, #3 in 2021)**
2 Broken Authentication and Session Management **(2)**
3 Sensitive Data Exposure **(-)**
4 XML External Entities **(-)**
5 Broken Access Control **(-)**
6 Security Misconfiguration **(-)**
7 Cross Site Scripting (XSS) **(3)**
8 Insecure Deserialization **(-)**
9 Using Components with Known Vulnerabilities **(-)**
10 Insufficient Logging & Monitoring **(-)**

Later!

- Insecure Direct Object Reference **(4)**
- Cross Site Request Forgery **(8)**
- Information Leakage and Improper Error Handling

Common Root for Many Problems

- Web applications use input from HTTP requests (and occasionally files) to determine how to respond
  - Attackers can tamper with any part of an HTTP request, including the URL, query string, headers, cookies, form fields, and hidden fields, to try to bypass the site's security mechanisms
  - Common input tampering attempts include XSS, SQL Injection, hidden field manipulation, buffer overflows, cookie poisoning, remote file inclusion...
- Some sites attempt to protect themselves by filtering known malicious input
  - Problem: There are many different ways of encoding information

Unvalidated Input

- A surprising number of web applications use only client-side mechanisms to validate input
  - Client side validation mechanisms are easily bypassed, leaving the web application without any protection against malicious parameters
- How to determine if you are vulnerable?
  - Any part of an HTTP request that is used by a web application without being carefully validated is known as a “tainted” parameter
  - The simplest way: to have a detailed code review, searching for all the calls where information is extracted from an HTTP request

Unvalidated Input

- How to protect yourself?
  - Ensure all parameters are validated before they are used
  - A centralized component or library is likely to be the most effective … remember complete mediation?
- Parameters should be validated against a "positive" specification that defines:
  - Data type (string, integer, real, etc…); Allowed character set; Minimum and maximum length; Whether null is allowed; Whether the parameter is required or not; Whether duplicates are allowed; Numeric range; Specific legal values (enumeration); Specific patterns (regular expressions)
  - Trying to specify negative specification (i.e., signature matching) is bound to fail / be incomplete

Injection Flaws

"***Injection flaws*** occur when an application sends *untrusted** data to an *interpreter*"

--- OWASP

* usually means attacker-controlled

Injection Attacks Overview

- Many webapps invoke interpreters
  - SQL
  - Shell command
  - Sendmail
  - LDAP
  - ...
- Interpreters execute the commands specified by the parameters or input data
  - If the parameters are under control of the user and are not properly sanitized, the user can inject its own commands in the interpreter

SQL Injection

SQL Injections

SQL injection is a particularly widespread and dangerous form of injection attack that consists of **injecting SQL commands into the database engine** through an existing application

Relational Databases

- A relational database contains one or more relations (i.e., tables)
  - Each table is identified by a name
  - Each table has a fixed number of named and *typed* columns
- Tables contain records (rows) with data

userID	Name	LastName	Login	Password
1	John	Smith	jsmith	hello
2	Adam	Taylor	adamt	qwerty
3	Daniel	Thompson	dthompson	dthompson

Structured Query Language (SQL)

- SQL is a data manipulation language (DML) to access databases and can
  - Query the content of a database (`SELECT`)
  - Modify data in a database:
    - `Insert` add rows
    - `Update` modify rows
    - `Delete` remove rows
- SQL is standard (ANSI and ISO) but most DBMS implement language extensions in addition to the standard

SQL Data Definition Language (DDL)

- SQL DML operates ***on data*** in relations
- DDL defines and modifies the ***structure of relations*** in the database
  - {CREATE,ALTER,DROP} TABLE
  - Assign types to columns
    e.g., `INT`, `CHAR`, `geography` (ellipsoidal spatial)
  - Default values
  - Referential integrity
  - Constraints (`NOT NULL`, `UNIQUE`, etc.)
- DDL and DML parsed by the same SQL engine

SQL – SELECT Definition

```
SELECT [ ALL | DISTINCT [ ON ( expression [, ...] ) ] ]
    * | expression [ [ AS ] output_name ] [, ...]
    [ FROM from_item [, ...] ]
    [ WHERE condition ]
    [ GROUP BY expression [, ...] ]
    [ HAVING condition [, ...] ]
    [ WINDOW window_name AS ( window_definition ) [, ...] ]
    [ { UNION | INTERSECT | EXCEPT } [ ALL ] select ]
    [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST | LAST } ] [,
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
    [ FOR { UPDATE | SHARE } [ OF table_name [, ...] ] [ NOWAIT ] [...] ]

where from_item can be one of:

    [ ONLY ] table_name [ * ] [ [ AS ] alias [ ( column_alias [, ...] ) ] ]
    ( select ) [ AS ] alias [ ( column_alias [, ...] ) ]
    with_query_name [ [ AS ] alias [ ( column_alias [, ...] ) ] ]
    function_name ( [ argument [, ...] ] ) [ AS ] alias [ ( column_alias [, ...] | colu
    function_name ( [ argument [, ...] ] ) AS ( column_definition [, ...] )
```

