

How SQL Database Engines Work

*D. Richard Hipp
OpenSQL
2008-11-15*

SQLite

How ~~SQL~~ Database Engines Work

*with occasional comments on how the
operation of SQLite compares to other
SQL database engines.*

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Why Do You Care?

So you can better understand what your query is doing.

So that you can appreciate how much work the database is saving you.

So that you can fix things when they go wrong.

So that you can write better SQL that runs faster and uses less memory and disk space.

Fire Hydrant Water Fountain, 1991

Former MIT President Jerome Wiesner (1971-1980) coined the colorful description of the MIT educational experience:

Getting an education at MIT is like
sitting a drink from a fire hose.

Most students and faculty agree that the analogy is appropriate. In 1991, a group of faculty managed to embody this sentiment by turning a fire hydrant into a working drinking fountain in front of the largest lecture hall on campus, 26-130.

MIT Museum
100 Technology Square
Cambridge, MA 02139
(617) 253-5900
www.mit.edu/museum



"Let's face it, MIT has a reputation as a serious place, a think tank, a paradigm of intellect, imagination, and ingenuity. While this may be true, there is another aspect of the institute little known to the world beyond MIT's long-standing tradition of humor. And I am not referring to techno-savants chuckling over cold fusion or sweeping jokes with mathematical equations in the punch line. I'm talking about high-tech high-jinks."



"Of all the animals in the world, the beaver is noted for his engineering and mechanical skills and habits of industry. He of nocturnal, he does his best work in the dark."



"This makes fun of engineering by representing it and then putting the seal out from under."

Source: Jay Rosen, "The Beavers of MIT," The New Yorker, 1991.

- Do not... the safety, hackers, improve the...
- Do not... evidence I never share...
- Leave things... (or for the...)
- If you find a... broken, call... local numbers... problems with... buildings and... Hardware often... that Institute... not frequent... may have... original plan...
- Leave no stone...
- Do not... about an...
- Beats force is in... respect of the... ("Don't tell... to find out what... left the path of... sometimes the... of the Random O...
- Do not... hands... while the influence of an... disappears...
- Do not... strip things... (buildings) without... errors...
- Do not... hands... since the... economy...
- Adverse... all... common sense...

Key Concept

SQL is a peculiar programming language

Each SQL statement is a separate program

SQL describes what instead of how

An RDBMS consists of...

Compiler to translate SQL into procedures

Virtual Machine to evaluate the procedures

Example

```
SELECT * FROM table1;
```

Translates into:

```
Open database file containing table1
Rewind the file
while not at end-of-file
    read all columns out of current record
    return the columns to the caller
    advance file to the next record
end-while
close the file
```

Imagine what this translates into:

```
SELECT eqptid, enclosureid
FROM eqpt
WHERE typeid IN (
    SELECT typeid FROM typespec
    WHERE attrid=(
        SELECT attrid FROM attribute
        WHERE name='detect_autoactuate'
    )
    AND value=1
INTERSECT
SELECT typeid FROM typespec
WHERE attrid=(
    SELECT attrid FROM attribute
    WHERE name='algorithm'
)
AND value IN ('sensor','wetbulb')
)
```

The Whole Point Of SQL....

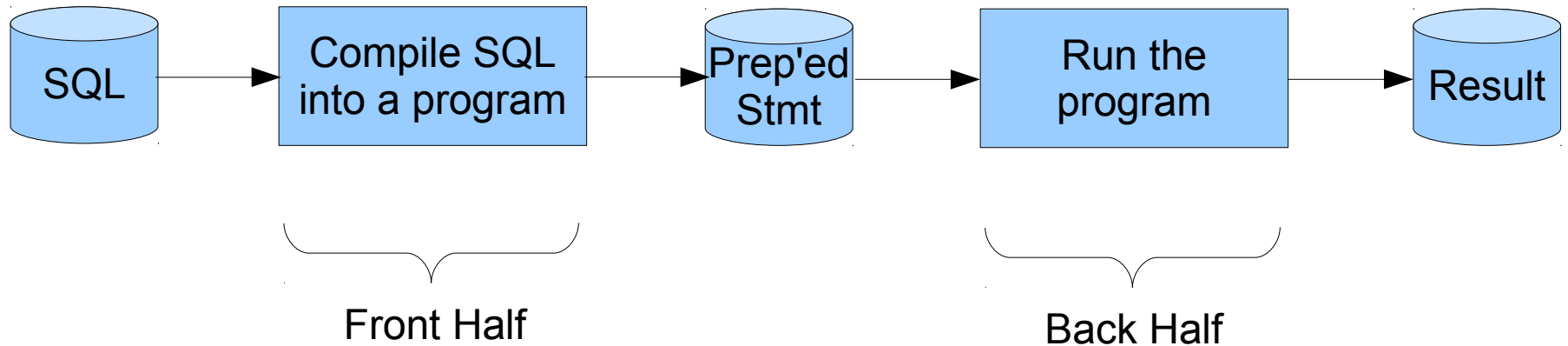
A few lines of SQL generates the equivalent of hundreds of lines of procedural code.

By adding an index, entirely new procedures are used without recoding.

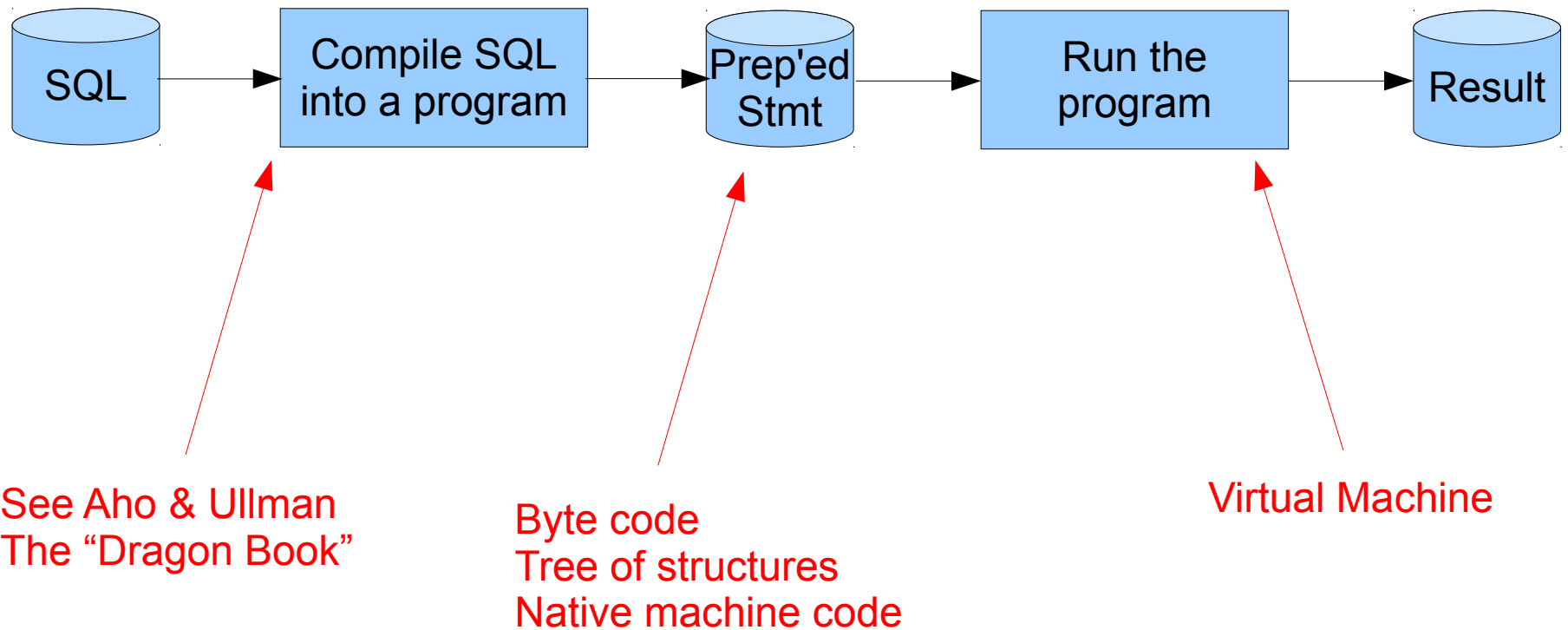
The SQL Query Optimizer is charged with picking the algorithm

so that the application developer doesn't have to

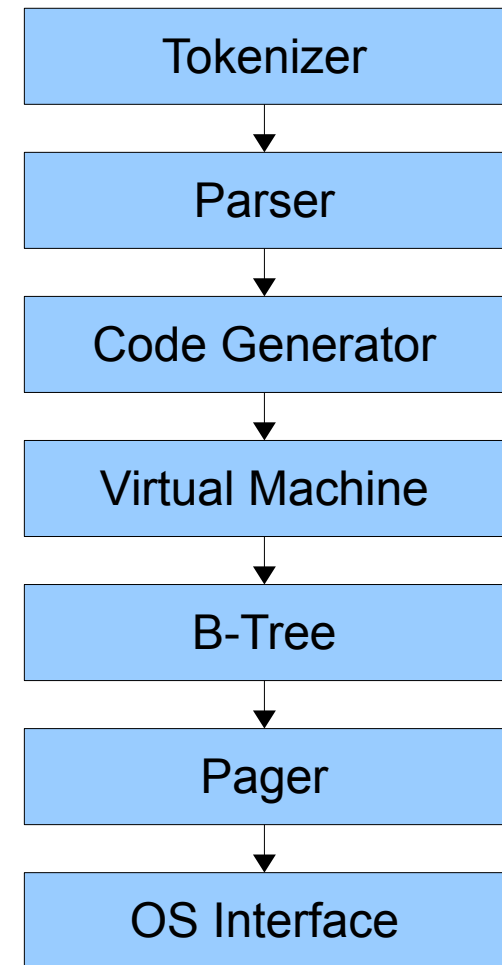
Ins and Outs of SQL



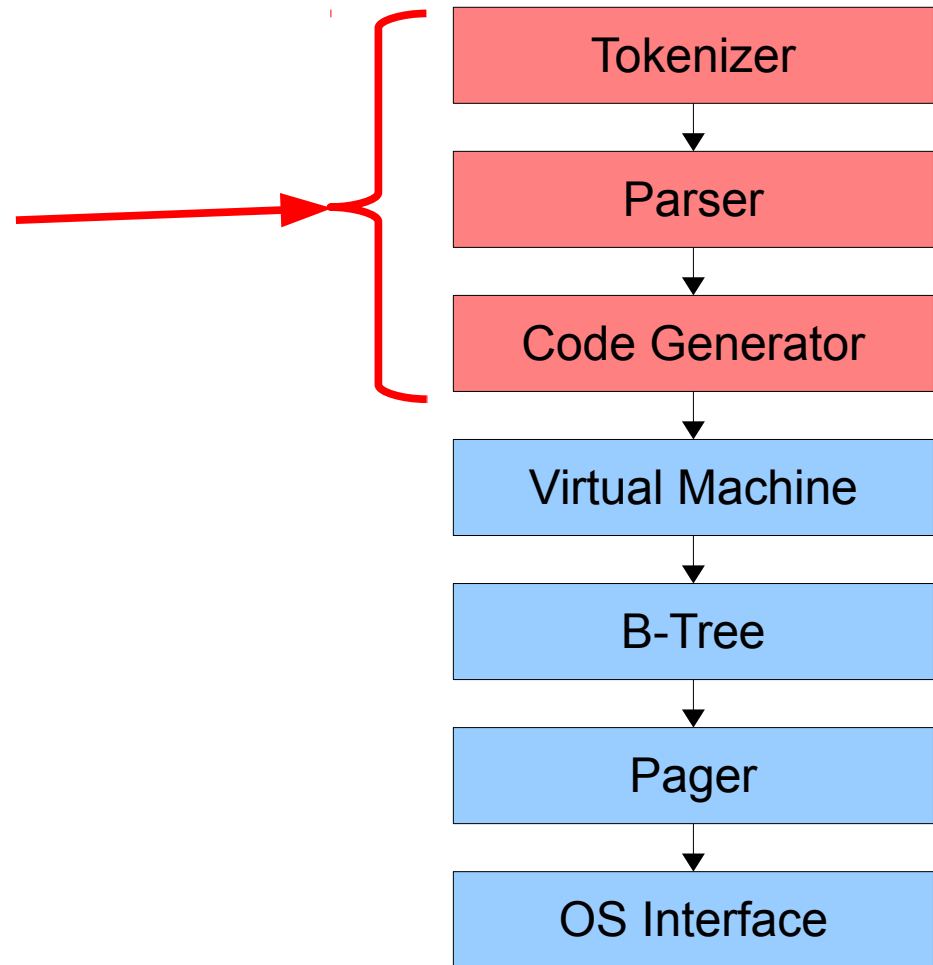
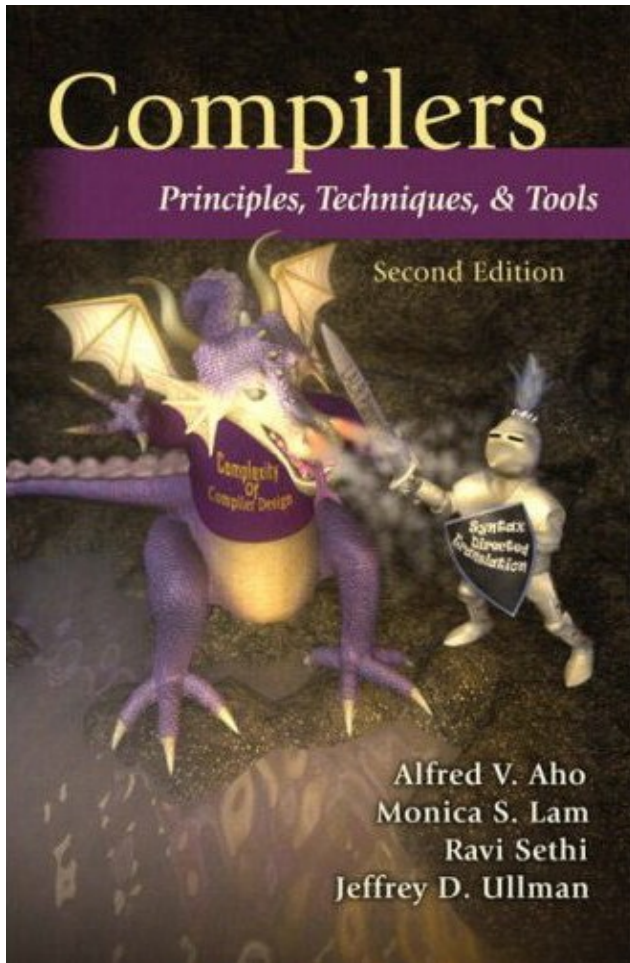
Ins and Outs of SQL

