

Database Programming (Part 2)

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Objectives

- We will cover:
 - **Databases (DBs) and database management systems (DBMSs)...**
 - With a focus on **relational** DBs and DBMSs...
 - With a focus on the **SQLite** DBMS...
 - With a focus on **programming** with SQLite

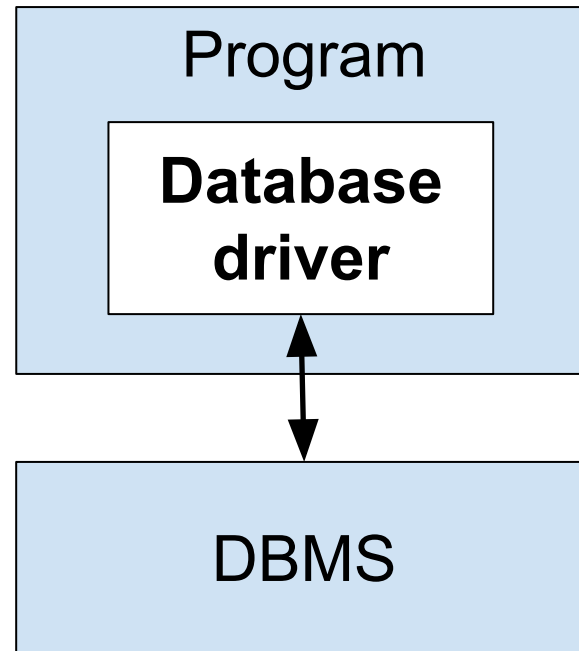
Objectives

- **Question:** How does one use SQLite?
- **Answer:** In this course:
 - Via the SQLite command-line client
 - Via programs that you compose...

