

Programming the SQL Way with Common Table Expressions

BRUCE MOMJIAN



Common Table Expressions (CTEs) allow queries to be more imperative, allowing looping and processing hierarchical structures that are normally associated only with imperative languages.

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Outline

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Imperative vs. Declarative: Imperative Programming Languages

In computer science, **imperative** programming is a programming paradigm that describes computation in terms of statements that change a program state. In much the same way that imperative mood in natural languages expresses commands to take action, imperative programs define sequences of commands for the computer to perform.

http://en.wikipedia.org/wiki/Imperative_programming

Declarative Programming Languages

The term is used in opposition to **declarative** programming, which expresses what the program should accomplish without prescribing how to do it in terms of sequence.

Imperative

BASIC:

```
10 PRINT "Hello";  
20 GOTO 10
```

C:

```
while (1)  
    printf("Hello\n");
```

Perl:

```
print("Hello\n") while (1);
```

Declarative

SQL:

```
SELECT 'Hello'  
UNION ALL  
SELECT 'Hello'  
UNION ALL  
SELECT 'Hello'  
UNION ALL  
SELECT 'Hello'
```

...

An infinite loop is not easily implemented in simple SQL.

Imperative Database Options

- ▶ Client application code (e.g. libpq, JDBC, DBD::Pg)
- ▶ Server-side programming (e.g. PL/pgSQL, PL/Perl, C)
- ▶ **Common table expressions**

Common Table Expression Syntax (CTE)

```
WITH [ RECURSIVE ] with_query_name [ ( column_name [, ...] ) ] AS  
    ( select ) [ , ... ]  
SELECT ...
```

CTE support was added in Postgres 8.4.

A Simple CTE

```
WITH source AS (  
    SELECT 1  
)  
SELECT * FROM source;  
?column?  
-----  
1  
(1 row)
```

The CTE created a *source* table that was referenced by the outer SELECT. All queries in this presentation can be downloaded from <http://momjian.us/main/writings/pgsql/cte.sql>

Let's Name the Returned CTE Column

```
WITH source AS (  
    SELECT 1 AS col1  
)  
SELECT * FROM source;  
col1  
-----  
    1  
(1 row)
```

The CTE returned column is *source.col1*.

The Column Can Also Be Named in the WITH Clause

```
WITH source (col1) AS (  
    SELECT 1  
)  
SELECT * FROM source;  
col1  
-----  
    1  
(1 row)
```

Columns Can Be Renamed

```
WITH source (col2) AS (  
    SELECT 1 AS col1  
)  
SELECT col2 AS col3 FROM source;  
col3  
-----  
    1  
(1 row)
```

The CTE column starts as *col1*, is renamed in the WITH clause as *col2*, and the outer SELECT renames it to *col3*.

Multiple CTE Columns Can Be Returned

```
WITH source AS (  
    SELECT 1, 2  
)  
SELECT * FROM source;  
?column? | ?column?  
-----+-----  
          1 |          2  
(1 row)
```

UNION Refresher

```
SELECT 1  
UNION  
SELECT 1;  
  ?column?
```

```
-----  
          1  
(1 row)
```

```
SELECT 1  
UNION ALL  
SELECT 1;  
  ?column?
```

```
-----  
          1  
          1  
(2 rows)
```

Possible To Create Multiple CTE Results

```
WITH source AS (  
    SELECT 1, 2  
)  
    ,  
    source2 AS (  
    SELECT 3, 4  
)  
SELECT * FROM source  
UNION ALL  
SELECT * FROM source2;  
  ?column? | ?column?  
-----+-----  
         1 |         2  
         3 |         4  
(2 rows)
```

CTE with Real Tables

```
WITH source AS (  
    SELECT lanname, rolname  
    FROM pg_language JOIN pg_roles ON lanowner = pg_roles.oid  
)
```

```
SELECT * FROM source;
```

lanname	rolname
internal	postgres
c	postgres
sql	postgres
plpgsql	postgres

(4 rows)

CTE Can Be Processed More than Once

```
WITH source AS (  
    SELECT lanname, rolname  
    FROM pg_language JOIN pg_roles ON lanowner = pg_roles.oid  
    ORDER BY lanname  
)  
SELECT * FROM source  
UNION ALL  
SELECT MIN(lanname), NULL  
FROM source;  
 lanname | rolname  
-----+-----  
c        | postgres  
internal | postgres  
plpgsql  | postgres  
sql      | postgres  
c        |  
(5 rows)
```