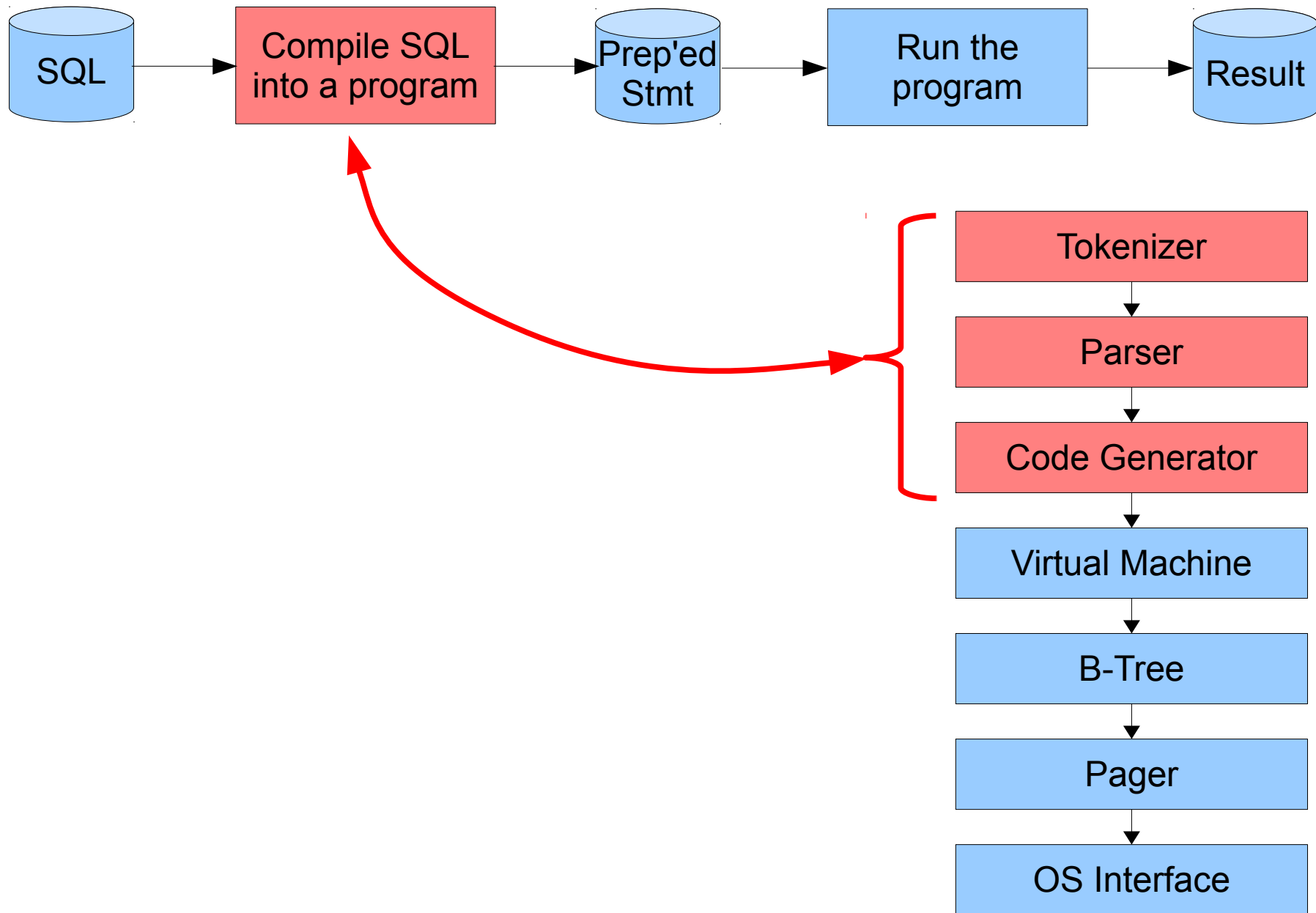


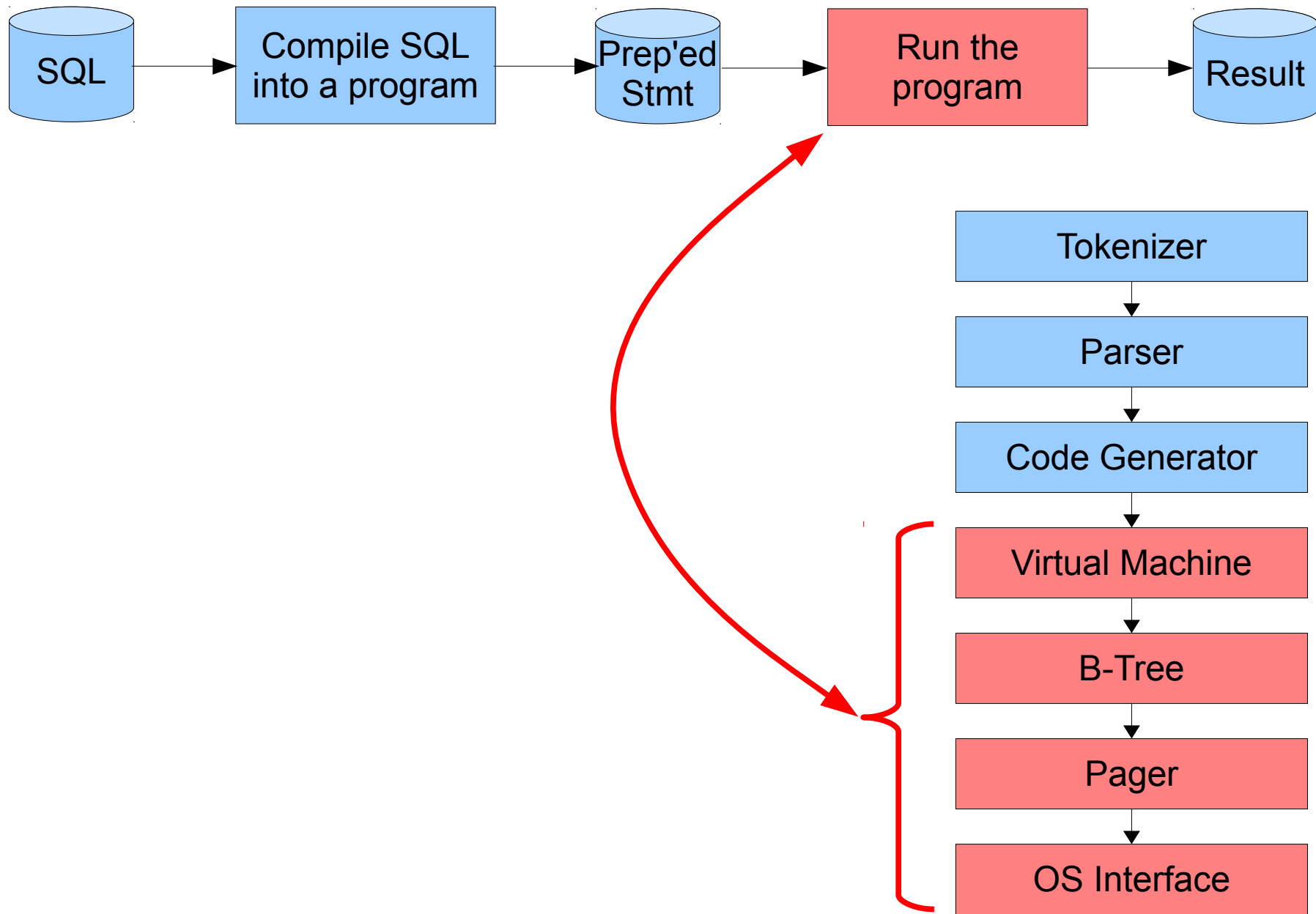
Architecture Of SQLite



Architecture Of SQLite







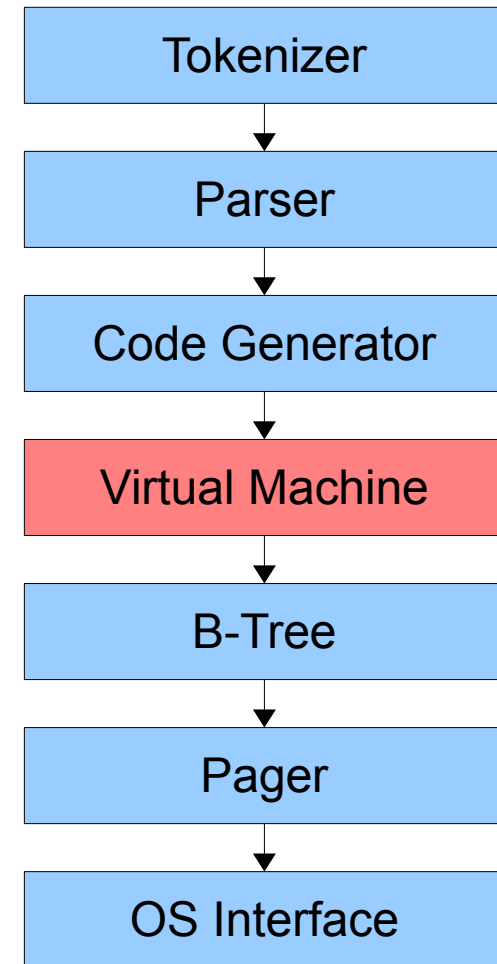
Architecture Of SQLite

Byte code interpreter

Big `switch` statement
inside a `for` loop.