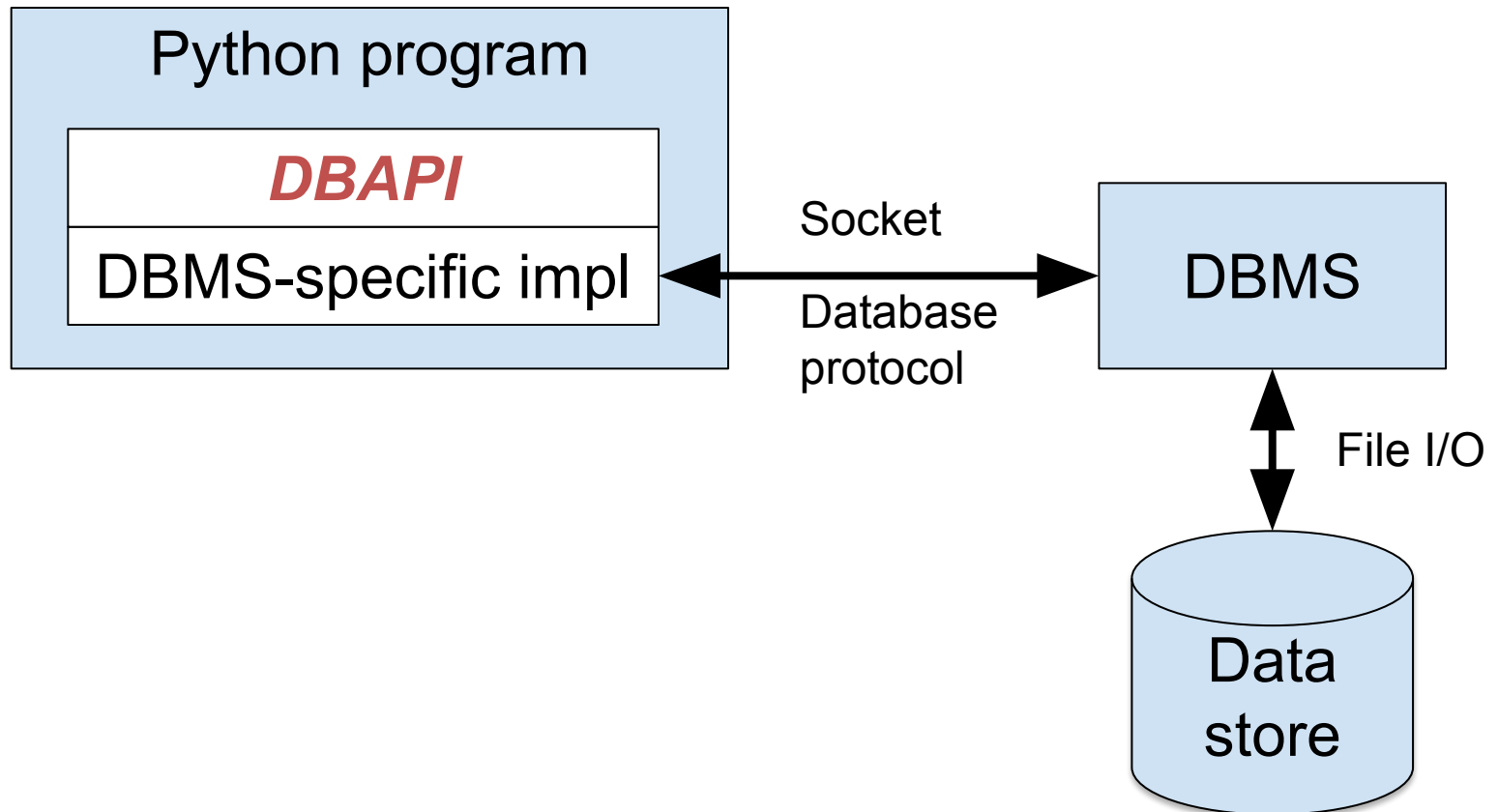
Agenda

- **Relational DB app architecture**
- Relational DB pgmming
- Relational DB pgmming: prepared stmts