CTE Can Be Joined

```
WITH class (oid, relname) AS (  
    SELECT oid, relname  
    FROM pg_class  
    WHERE relkind = 'r'  
)  
SELECT class.relname, attname  
FROM pg_attribute, class  
WHERE class.oid = attrelid  
ORDER BY 1, 2  
LIMIT 5;
```

relname	attname
pg_aggregate	aggfinalfn
pg_aggregate	aggfnoid
pg_aggregate	agginitval
pg_aggregate	aggsortop
pg_aggregate	aggtransfn

(5 rows)

Imperative Control With CASE

```
CASE  
WHEN condition THEN result  
ELSE result  
END
```

For example:

```
SELECT col,  
       CASE  
         WHEN col > 0 THEN 'positive'  
         WHEN col = 0 THEN 'zero'  
         ELSE 'negative'  
       END  
FROM tab;
```

Recursive CTEs: Looping

```
WITH RECURSIVE source AS (  
    SELECT 1  
)  
SELECT * FROM source;  
?column?  
-----  
1  
(1 row)
```

This does not loop because *source* is not mentioned in the CTE.

This Is an Infinite Loop

```
SET statement_timeout = '1s';
SET
WITH RECURSIVE source AS (
    SELECT 1
    UNION ALL
    SELECT 1 FROM source
)
SELECT * FROM source;
ERROR: canceling statement due to statement timeout
```

Flow Of Rows

```
WITH RECURSIVE source AS (  
  SELECT 1  
  UNION ALL  
  SELECT 1 FROM source  
)  
SELECT * FROM source;
```

The diagram illustrates the flow of rows in a recursive query. Three blue circles labeled 1, 2, and 3 are connected by red arrows. Circle 1 points to the word "source" in the AS clause. Circle 2 points to the word "source" in the FROM clause. Circle 3 points to the word "source" in the FROM clause of the recursive query.

The 'Hello' Example in SQL

```
WITH RECURSIVE source AS (  
    SELECT 'Hello'  
    UNION ALL  
    SELECT 'Hello' FROM source  
)  
SELECT * FROM source;  
ERROR: canceling statement due to statement timeout  
RESET statement_timeout;  
RESET
```

UNION without ALL Avoids Recursion

```
WITH RECURSIVE source AS (  
    SELECT 'Hello'  
    UNION  
    SELECT 'Hello' FROM source  
)  
SELECT * FROM source;  
?column?  
-----  
Hello  
(1 row)
```


CTEs Are Useful When Loops Are Constrained

```
WITH RECURSIVE source (counter) AS (  
    -- seed value  
    SELECT 1  
    UNION ALL  
    SELECT counter + 1  
    FROM source  
    -- terminal condition  
    WHERE counter < 10  
)  
SELECT * FROM source;
```

Output

```
counter
-----
  1
  2
  3
  4
  5
  6
  7
  8
  9
 10
(10 rows)
```

Of course, this can be more easily accomplished using `generate_series(1, 10)`.

Perl Example

```
for (my $i = 1; $i <= 10; $i++)  
{  
    print "$i\n";  
}
```

Perl Using Recursion

```
sub f
{
    my $arg = shift;
    print "$arg\n";
    f($arg + 1) if ($arg < 10);
}
f(1);
```

Perl Recursion Using an Array

```
my @table;
sub f
{
    my $arg = shift;
    push @table, !defined($arg) ? 1 : $arg;
    f($arg + 1) if ($arg < 10);
}
f();
map {print "$_\n"} @table;
```

This is the most accurate representation of CTEs because it accumulates results in an array (similar to a table result).

Examples: Ten Factorial Using CTE

```
WITH RECURSIVE source (counter, product) AS (  
    SELECT 1, 1  
    UNION ALL  
    SELECT counter + 1, product * (counter + 1)  
    FROM source  
    WHERE counter < 10  
)  
SELECT counter, product FROM source;
```

Output

counter		product
1		1
2		2
3		6
4		24
5		120
6		720
7		5040
8		40320
9		362880
10		3628800

(10 rows)

Only Display the Desired Row

```
WITH RECURSIVE source (counter, product) AS (  
    SELECT 1, 1  
    UNION ALL  
    SELECT counter + 1, product * (counter + 1)  
    FROM source  
    WHERE counter < 10  
)  
SELECT counter, product  
FROM source  
WHERE counter = 10;  
  counter | product  
-----+-----  
         10 | 3628800  
(1 row)
```