Other engines walk a
tree of structures

Similar to JVM or Parrot
or P-Code

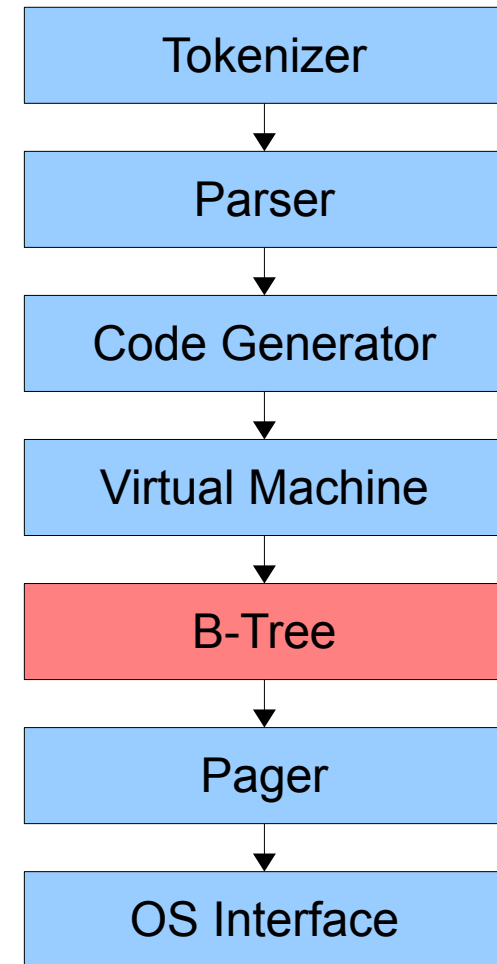


Architecture Of SQLite

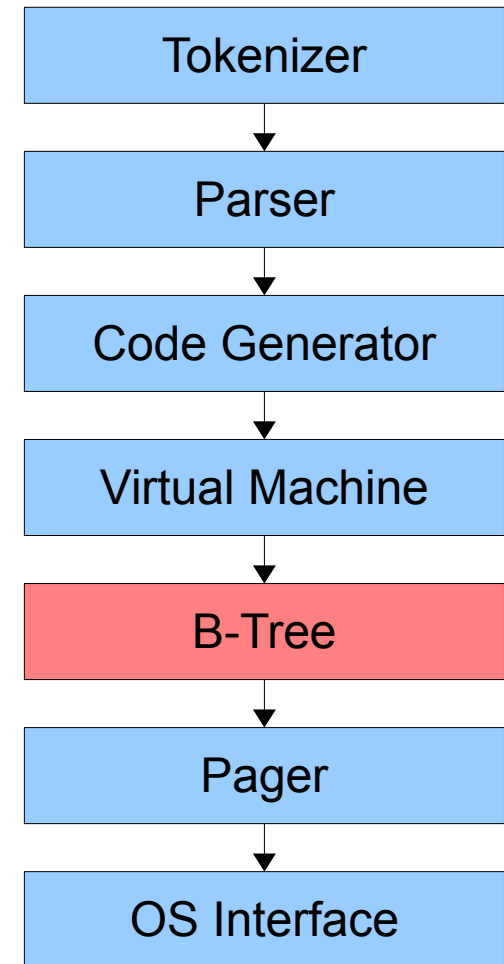
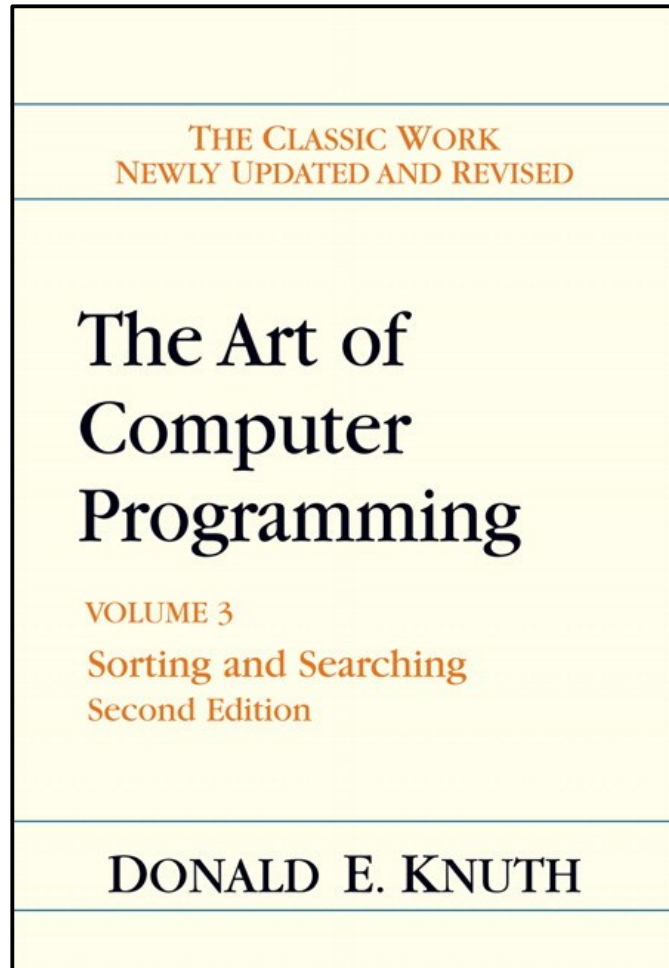
Ordered key/value pairs
with unique keys

$O(\log N)$ insert, seek,
and delete

$O(1)$ next and previous



Architecture Of SQLite



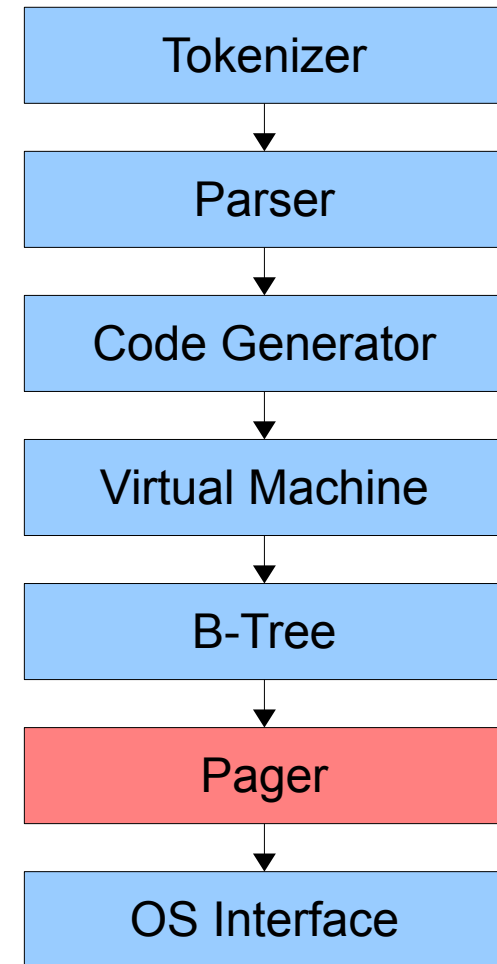
Architecture Of SQLite

Atomic commit and
rollback

Uniform size pages
numbered from 1

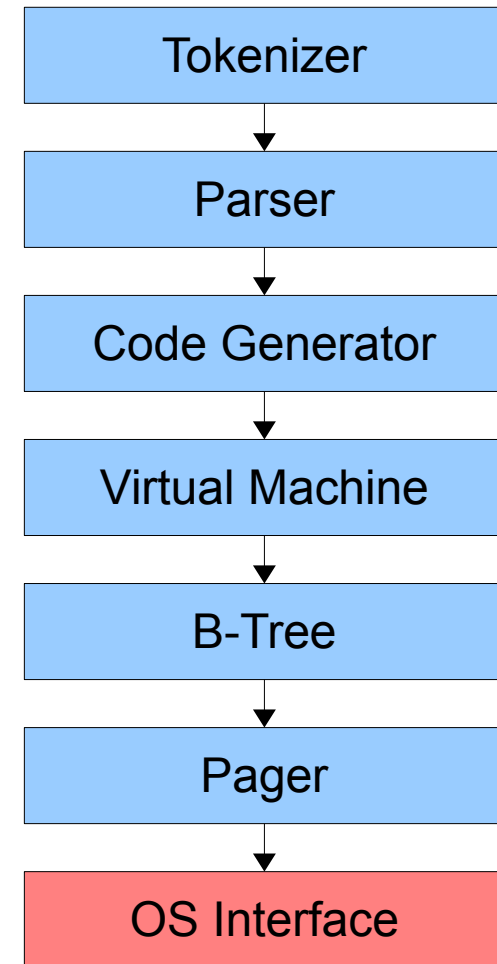
No interpretation of
page content

Cache



Architecture Of SQLite

Platform-specific
interface to the OS
Run-time changeable
Portability layer



```
CREATE TABLE tab(  
  Fruit TEXT,  
  GrownIn TEXT,  
  UnitPrice REAL  
);
```

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

```
CREATE TABLE tab(  
  Fruit TEXT,  
  GrownIn TEXT,  
  UnitPrice REAL  
);
```

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05



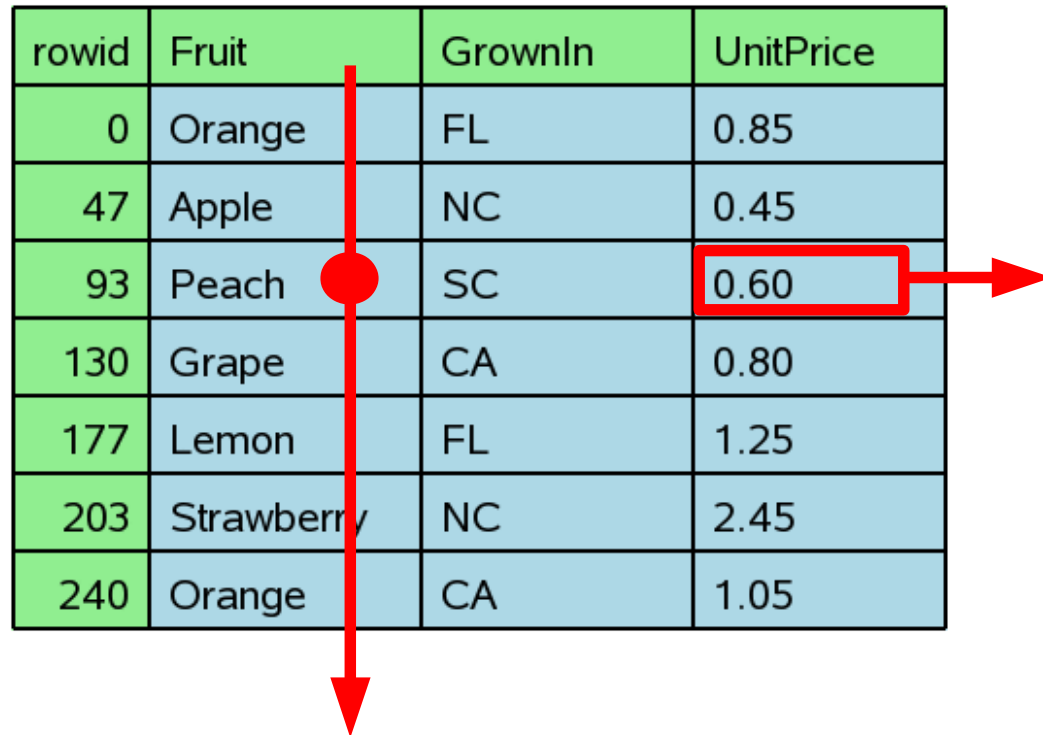
Key



Data

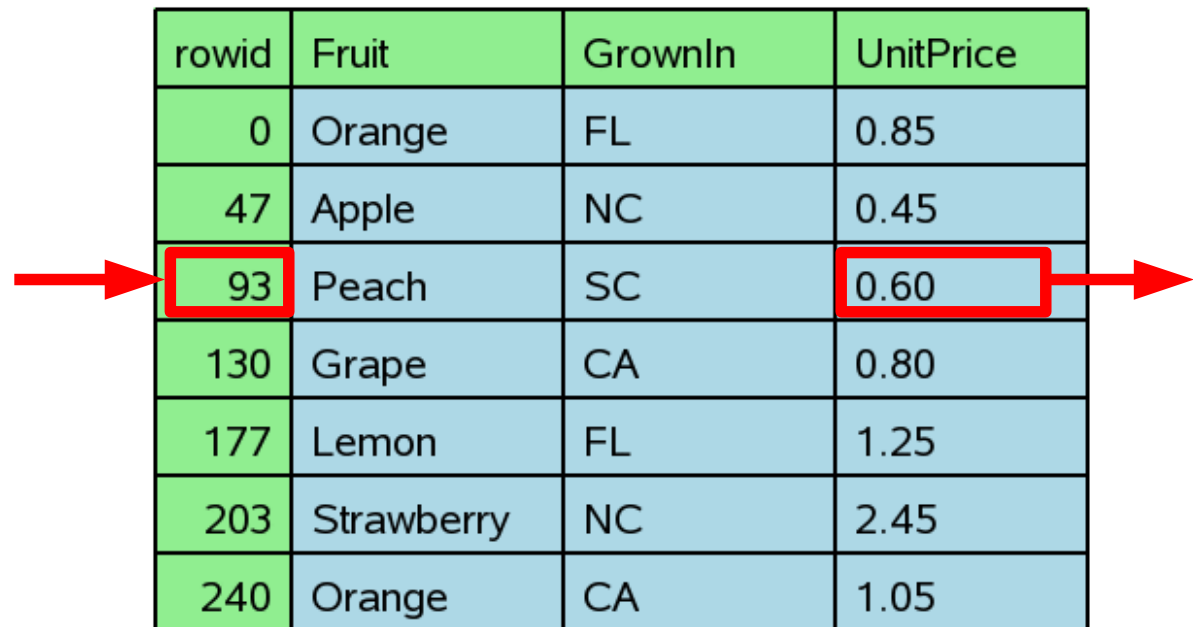
SELECT unitprice FROM tab WHERE fruit='Peach'

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05



SELECT unitprice FROM tab WHERE rowid=93

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05



CREATE INDEX idx1 ON tab(fruit)

idx1

Fruit	rowid
Apple	47
Grape	130
Lemon	177
Orange	0
Orange	240
Peach	93
Strawberry	203

tab

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

CREATE INDEX idx1 ON tab(fruit)

1:1



Fruit	rowid
Apple	47
Grape	130
Lemon	177
Orange	0
Orange	240
Peach	93
Strawberry	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

CREATE INDEX idx1 ON tab(fruit)



Fruit	rowid
Apple	47
Grape	130
Lemon	177
Orange	0
Orange	240
Peach	93
Strawberry	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

CREATE INDEX idx1 ON tab(fruit)



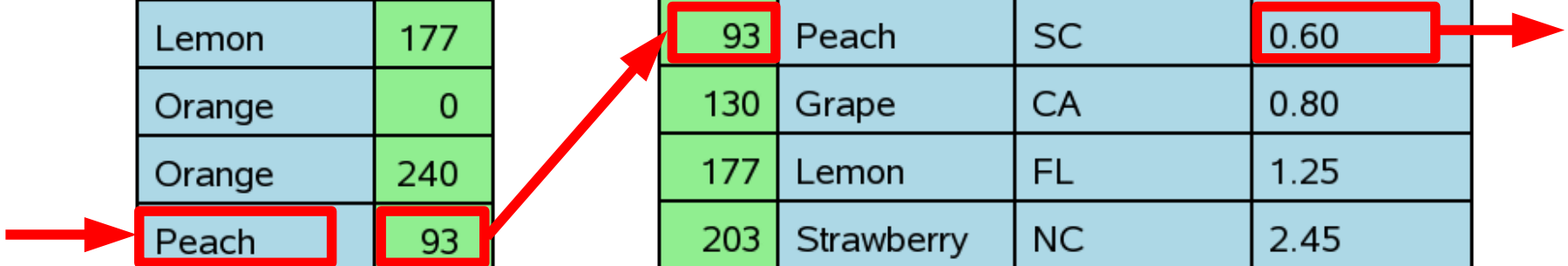
Fruit	rowid
Apple	47
Grape	130
Lemon	177
Orange	0
Orange	240
Peach	93
Strawberry	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