SQL Example

To extract the last name of a user from the previous table

```
mysql> SELECT LastName FROM users WHERE UserID = 1;
+----------------+
| LastName       |
+----------------+
| Smith          |
+----------------+
1 row in set (0.00 sec)
```

SQL Example

Extract information on user based on username + password (e.g., to perform authentication during login)

```
mysql> SELECT * FROM users WHERE login =‘jsmith‘ AND
password = ‘hello‘;
+--------+------+----------+--------+----------+
| UserID | Name | LastName | Login  | Password |
+--------+------+----------+--------+----------+
| 1      | John | Smith    | jsmith | hello    |
+--------+------+----------+------- +----------+
1 row in set (0.00 sec)
```

SQL Injections

- To exploit a SQL injection flaw, the attacker must find a parameter that the web application uses to construct a database query
- By carefully embedding malicious SQL commands into the content of the parameter, the attacker can trick the web application into forwarding a malicious query to the database
- The consequences are particularly damaging, as an attacker can obtain, corrupt, or destroy database contents

SQL Injections

- Not a DB or web server problem
  It is a flaw in the web application!
  - Many programmers are still not aware of this problem
  - Many of the tutorials and demo “templates” are vulnerable
  - Even worse, many of solutions posted on the Internet are not good enough

Simple SQL Injection Example

Perl script looks up *username* and *password*

```
…
$query = new CGI;
$username = $query->param(“username”);
$password = $query->param(“password”);
…
$sql_command = “select * from users where
username=‘$username’ and password=‘$password’”;
$sth = $dbh->prepare($sql_command)
…
```

No Validation!

Simple SQL Injection Example

- If the user enters a ‘ (single quote) as the password, the SQL statement in the script would become:
  - `select * from users where login =‘ ‘ and password = ‘‘‘`
  - An SQL error message would be generated

- If the user enters (injects): ‘ or login =‘jsmith as the password, the SQL statement in the script would become:
  - `select * from users where login =‘ ‘ and password = ‘‘ or login = ‘jsmith‘`
  - Hence, a *different* SQL statement has been injected than what was originally intended by the programmer!

Obtaining Information using Errors

- Errors returned from the application might help the attacker (e.g., ASP – default behavior)
  - Username: ' union select sum(id) from users

    Microsoft OLE DB Provider for ODBC Drivers error '80040e14' [Microsoft][ODBC SQL Server Driver][SQL Server]Column 'users.id' is invalid in the select list because it is not contained in an aggregate function and there is no GROUP BY clause.

    /process_login.asp, line 35
- Make sure that you do not display unnecessary debugging and error messages to users.
  - For debugging, it is always better to use log files (e.g., error log).

Some SQL Attack Examples

- `select * …;`
  `insert into user values(“user”,”h4x0r”);`
  - Attacker inserts a new user into the database
- Call “stored procedures” (e.g., in SQL Server)
  - `xp_cmdshell()` → arbitrary command execution
  - “bulk insert” statement to read any file on the server
  - e-mail data to the attacker’s mail account
  - Play around with the registry settings
- `select *… ; drop table SensitiveData;`
- Appending “`;`” character does not work for all databases. Might depend on the driver (e.g., MySQL)

DEMO
Simple SQL Injection

Advanced SQL Injection

- Web apps often escape the ‘ and “ (e.g., in PHP)
  - Will prevent most SQL injection attacks… but there might still be vulnerabilities
- Database columns have ***types***
  - ‘ or “ characters not necessary (e.g., … where id=1)
- Attacker might still inject strings into a database by using the `char` function (e.g., SQL Server):
  - insert into users values(666,char(0x63)+char(0x65)…)

Blind SQL Injection

- Typical countermeasure: Don't display error messages. But, is this enough?
  - No, your application may still be vulnerable to *blind SQL injection*
- Example: Suppose there is a news site
  - Press releases are accessed with pressRelease.jsp?id=5
  - An SQL query is created and sent to the database:

    select title, description FROM pressReleases where id=5;
  - Any error messages are smartly filtered by the application

Blind SQL Injection

- How can we inject statements into the application and exploit it?
  - We do not receive feedback from the application so we can use a trial-and-error approach
  - First, we try to inject pressRelease.jsp?id=5 AND 1=1
  - The SQL query is created and sent to the database:

  select title, description FROM pressReleases where id=5 AND 1=1
  - If there is an SQL injection vulnerability, the *same* press release should be returned
  - If input is validated, id=5 AND 1=1 should be treated as value

Blind SQL Injection

- When testing for vulnerability, we know 1=1 is always true
  - However, when we inject other statements, we do not have any information
  - What we know: If the same record is returned, the statement must have been true
  - For example, we can ask server if the current user is “h4x0r”:

pressRelease.jsp?id=5 AND user_name()=‘h4x0r’

  - By combining subqueries and functions, we can ask more complex questions (e.g., extract the name of a database character by character)

SQL Injection Solution

- Instead of string-building SQL, call stored procedure (e.g., in Java):

```
CallableStatements cs =
    dbConnection.prepareCall("{call
    getPressRelease(?)}");
cs.setInt(1,Integer.parseInt(request.getParameter(
    "id")));
ResultSet rs = cs.executeQuery();
```

- In ASP.NET, there is a similar mechanism

Exploits Of A Mom