Ten Factorial in Perl

```
my @table;
sub f
{
    my ($counter, $product) = @_;
    my ($counter_new, $product_new);
    if (!defined($counter)) {
        $counter_new = 1;
        $product_new = 1;
    } else {
        $counter_new = $counter + 1;
        $product_new = $product * ($counter + 1);
    }
    push(@table, [$counter_new, $product_new]);
    f($counter_new, $product_new) if ($counter < 10);
}
f();
map {print "@$_\n" if ($_->[0]) == 10} @table;
```

String Manipulation Is Also Possible

```
WITH RECURSIVE source (str) AS (  
    SELECT 'a'  
    UNION ALL  
    SELECT str || 'a'  
    FROM source  
    WHERE length(str) < 10  
)  
SELECT * FROM source;
```

Output

str

a

aa

aaa

aaaa

aaaaa

aaaaaa

aaaaaaa

aaaaaaaa

aaaaaaaaa

aaaaaaaaaa

(10 rows)

Characters Can Be Computed

```
WITH RECURSIVE source (str) AS (  
    SELECT 'a'  
    UNION ALL  
    SELECT str || chr(ascii(substr(str, length(str))) + 1)  
    FROM source  
    WHERE length(str) < 10  
)  
SELECT * FROM source;
```

Output

str

a

ab

abc

abcd

abcde

abcdef

abcdefg

abcdefgh

abcdefghi

abcdefghij

(10 rows)

ASCII Art Is Even Possible

```
WITH RECURSIVE source (counter) AS (  
    SELECT -10  
    UNION ALL  
    SELECT counter + 1  
    FROM source  
    WHERE counter < 10  
)  
SELECT repeat(' ', 5 - abs(counter) / 2) ||  
       'X' ||  
       repeat(' ', abs(counter)) ||  
       'X'  
FROM source;
```


How Is that Done?

```
WITH RECURSIVE source (counter) AS (  
    SELECT -10  
    UNION ALL  
    SELECT counter + 1  
    FROM source  
    WHERE counter < 10  
)  
SELECT counter,  
    repeat(' ', 5 - abs(counter) / 2) ||  
    'X' ||  
    repeat(' ', abs(counter)) ||  
    'X'  
FROM source;
```

This generates Integers from -10 to 10, and these numbers are used to print an appropriate number of spaces.

Output

counter		?column?
-10		X X
-9		X X
-8		X X
-7		X X
-6		X X
-5		X X
-4		X X
-3		X X
-2		X X
-1		X X
0		XX
1		X X
2		X X
3		X X
4		X X
5		X X
6		X X
7		X X
8		X X
9		X X
10		X X

(21 rows)

ASCII Circles Are Even Possible

```
WITH RECURSIVE source (counter) AS (  
    SELECT -10  
    UNION ALL  
    SELECT counter + 1  
    FROM source  
    WHERE counter < 10  
)  
SELECT repeat(' ', abs(counter)/2) ||  
       'X' ||  
       repeat(' ', 10 - abs(counter)) ||  
       'X'  
FROM source;
```


More Rounded

```
WITH RECURSIVE source (counter) AS (  
    SELECT -10  
    UNION ALL  
    SELECT counter + 1  
    FROM source  
    WHERE counter < 10  
)  
SELECT repeat(' ', int4(pow(counter, 2)/10)) ||  
       'X' ||  
       repeat(' ', 2 * (10 - int4(pow(counter, 2)/10))) ||  
       'X'  
FROM source;
```

An Oval

?column?

```
      XX
     X  X
    X  X
   X  X
  X  X
 X  X
X  X
X  X
X  X
X  X
X  X
 X  X
  X  X
   X  X
    X  X
     X  X
      XX
```

(21 rows)

A Real Circle

```
WITH RECURSIVE source (counter) AS (  
    SELECT -10  
    UNION ALL  
    SELECT counter + 1  
    FROM source  
    WHERE counter < 10  
)  
SELECT repeat(' ', int4(pow(counter, 2)/5)) ||  
    'X' ||  
    repeat(' ', 2 * (20 - int4(pow(counter, 2)/5))) ||  
    'X'  
FROM source;
```


Prime Factors

The prime factors of X are the prime numbers that must be multiplied to equal a X , e.g.:

$$10 = 2 * 5$$

$$27 = 3 * 3 * 3$$

$$48 = 2 * 2 * 2 * 2 * 3$$

$$66 = 2 * 3 * 11$$

$$70 = 2 * 5 * 7$$

$$100 = 2 * 2 * 5 * 5$$

Prime Factorization in SQL

```
WITH RECURSIVE source (counter, factor, is_factor) AS (  
    SELECT 2, 56, false  
    UNION ALL  
    SELECT  
        CASE  
            WHEN factor % counter = 0 THEN counter  
            ELSE counter + 1  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN factor / counter  
            ELSE factor  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN true  
            ELSE false  
        END  
    FROM source  
    WHERE factor <> 1  
)  
SELECT * FROM source;
```