SELECT unitprice FROM tab WHERE fruit='Peach'

Fruit	rowid
Apple	47
Grape	130
Lemon	177
Orange	0
Orange	240
Peach	93
Strawberry	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05



**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

Fruit	rowid
Apple	47
Grape	130
Lemon	177
Orange	0
Orange	240
Peach	93
Strawberry	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL X	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

CREATE INDEX idx2 ON tab(grownin)

idx2

GrownIn	rowid
CA	130
CA	240
FL	0
FL	177
NC	47
NC	203
SC	93

tab

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

GrownIn	rowid
CA	130
CA	240
FL	0
FL	177
NC	47
NC	203
SC	93

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

CREATE INDEX idx3 ON tab(fruit, grownin)

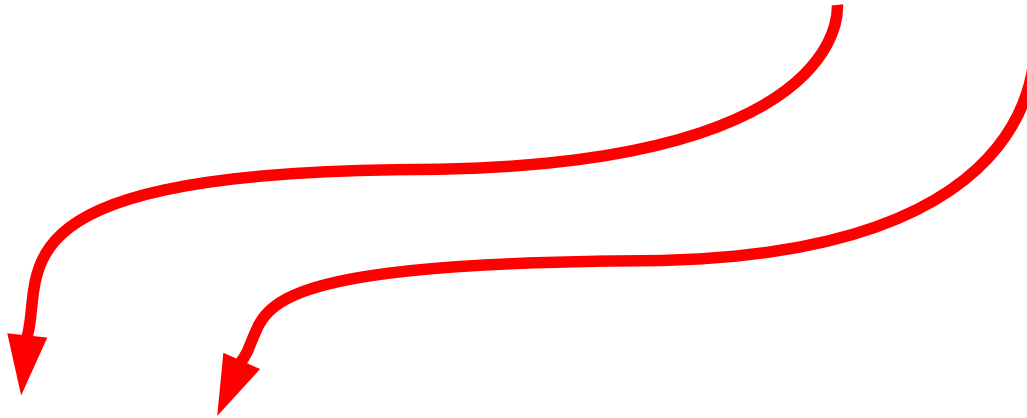
idx3

Fruit	GrownIn	rowid
Apple	NC	47
Grape	CA	130
Lemon	FL	177
Orange	CA	240
Orange	FL	0
Peach	SC	93
Strawberry	NC	203

tab

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

CREATE INDEX idx2 ON tab(fruit, grownIn)



Fruit	GrownIn	rowid
Apple	NC	47
Grape	CA	130
Lemon	FL	177
Orange	CA	240
Orange	FL	0
Peach	SC	93
Strawberry	NC	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

CREATE INDEX idx2 ON tab(fruit, grownin)

Fruit	GrownIn	rowid
Apple	NC	47
Grape	CA	130
Lemon	FL	177
Orange	CA	240
Orange	FL	0
Peach	SC	93
Strawberry	NC	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

Fruit	GrownIn	rowid
Apple	NC	47
Grape	CA	130
Lemon	FL	177
Orange	CA	240
Orange	FL	0
Peach	SC	93
Strawberry	NC	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

```
SELECT unitprice FROM tab  
WHERE fruit='Orange'  
AND grownin='CA'
```

*4 ways to do this query
(so far...)*

**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

1

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

2

Fruit	rowid	rowid	Fruit	GrownIn	UnitPrice
Apple	47	0	Orange	FL X	0.85
Grape	130	47	Apple	NC	0.45
Lemon	177	93	Peach	SC	0.60
Orange	0	130	Grape	CA	0.80
Orange	240	177	Lemon	FL	1.25
Peach	93	203	Strawberry	NC	2.45
Strawberry	203	240	Orange	CA	1.05

**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

3

GrownIn	rowid
CA	130
CA	240
FL	0
FL	177
NC	47
NC	203
SC	93

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

4

Fruit	GrownIn	rowid
Apple	NC	47
Grape	CA	130
Lemon	FL	177
Orange	CA	240
Orange	FL	0
Peach	SC	93
Strawberry	NC	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

CREATE INDEX idx4 ON tab(fruit, grownin, unitprice)

idx4

Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

tab

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

5

Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

**SELECT unitprice FROM tab
WHERE fruit='Orange'**

Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

**SELECT grownIn FROM tab
WHERE fruit='Orange'
AND unitprice<1.00**

Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203



**SELECT grownIn FROM tab
WHERE fruit='Orange'
AND unitprice<1.00**

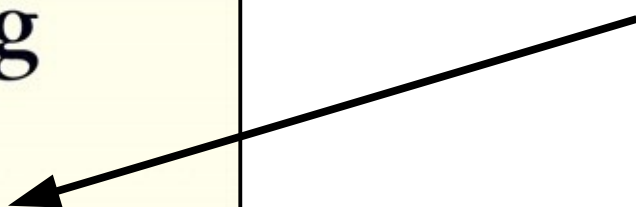
Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