Relational DB App Arch

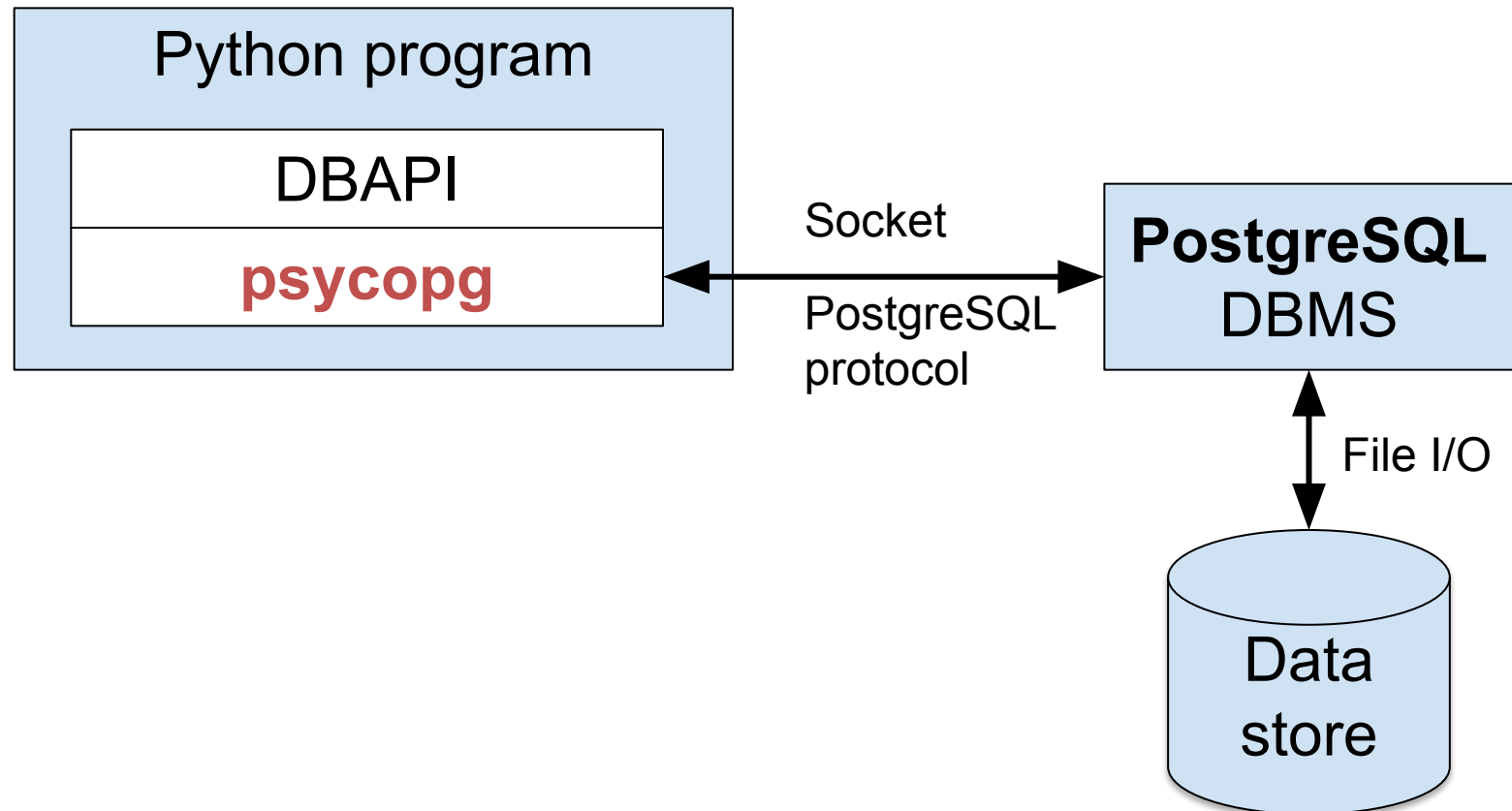


Relational DB App Arch



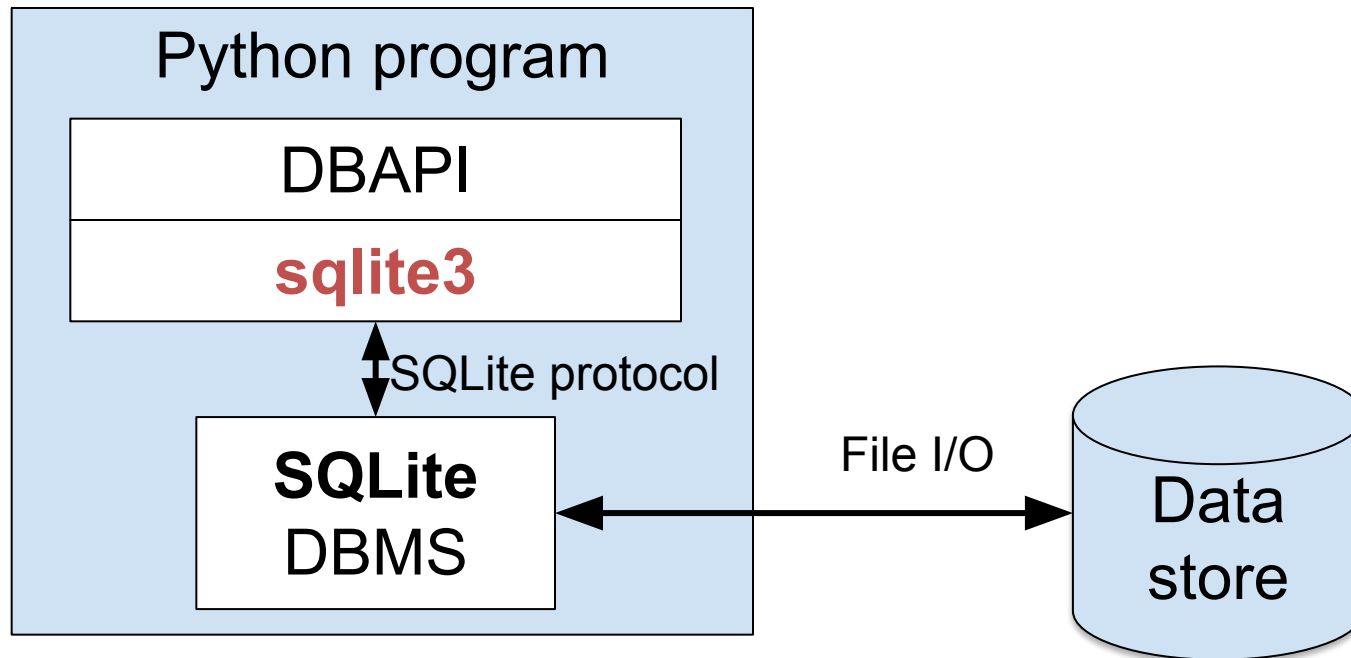
Relational DB App Arch

When using PostgreSQL



Relational DB App Arch

When using SQLite



Agenda

- Relational DB app architecture
- **Relational DB pgmming**
- Relational DB pgmming: prepared stmts

Relational DB Programming

- Code structure

Baseline:

```
connection = connect(...)
...
...
connection.close()
```

Better:

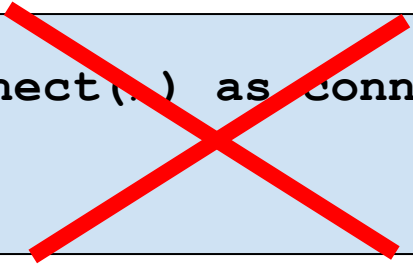
```
connection = connect(...)
try:
    ...
    ...
finally:
    connection.close()
```

Better still (but see next slide):

```
with connect(...) as connection:
    ...
    ...
```

Relational DB Programming

- Code structure



```
with connect(...) as connection:  
    ...  
    ...
```

Doesn't close the
connection!!!

```
import contextlib  
...  
with contextlib.closing(connect(...)) as connection:  
    ...  
    ...
```

For more info: <https://realpython.com/python-with-statement/>

Relational DB Programming

- Code structure

Baseline:

```
cursor = connection.cursor()  
...  
...  
cursor.close()
```

Better:

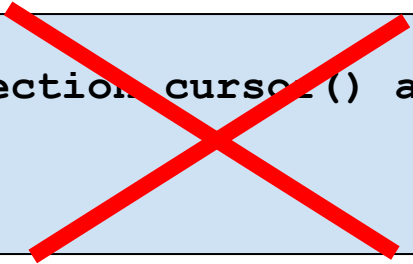
```
cursor = connection.cursor()  
try:  
    ...  
    ...  
finally:  
    cursor.close()
```

Better still (but see next slide):