Output

counter	factor	is_factor
2	56	f
2	28	t
2	14	t
2	7	t
3	7	f
4	7	f
5	7	f
6	7	f
7	7	f
7	1	t

(10 rows)

Only Return Prime Factors

```
WITH RECURSIVE source (counter, factor, is_factor) AS (  
    SELECT 2, 56, false  
    UNION ALL  
    SELECT  
        CASE  
            WHEN factor % counter = 0 THEN counter  
            ELSE counter + 1  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN factor / counter  
            ELSE factor  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN true  
            ELSE false  
        END  
    FROM source  
    WHERE factor <> 1  
)  
SELECT * FROM source WHERE is_factor;
```

Output

counter	factor	is_factor
2	28	t
2	14	t
2	7	t
7	1	t

(4 rows)

Factors of 322434

```
WITH RECURSIVE source (counter, factor, is_factor) AS (  
    SELECT 2, 322434, false  
    UNION ALL  
    SELECT  
        CASE  
            WHEN factor % counter = 0 THEN counter  
            ELSE counter + 1  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN factor / counter  
            ELSE factor  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN true  
            ELSE false  
        END  
    FROM source  
    WHERE factor <> 1  
)  
SELECT * FROM source WHERE is_factor;
```

Output

counter	factor	is_factor
2	161217	t
3	53739	t
3	17913	t
3	5971	t
7	853	t
853	1	t

(6 rows)

Prime Factors of 66

```
WITH RECURSIVE source (counter, factor, is_factor) AS (  
    SELECT 2, 66, false  
    UNION ALL  
    SELECT  
        CASE  
            WHEN factor % counter = 0 THEN counter  
            ELSE counter + 1  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN factor / counter  
            ELSE factor  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN true  
            ELSE false  
        END  
    FROM source  
    WHERE factor <> 1  
)  
SELECT * FROM source;
```

Inefficient

counter	factor	is_factor
2	66	f
2	33	t
3	33	f
3	11	t
4	11	f
5	11	f
6	11	f
7	11	f
8	11	f
9	11	f
10	11	f
11	11	f
11	1	t

(13 rows)

Skip Evens >2, Exit Early with a Final Prime

```
WITH RECURSIVE source (counter, factor, is_factor) AS (  
    SELECT 2, 66, false  
    UNION ALL  
    SELECT  
        CASE  
            WHEN factor % counter = 0 THEN counter  
            -- is 'factor' prime?  
            WHEN counter * counter > factor THEN factor  
            -- now only odd numbers  
            WHEN counter = 2 THEN 3  
            ELSE counter + 2  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN factor / counter  
            ELSE factor  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN true  
            ELSE false  
        END  
    FROM source  
    WHERE factor <> 1  
)  
SELECT * FROM source;
```

Output

counter	factor	is_factor
2	66	f
2	33	t
3	33	f
3	11	t
5	11	f
11	11	f
11	1	t

(7 rows)

Return Only Prime Factors

```
WITH RECURSIVE source (counter, factor, is_factor) AS (  
    SELECT 2,66, false  
    UNION ALL  
    SELECT  
        CASE  
            WHEN factor % counter = 0 THEN counter  
            -- is 'factor' prime?  
            WHEN counter * counter > factor THEN factor  
            -- now only odd numbers  
            WHEN counter = 2 THEN 3  
            ELSE counter + 2  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN factor / counter  
            ELSE factor  
        END,  
        CASE  
            WHEN factor % counter = 0 THEN true  
            ELSE false  
        END  
    FROM source  
    WHERE factor <> 1  
)  
SELECT * FROM source WHERE is_factor;
```

Output

counter	factor	is_factor
2	33	t
3	11	t
11	1	t

(3 rows)

Optimized Prime Factors of 66 in Perl

```
my @table;
sub f
{
    my ($counter, $factor, $is_factor) = @_;
    my ($counter_new, $factor_new, $is_factor_new);
    if (!defined($counter)) {
        $counter_new = 2;
        $factor_new = 66;
        $is_factor_new = 0;
    } else {
        $counter_new = ($factor % $counter == 0) ?
            $counter :
            ($counter * $counter > $factor) ?
                $factor :
            ($counter == 2) ?
                3 :
                $counter + 2;
        $factor_new = ($factor % $counter == 0) ?
            $factor / $counter :
            $factor;
        $is_factor_new = ($factor % $counter == 0);
    }
    push(@table, [$counter_new, $factor_new, $is_factor_new]);
    f($counter_new, $factor_new) if ($factor != 1);
}
f();
map {print "$_->[0] $_->[1] $_->[2]\n" if ($_->[2]) == 1} @table;
```