THE CLASSIC WORK
NEWLY UPDATED AND REVISED

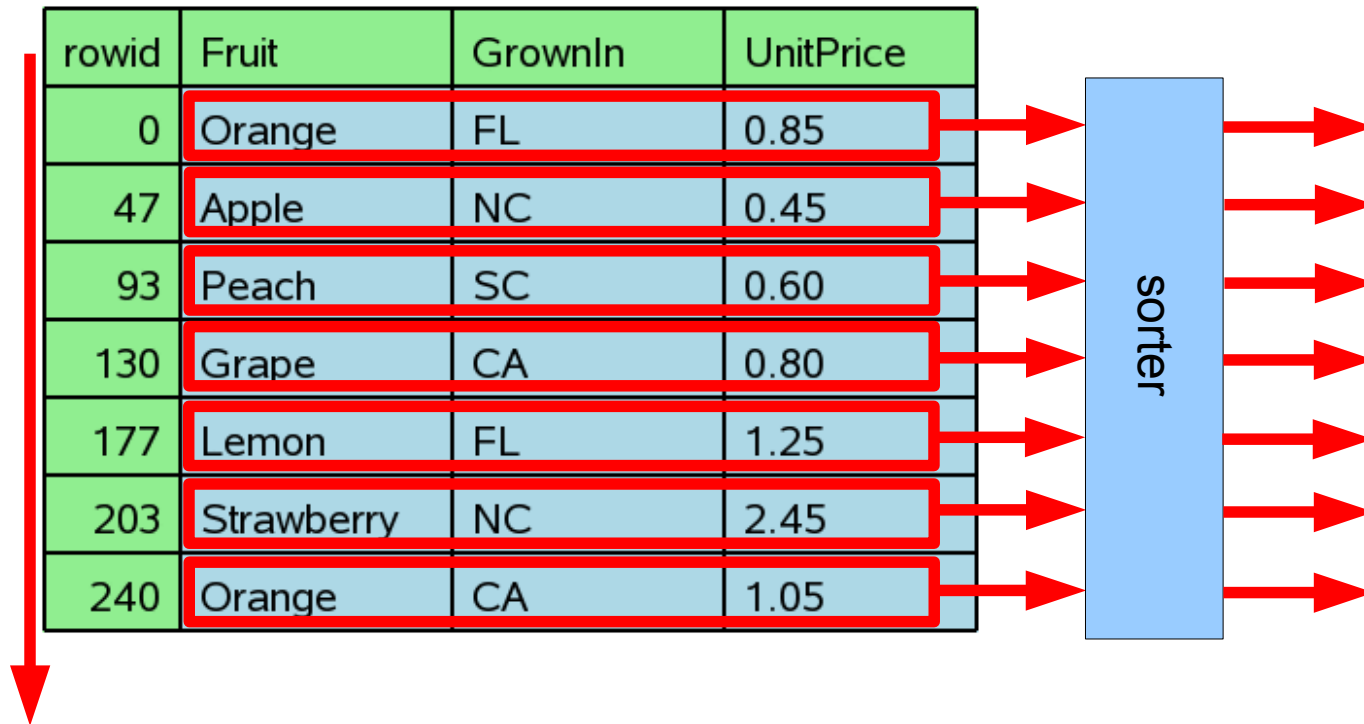
The Art of Computer Programming

VOLUME 3
Sorting and Searching
Second Edition

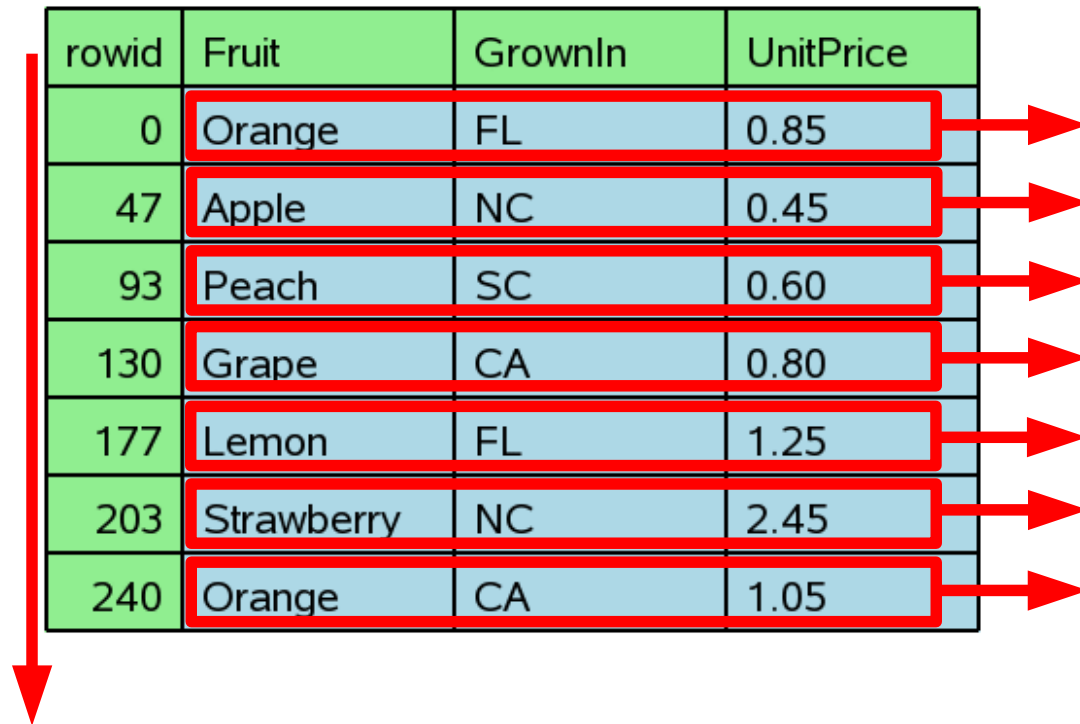


DONALD E. KNUTH

SELECT * FROM tab ORDER BY fruit

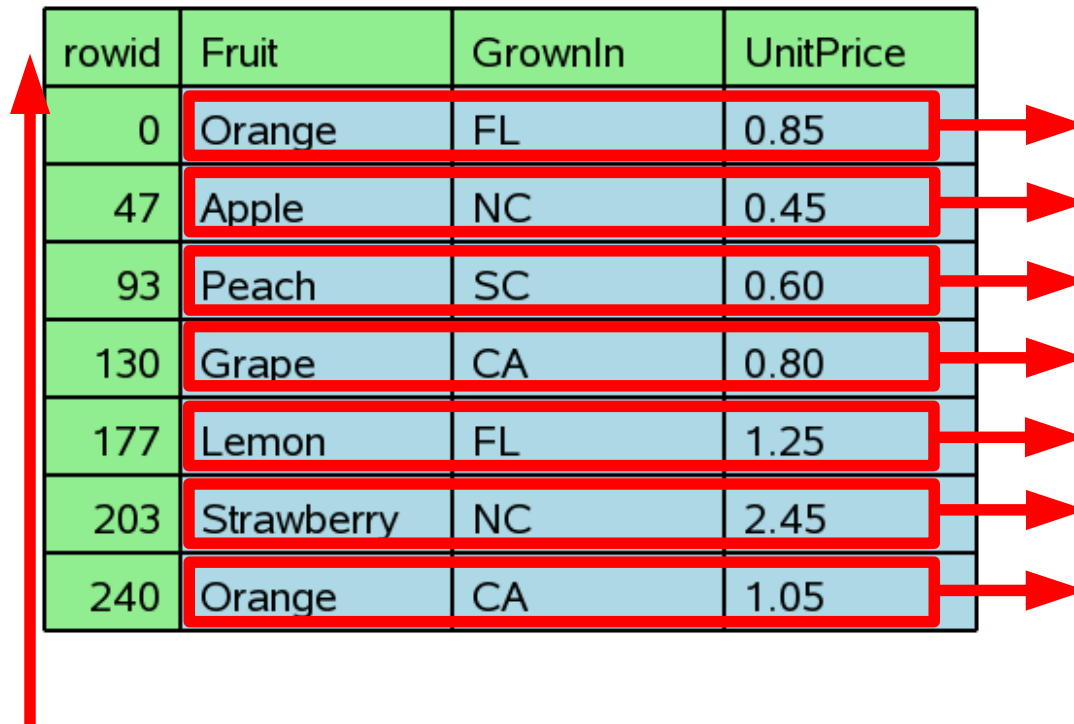


SELECT * FROM tab ORDER BY rowid



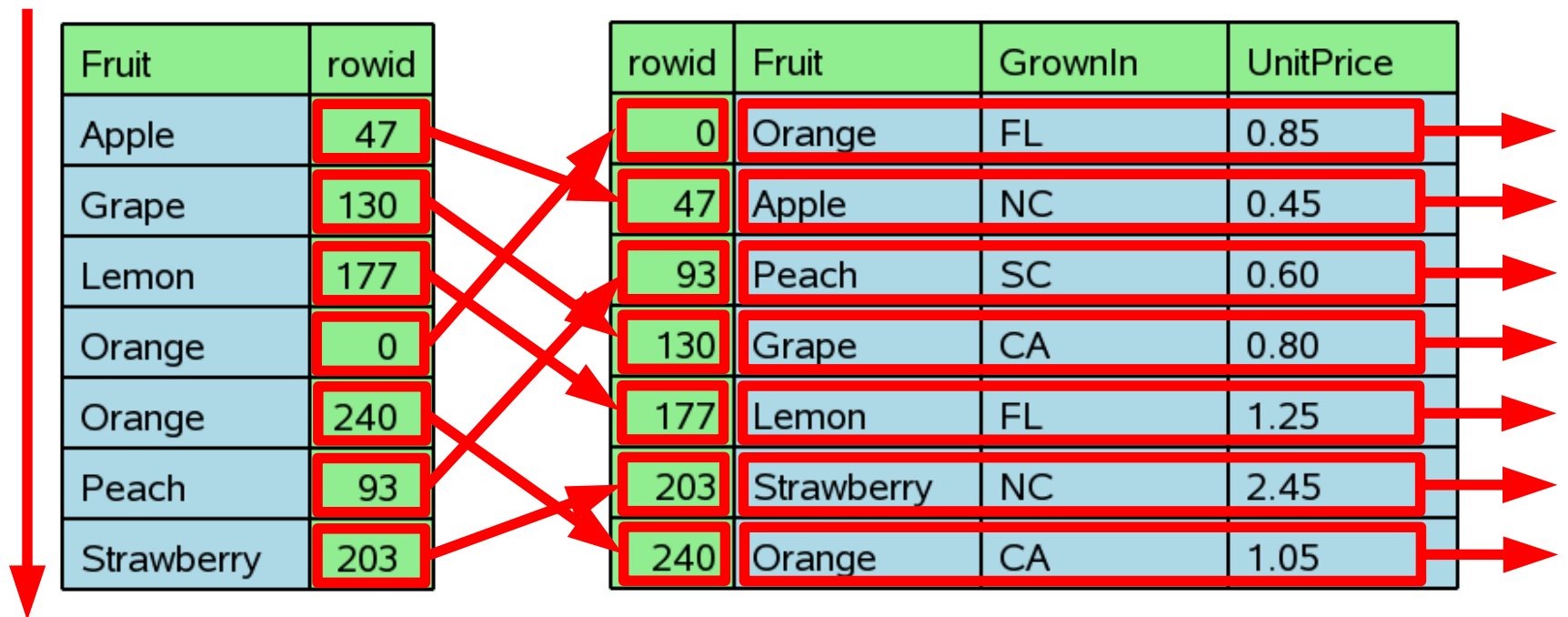
rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

SELECT * FROM tab ORDER BY rowid DESC

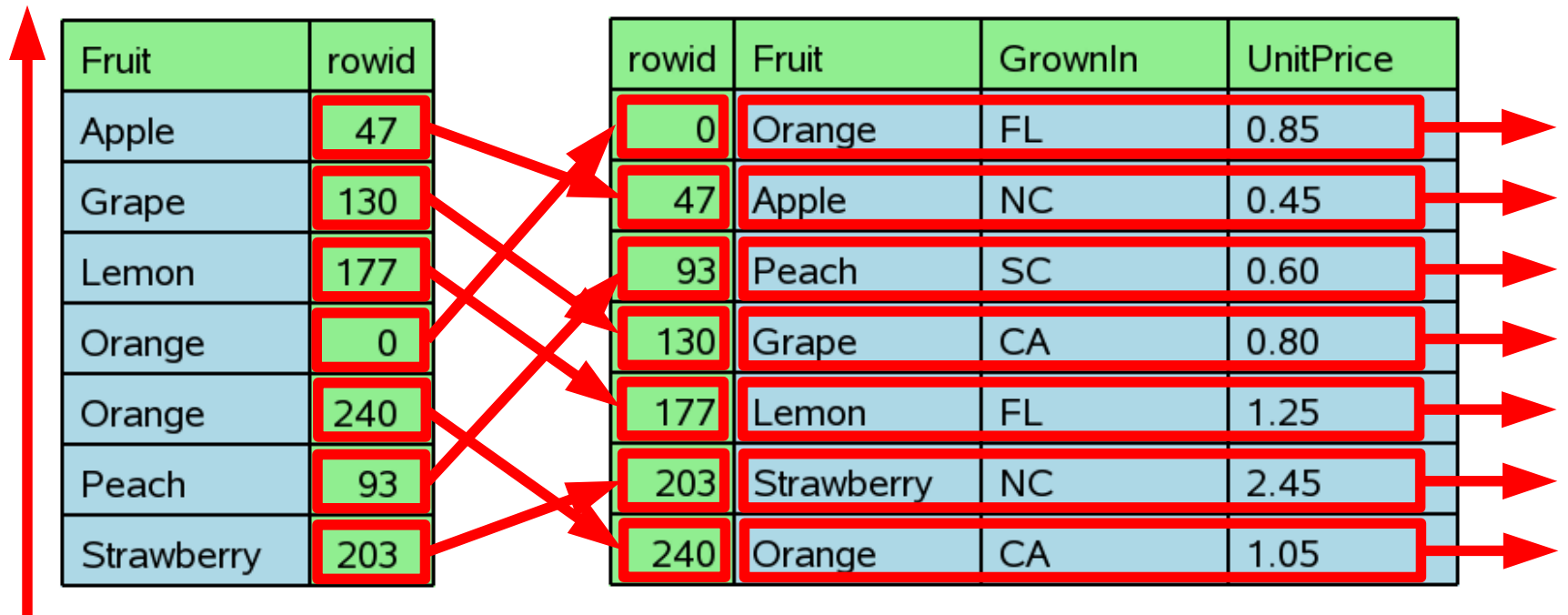


rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

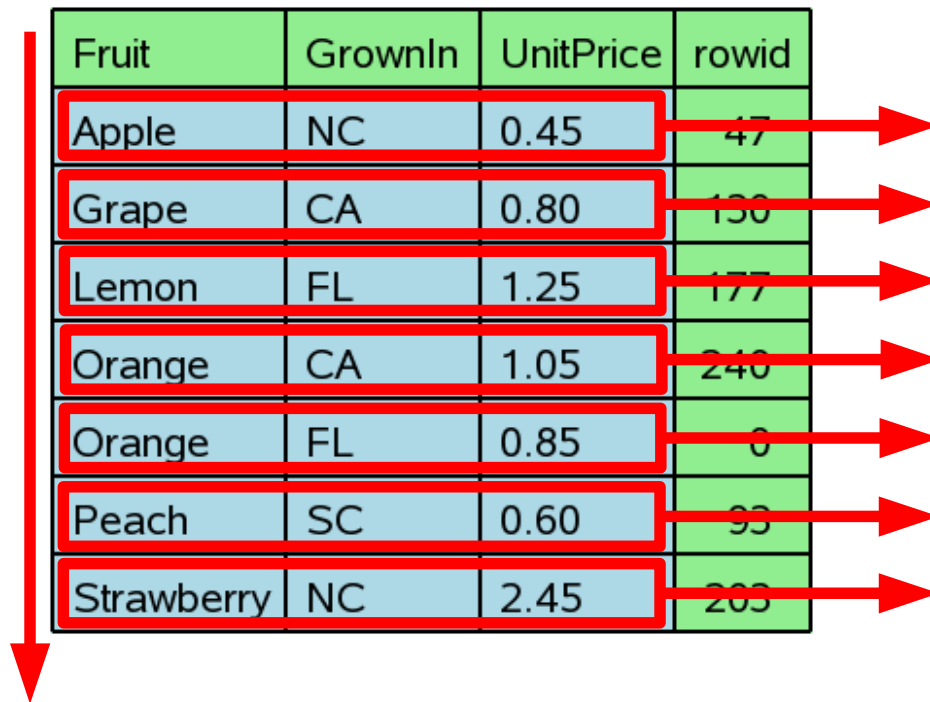
SELECT * FROM tab ORDER BY fruit



SELECT * FROM tab ORDER BY fruit DESC

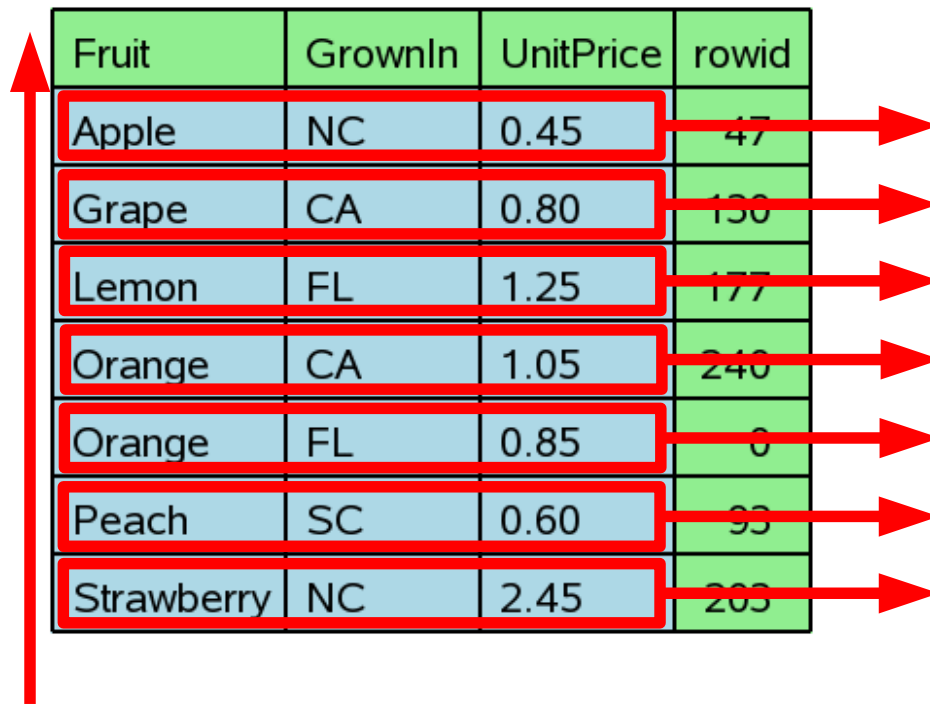


SELECT * FROM tab ORDER BY fruit



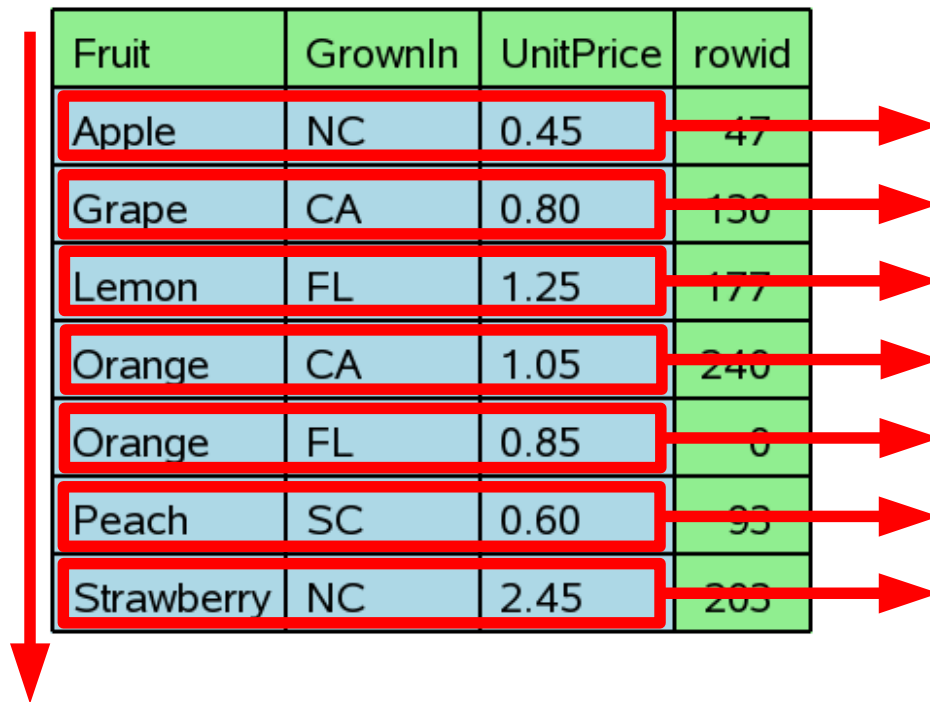
Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