```
with connection.cursor() as cursor  
    ...  
    ...
```

Relational DB Programming

- Code structure



```
with connection.cursor() as cursor:  
    ...  
    ...
```

Not supported

```
import contextlib  
...  
with contextlib.closing(connection.cursor()) as cursor:  
    ...  
    ...
```

For more info: <https://realpython.com/python-with-statement/>

Relational DB Programming

- See **create.py**

```
$ python create.py  
$
```

Relational DB Programming

- See **display.py**

```
$ python display.py
```

```
books
```

```
-----  
( '123', 'The Practice of Programming'  
( '234', 'The C Programming Language'  
( '345', 'Algorithms in C', 650)  
-----
```

```
authors
```

```
-----  
( '123', 'Kernighan')  
( '123', 'Pike')  
( '234', 'Kernighan')  
( '234', 'Ritchie')  
( '345', 'Sedgewick')  
-----
```

```
-----  
zipcodes
```

```
-----  
( '08540', 'Princeton', 'NJ')  
( '02138', 'Cambridge', 'MA')  
( '02142', 'Cambridge', 'MA')  
-----
```

```
customers
```

```
-----  
( '111', 'Princeton', '114 Nassau St',  
'08540')  
( '222', 'Harvard', '1256 Mass Ave',  
'02138')  
( '333', 'MIT', '292 Main St', '02142')  
-----
```

```
orders
```

```
-----  
( '123', '222', 20)  
( '345', '222', 100)  
( '123', '111', 30)  
-----
```

```
$
```