SELECT * FROM tab ORDER BY fruit DESC



Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

SELECT * FROM tab ORDER BY fruit, grownin



Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

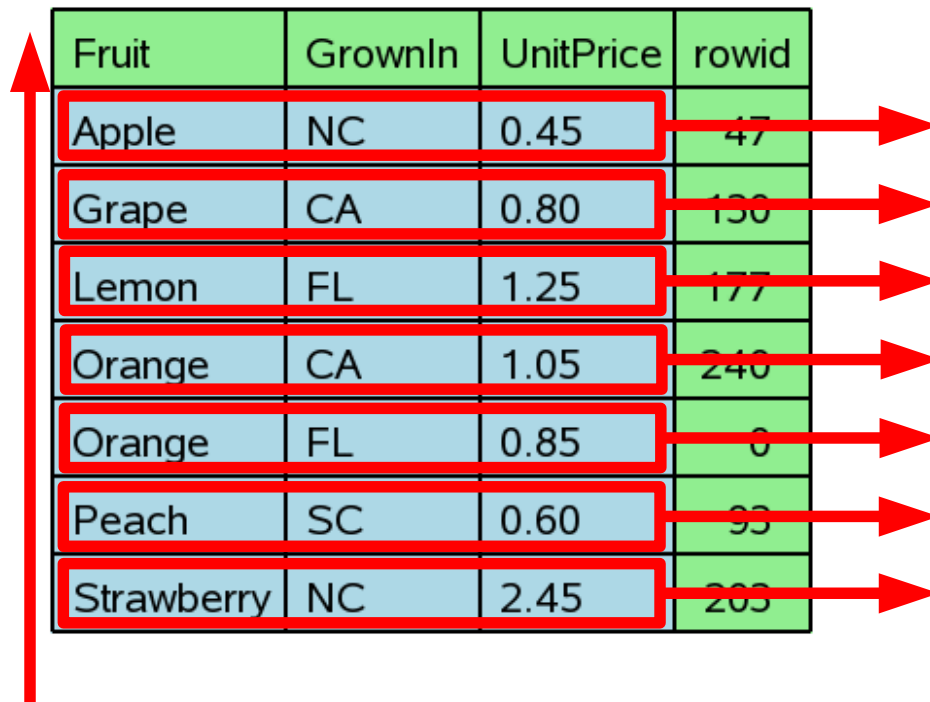
SELECT * FROM tab ORDER BY fruit, grownin, unitprice

Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

SELECT * FROM tab ORDER BY fruit DESC, grownin DESC

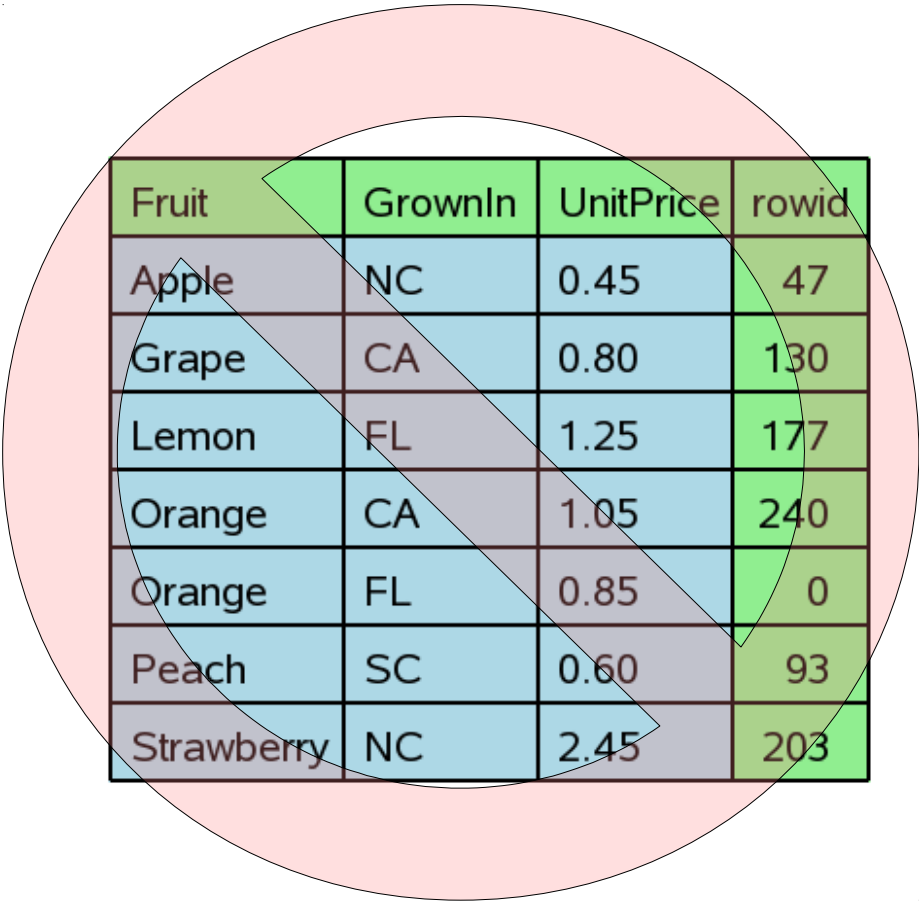
Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

SELECT * FROM tab
ORDER BY fruit DESC, grownin DESC, unitprice DESC



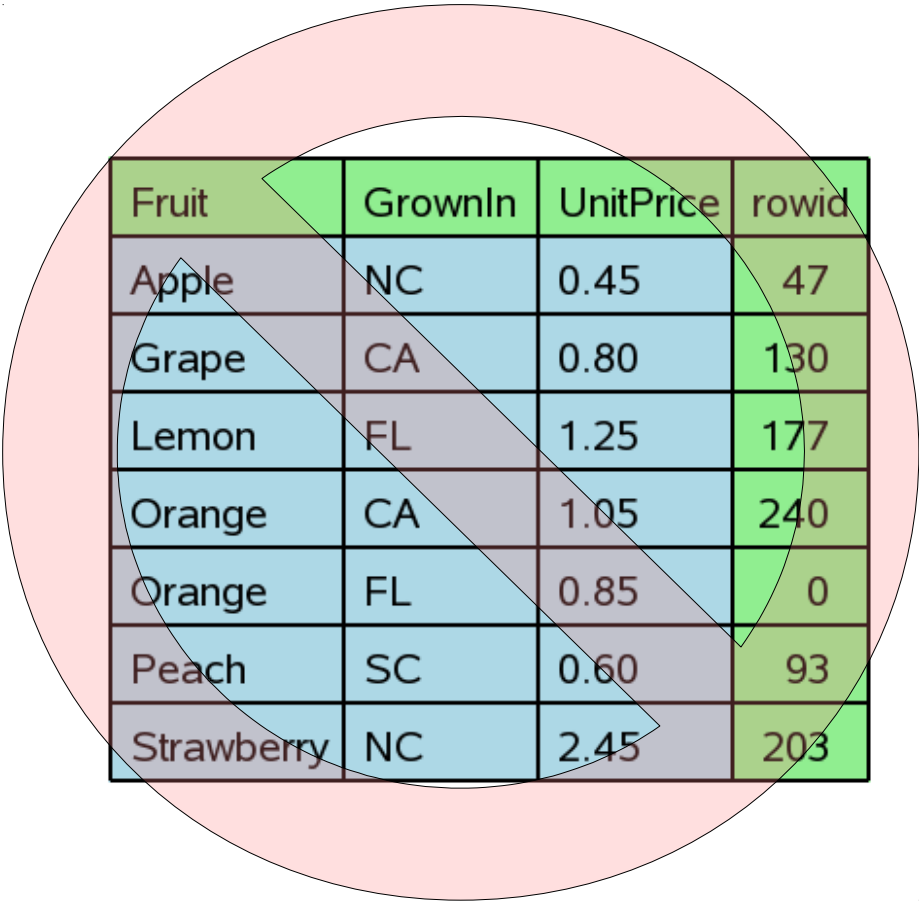
Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

SELECT * FROM tab ORDER BY fruit DESC, grownin



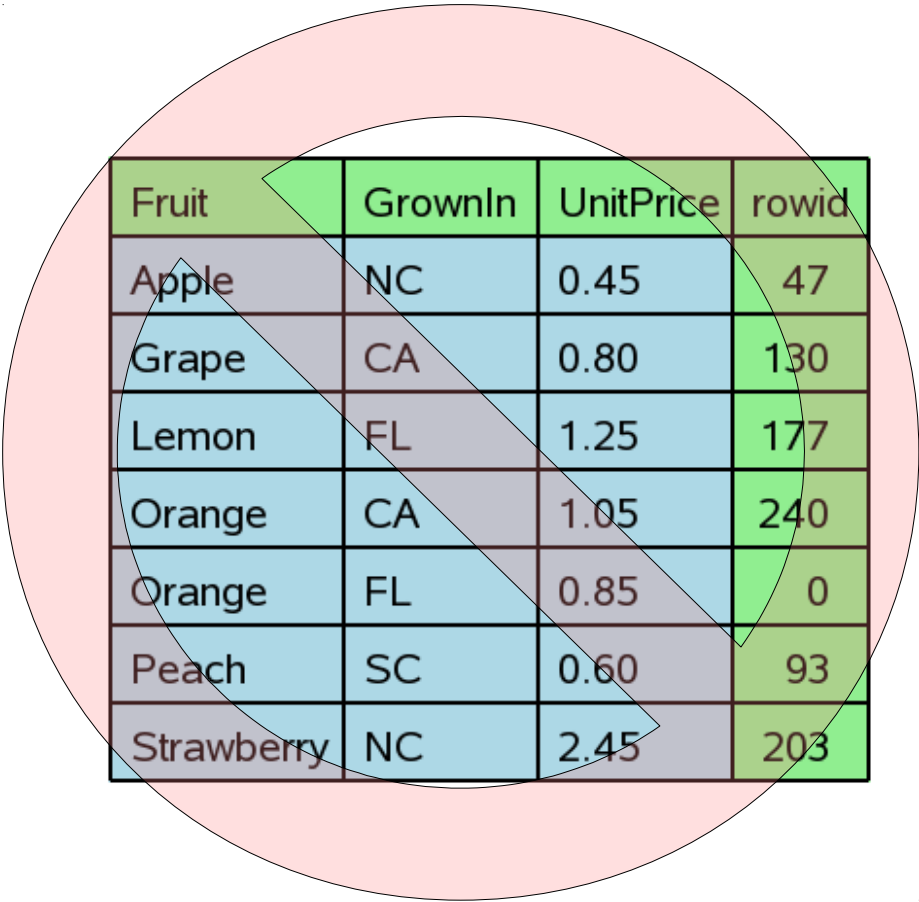
Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

SELECT * FROM tab ORDER BY fruit, unitprice



Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

SELECT * FROM tab ORDER BY grownin



Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

**SELECT grownin, unitprice FROM tab
WHERE fruit='Orange'
ORDER BY grownin**

Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

Index Column Order

```
SELECT x, y, z FROM t1 WHERE w=5 AND x=6 ORDER BY x, y;
```

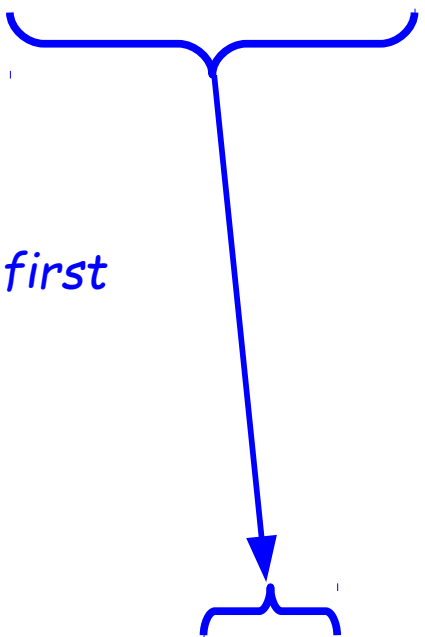
```
CREATE INDEX t1i1 ON t1(w,x,y,z);
```

Index Column Order

```
SELECT x, y, z FROM t1 WHERE w=5 AND x=6 ORDER BY x, y;
```

WHERE clause terms first

```
CREATE INDEX t1i1 ON t1 (w, x, y, z);
```

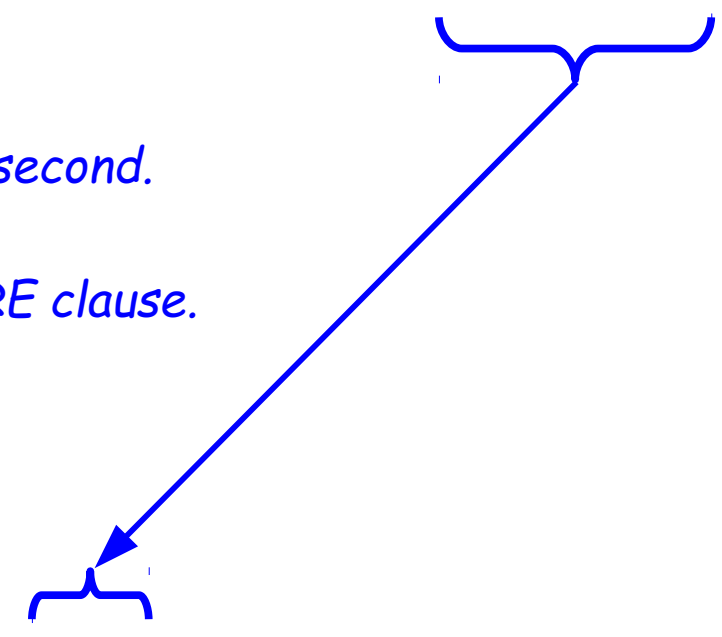
A blue bracket above the WHERE clause terms 'w=5 AND x=6' in the first query points down via a blue arrow to a blue bracket below the first two columns 'w, x' in the index definition of the second query. This illustrates that the columns used in the WHERE clause should be the leading columns in the index.