Relational DB Programming

- See **display.py** (cont.)
 - To use a cursor to select data:

```
cursor.execute('SELECT * FROM books')
table = cursor.fetchall()
for row in table:
    print(row)
```

or

```
cursor.execute('SELECT * FROM books')
row = cursor.fetchone()
while row is not None:
    print(row)
    row = cursor.fetchone()
```

Relational DB Programming

- See **authorsearch.py**

```
$ python authorsearch.py Kernighan
ISBN: 123
Title: The Practice of Programming
Quantity: 500

ISBN: 234
Title: The C Programming Language
Quantity: 800

$
```

Relational DB Programming

- See **order.py**

```
$ python display.py
...
-----
orders
-----
('123', '222', 20)
('345', '222', 100)
('123', '111', 30)
$ python order.py 123 222
$ python display.py
...
-----
orders
-----
('123', '222', 21)
('345', '222', 100)
('123', '111', 30)
$
```

Agenda

- Relational DB app architecture
- Relational DB pgmming
- **Relational DB pgmming: prepared stmts**

DB Pgmming: Prepared Stmts

- **Problem:**

Consider this SQL statement executed by authorsearch.py:

```
SELECT books.isbn, title, quantity
FROM books, authors
WHERE books.isbn = authors.isbn
AND author = '{author}'
```

SQL Injection Attacks

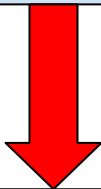
- User provides this `author` to `authorsearch.py`:



O'Reilly

DB Pgmming: Prepared Stmts

```
SELECT books.isbn, title, quantity  
FROM books, authors  
WHERE books.isbn = authors.isbn  
AND author = '{author}'
```

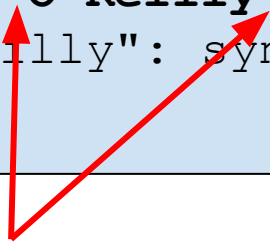


O'Reilly

```
SELECT books.isbn, title, quantity  
FROM books, authors  
WHERE books.isbn = authors.isbn  
AND author = 'O'Reilly'
```

DB Pgmming: Prepared Stmts

```
$ python authorsearch.py "O'Reilly"  
authorsearch.py: near "Reilly": syntax error  
$
```



Double quotes here tell bash to consider the single quote within `O'Reilly` to be an ordinary character

DB Pgmming: Prepared Stmts

Consider this SQL statement executed by order.py:

```
UPDATE orders SET quantity = quantity+1  
WHERE isbn='{isbn}' AND custid='{custid}'
```