Index Column Order

```
SELECT x, y, z FROM t1 WHERE w=5 AND x=6 ORDER BY x, y;
```

*ORDER BY terms second.
No gaps!
Can overlap WHERE clause.*

```
CREATE INDEX t1i1 ON t1 (w, x, y, z);
```



The diagram illustrates the relationship between the SQL query and the index. A blue bracket above the 'ORDER BY x, y;' part of the query is connected by a diagonal blue line with an arrow pointing to a blue bracket below the '(w, x, y, z)' part of the index definition. This visualizes that the columns used for ordering (x, y) are part of the index, allowing for an efficient index scan.

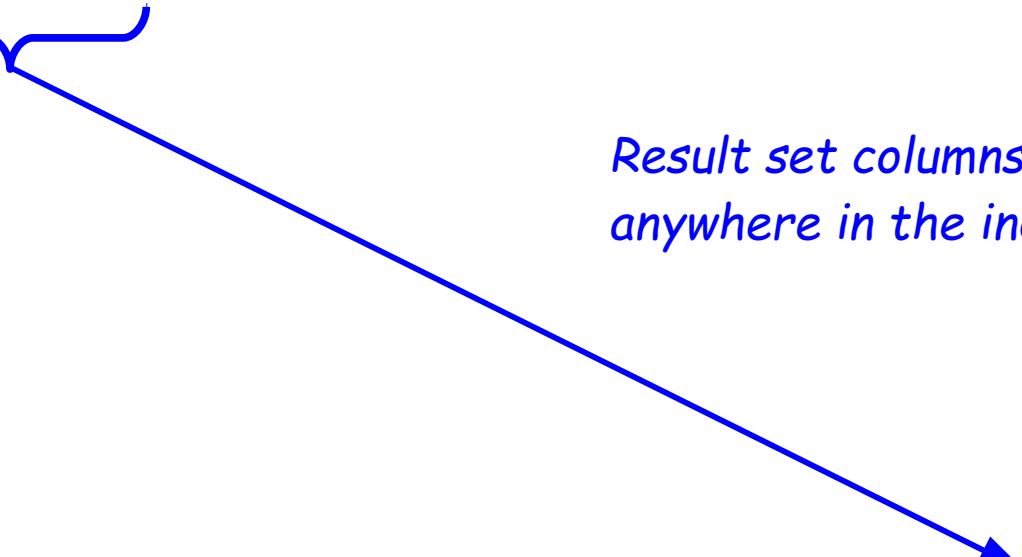
Index Column Order

```
SELECT x, y, z FROM t1 WHERE w=5 AND x=6 ORDER BY x, y;
```



*Result set columns can appear
anywhere in the index. Gaps allowed*

```
CREATE INDEX t1i1 ON t1 (w, x, y, z);
```



```
SELECT unitprice FROM tab  
WHERE fruit='Orange'  
OR grownin='CA'
```

Pesky O R

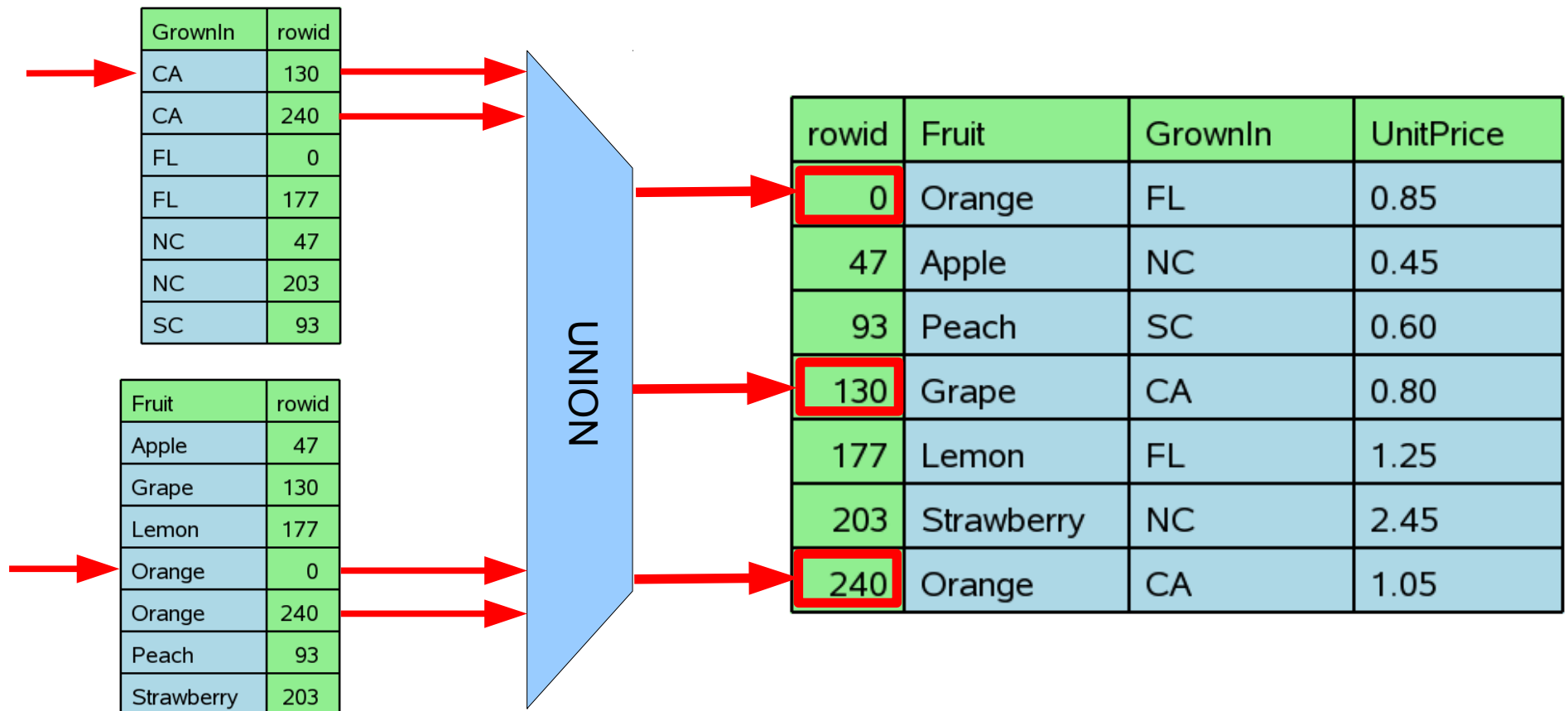


**SELECT unitprice FROM tab
WHERE fruit='Orange'
OR grownin='CA'**

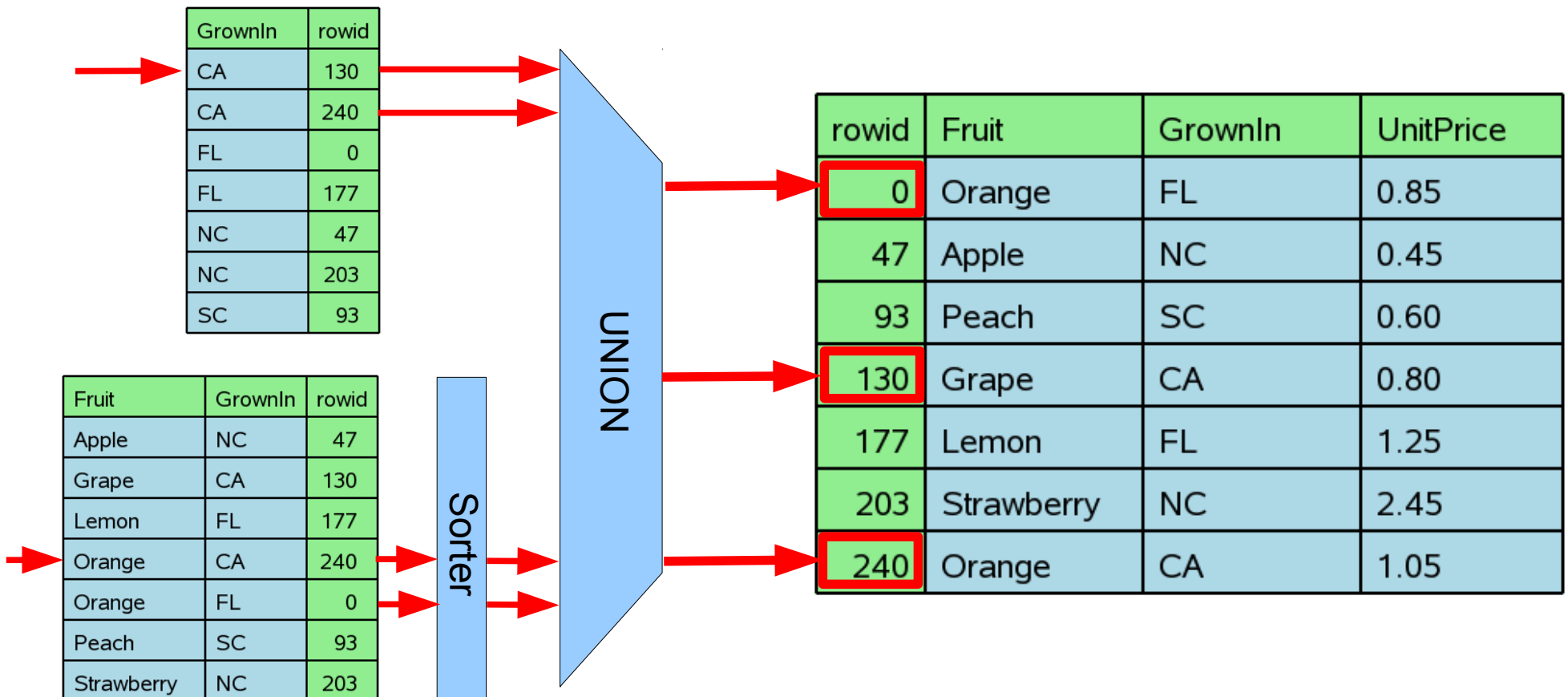
rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05



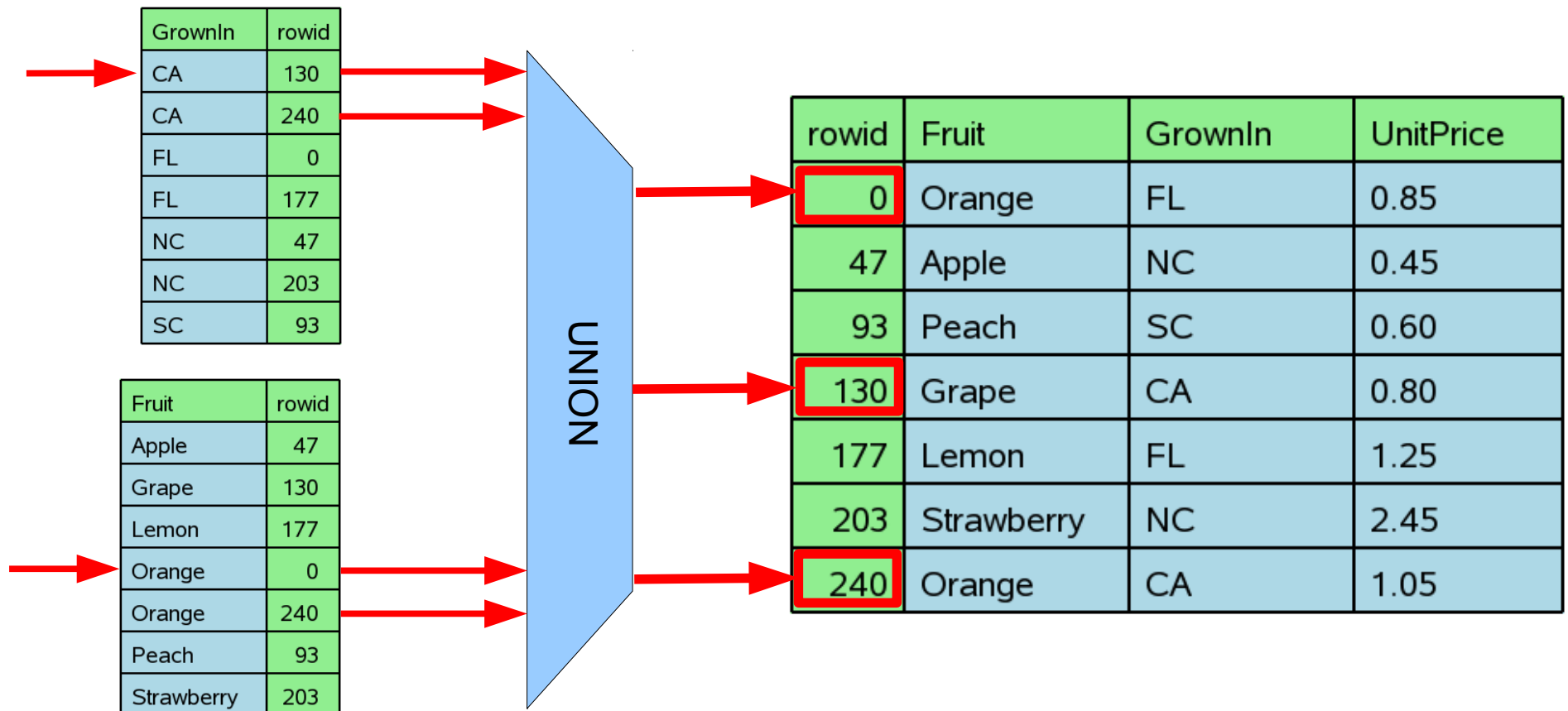
**SELECT unitprice FROM tab
WHERE fruit='Orange'
OR grownin='CA'**



**SELECT unitprice FROM tab
WHERE fruit='Orange'
OR grownin='CA'**

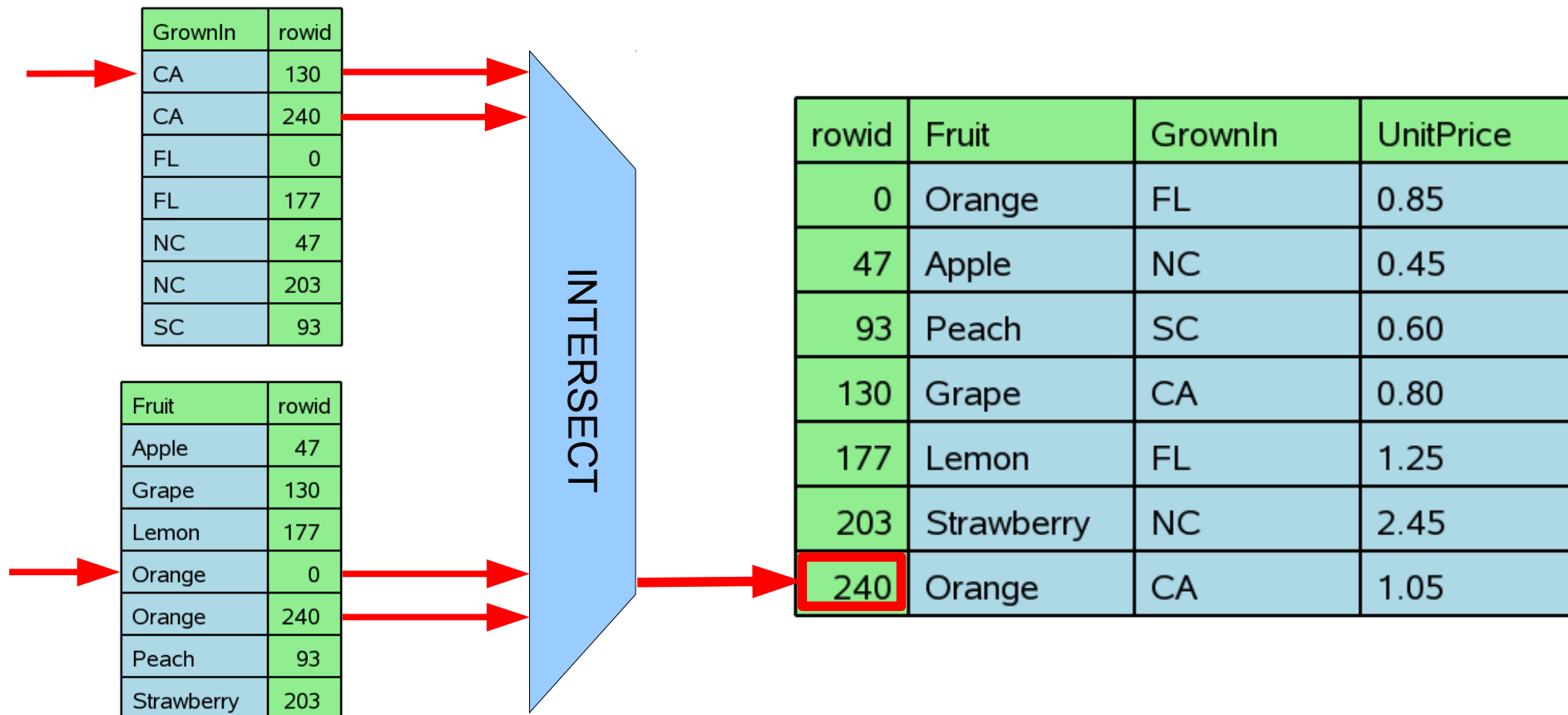


**SELECT unitprice FROM tab
WHERE fruit='Orange'
OR grownin='CA'**



**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

6



**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

4

Fruit	GrownIn	rowid
Apple	NC	47
Grape	CA	130
Lemon	FL	177
Orange	CA	240
Orange	FL	0
Peach	SC	93
Strawberry	NC	203

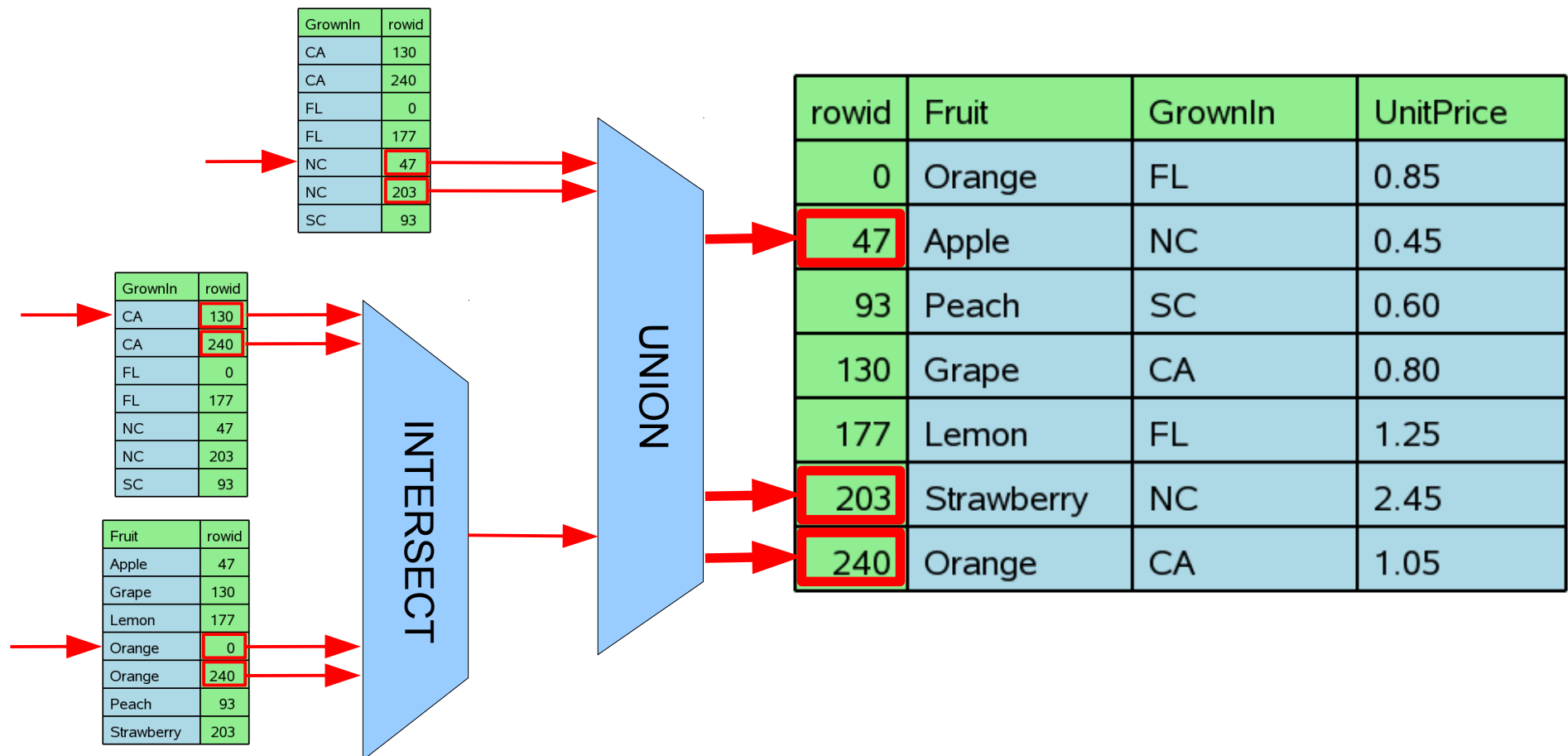
rowid	Fruit	GrownIn	UnitPrice
0	Orange	FL	0.85
47	Apple	NC	0.45
93	Peach	SC	0.60
130	Grape	CA	0.80
177	Lemon	FL	1.25
203	Strawberry	NC	2.45
240	Orange	CA	1.05

**SELECT unitprice FROM tab
WHERE fruit='Orange'
AND grownin='CA'**

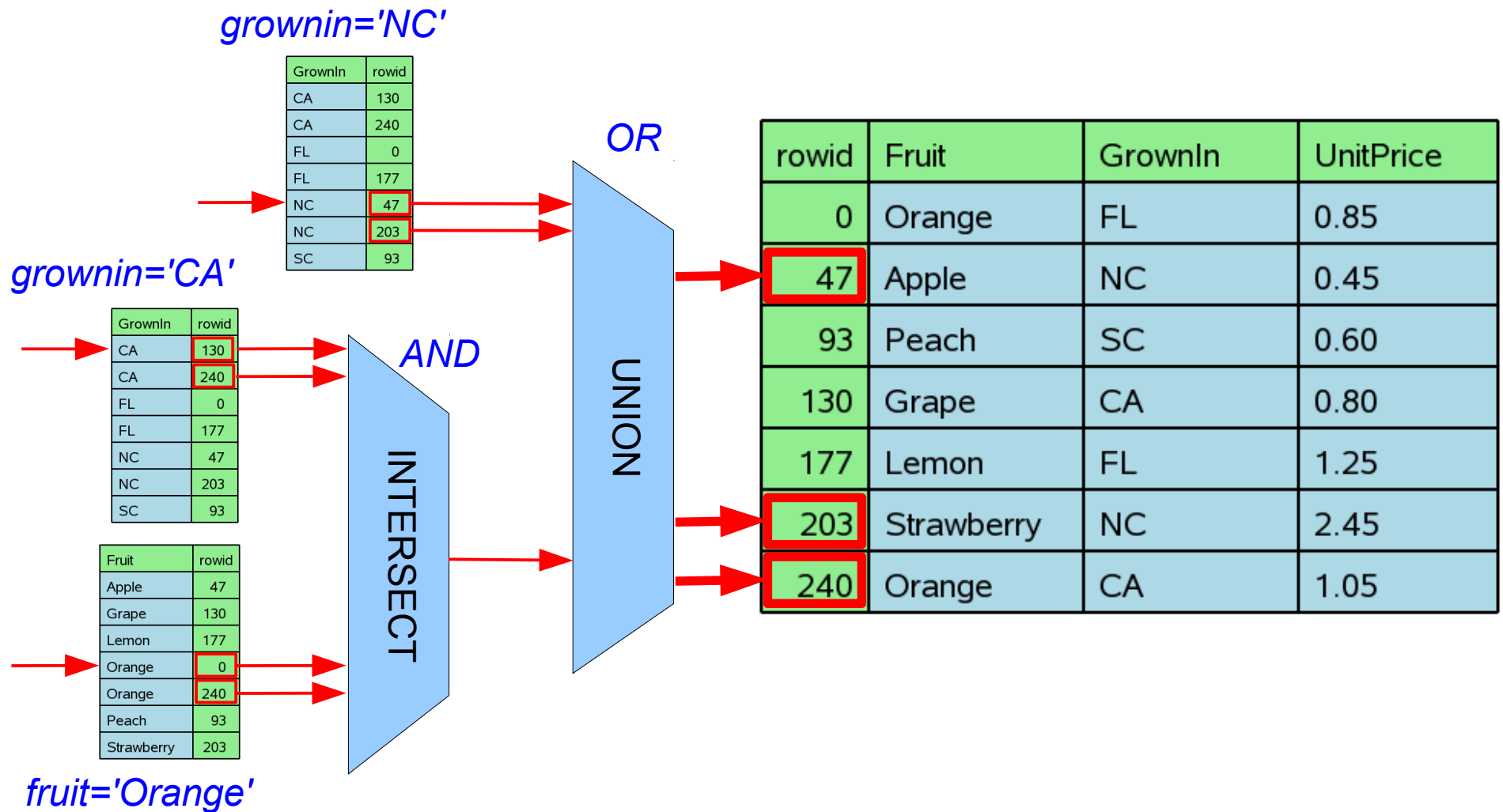
5

Fruit	GrownIn	UnitPrice	rowid
Apple	NC	0.45	47
Grape	CA	0.80	130
Lemon	FL	1.25	177
Orange	CA	1.05	240
Orange	FL	0.85	0
Peach	SC	0.60	93
Strawberry	NC	2.45	203

**SELECT unitprice FROM tab
WHERE (fruit='Orange' AND grownin='CA')
OR grownin='NC'**



**SELECT unitprice FROM tab
WHERE (fruit='Orange' AND grownin='CA')
OR grownin='NC'**



Remember This:

SQL is a programming language

There is a compiler

There is a virtual machine

Indices are not magic – they need to make sense

Avoid too many indices

The more options the optimizer has, the more chances it has to make a poor choice.