SQL Injection Attacks

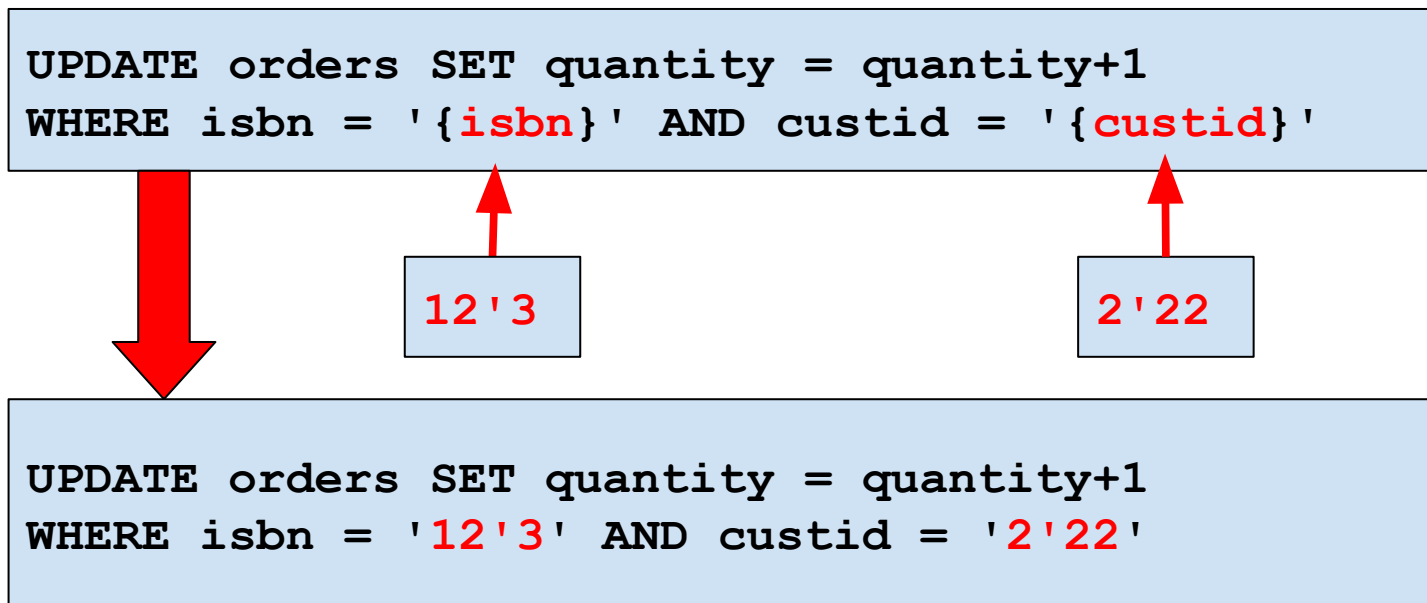
- User provides to order.py this isbn:

12'3

- ... and this custid:

22'2

DB Pgmming: Prepared Statements



DB Pgmming: Prepared Stmts

```
$ python order.py "12'3" "2'22"  
order.py: near "3": syntax error  
$
```

DB Pgmming: Prepared Stmts

- Actually...
 - The problem is **much** worse than indicated
 - See **Appendix 1: SQL Injection Attacks**
 - See *Security Issues in Web Programming* lectures (later in the course)

DB Pgmming: Prepared Stmts

- ***Solution: Prepared statements***

DB Pgmming: Prepared Stmts

- See **authorsearchprep.py**

```
$ python authorsearchprep.py Kernighan
ISBN: 123
Title: The Practice of Programming
Quantity: 500

ISBN: 234
Title: The C Programming Language
Quantity: 800

$
```

DB Pgmming: Prepared Stmts

- See **authorsearchprep.py** (cont.)

```
$ python authorsearchprep.py "O'Reilly"  
$
```

DB Pgmming: Prepared Stmts

- See **orderprep.py**

```
$ python display.py
...
-----
orders
-----
('123', '222', 20)
('345', '222', 100)
('123', '111', 30)
$ python orderprep.py 123 222
$ python display.py
...
-----
orders
-----
('123', '222', 21)
('345', '222', 100)
('123', '111', 30)
$
```

DB Pgmming: Prepared Stmts

- See **orderprep.py** (cont.)

```
$ python display.py
...
-----
orders
-----
('123', '222', 20)
('345', '222', 100)
('123', '111', 30)
$ python orderprep.py "12'3" "2'22"
$ python display.py
...
-----
orders
-----
('123', '222', 20)
('345', '222', 100)
('123', '111', 30)
$
```

Lecture Summary

- In this lecture we covered:
 - Relational DB app architecture
 - Relational DB pgmming
 - Relational DB pgmming: prepared stmts
- See also
 - **Appendix 1: SQL Injection Attacks**

Appendix 1:

SQL Injection Attacks

SQL Injection Attacks

- **Problem:**

Consider this SQL statement executed by authorsearch.py:

```
SELECT books.isbn, title, quantity
FROM books, authors
WHERE books.isbn = authors.isbn
AND author = '{author}'
```

SQL Injection Attacks

- Malicious user provides this `author` to `authorsearch.py`:

```
junk' OR 'x'='x
```

SQL Injection Attacks

```
SELECT books.isbn, title, quantity  
FROM books, authors  
WHERE books.isbn = authors.isbn  
AND author = '{author}'
```



```
junk' OR 'x'='x'
```



```
SELECT books.isbn, title, quantity  
FROM books, authors  
WHERE books.isbn = authors.isbn  
AND author = 'junk' OR 'x'='x'
```

SQL Injection Attacks

```
SELECT books.isbn, title, quantity  
FROM books, authors  
WHERE books.isbn = authors.isbn  
AND author = 'junk' OR 'x'='x'
```



AND has higher precedence than OR

```
SELECT books.isbn, title, quantity  
FROM books, authors  
WHERE (books.isbn = authors.isbn  
AND author = 'junk') OR ('x'='x')
```

SQL Injection Attacks

SQL injection attack

```
$ python authorsearch.py "junk' OR 'x'='x"
```

```
ISBN: 123
```

```
Title: The Practice of Pro
```

```
Quantity: 500
```

```
ISBN: 123
```

```
Title: The Practice of Pro
```

```
Quantity: 500
```

```
ISBN: 123
```

```
Title: The Practice of Pro
```

```
Quantity: 500
```

```
ISBN: 123
```

```
Title: The Practice of Pro
```

```
Quantity: 500
```

```
ISBN: 123
```

```
Title: The Practice of Pro
```

```
Quantity: 500
```

```
ISBN: 234
```

```
Title: The C Programming Language
```

```
Quantity: 800
```

```
ISBN: 234
```

```
Title: The C Programming
```

```
Quantity: 800
```

```
ISBN: 234
```

```
Title: The C Programming
```

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Quantity: 800
```

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ISBN: 234
```

```
Title: The C Programming
```

```
Quantity: 800
```

```
ISBN: 234
```

```
Title: The C Programming
```

```
Quantity: 800
```

```
ISBN: 345
```

```
Title: Algorithms in C
```

```
Quantity: 650
```

```
ISBN: 345
```

```
Title: Algorithms in C
```

```
Quantity: 650
```

```
ISBN: 345
```

```
Title: Algorithms in C
```

```
Quantity: 650
```

```
ISBN: 345
```

```
Title: Algorithms in C
```

```
Quantity: 650
```

```
ISBN: 345
```

```
Title: Algorithms in C
```

```
Quantity: 650
```

```
$
```

SQL Injection Attacks

- Problem (via another example)

Consider this SQL statement executed by order.py:

```
UPDATE orders SET quantity = quantity+1  
WHERE isbn='{isbn}' AND custid='{custid}'
```

SQL Injection Attacks

- Malicious user provides to order.py this isbn:

123

- ... and this custid:

222' OR 'x'='x

SQL Injection Attacks

```
UPDATE orders SET quantity = quantity+1  
WHERE isbn='{isbn}' AND custid='{custid}'
```

123

222' OR 'x'='x'

```
UPDATE orders SET quantity = quantity+1  
WHERE isbn='123' AND custid='222' OR 'x'='x'
```

AND has higher precedence than OR

```
UPDATE orders SET quantity = quantity+1  
WHERE (isbn='123' AND custid='222') OR ('x'='x')
```

SQL Injection Attacks

```
$ python display.py
...
-----
orders
-----
('123', '222', 20)
('345', '222', 100)
('123', '111', 30)
$ python order.py 123 "222' OR 'x'='x"
$ python display.py
...
-----
orders
-----
('123', '222', 21)
('345', '222', 101)
('123', '111', 31)
```

**SQL
injection
attack**

SQL Injection Attacks

- For more examples of SQL injection attacks:
 - <http://unixwiz.net/techtips/sql-injection.html>

SQL Injection Attacks

- A solution...
- *Prepared statements*

SQL Injection Attacks

```
$ python authorsearchprep.py "junk' OR 'x'='x"  
$
```

SQL Injection Attacks

```
$ python display.py
...
-----
orders
-----
('123', '222', 20)
('345', '222', 100)
('123', '111', 30)
$ python orderprep.py 123 "junk' OR 'x'='x"
$ python display.py
...
-----
orders
-----
('123', '222', 20)
('345', '222', 100)
('123', '111', 30)
$
```