Recursive Table Processing: Setup

```
CREATE TEMPORARY TABLE part (parent_part_no INTEGER, part_no INTEGER);
CREATE TABLE
INSERT INTO part VALUES (1, 11);
INSERT 0 1
INSERT INTO part VALUES (1, 12);
INSERT 0 1
INSERT INTO part VALUES (1, 13);
INSERT 0 1
INSERT INTO part VALUES (2, 21);
INSERT 0 1
INSERT INTO part VALUES (2, 22);
INSERT 0 1
INSERT INTO part VALUES (2, 23);
INSERT 0 1
INSERT INTO part VALUES (11, 101);
INSERT 0 1
INSERT INTO part VALUES (13, 102);
INSERT 0 1
INSERT INTO part VALUES (13, 103);
INSERT 0 1
INSERT INTO part VALUES (22, 221);
INSERT 0 1
INSERT INTO part VALUES (22, 222);
INSERT 0 1
INSERT INTO part VALUES (23, 231);
```

Use CTEs To Walk Through Parts Heirarchy

```
WITH RECURSIVE source (part_no) AS (  
    SELECT 2  
    UNION ALL  
    SELECT part.part_no  
    FROM source JOIN part ON (source.part_no = part.parent_part_no)  
)  
SELECT * FROM source;  
part_no  
-----  
    2  
   21  
   22  
   23  
  221  
  222  
  231  
(7 rows)
```

Add Dashes

```
WITH RECURSIVE source (level, part_no) AS (  
    SELECT 0, 2  
    UNION ALL  
    SELECT level + 1, part.part_no  
    FROM source JOIN part ON (source.part_no = part.parent_part_no)  
)  
SELECT '+' || repeat('-', level * 2) || part_no::text AS part_tree  
FROM source;  
part_tree  
-----  
+2  
+--21  
+--22  
+--23  
+----221  
+----222  
+----231  
(7 rows)
```


The Parts in ASCII Order

```
WITH RECURSIVE source (level, tree, part_no) AS (  
    SELECT 0, '2', 2  
    UNION ALL  
    SELECT level + 1, tree || ' ' || part.part_no::text, part.part_no  
    FROM source JOIN part ON (source.part_no = part.parent_part_no)  
)  
SELECT '+' || repeat('-', level * 2) || part_no::text AS part_tree, tree  
FROM source
```

ORDER BY tree;

part_tree	tree
-----+-----	
+2	2
+--21	2 21
+--22	2 22
+----221	2 22 221
+----222	2 22 222
+--23	2 23
+----231	2 23 231

(7 rows)

The Parts in Numeric Order

```
WITH RECURSIVE source (level, tree, part_no) AS (  
    SELECT 0, '{2}'::int[], 2  
    UNION ALL  
    SELECT level + 1, array_append(tree, part.part_no), part.part_no  
    FROM source JOIN part ON (source.part_no = part.parent_part_no)  
)  
SELECT '+' || repeat('-', level * 2) || part_no::text AS part_tree, tree  
FROM source  
ORDER BY tree;
```

part_tree	tree
+2	{2}
+--21	{2,21}
+--22	{2,22}
+----221	{2,22,221}
+----222	{2,22,222}
+--23	{2,23}
+----231	{2,23,231}

(7 rows)

Full Output

```
WITH RECURSIVE source (level, tree, part_no) AS (  
    SELECT 0, '{2}'::int[], 2  
    UNION ALL  
    SELECT level + 1, array_append(tree, part.part_no), part.part_no  
    FROM source JOIN part ON (source.part_no = part.parent_part_no)  
)  
SELECT *, '+' || repeat('-', level * 2) || part_no::text AS part_tree  
FROM source  
ORDER BY tree;
```

level	tree	part_no	part_tree
0	{2}	2	+2
1	{2,21}	21	+--21
1	{2,22}	22	+--22
2	{2,22,221}	221	+----221
2	{2,22,222}	222	+----222
1	{2,23}	23	+--23
2	{2,23,231}	231	+----231

(7 rows)

CTE for SQL Object Dependency

```
CREATE TEMPORARY TABLE deptest (x1 INTEGER);  
CREATE TABLE
```

CTE for SQL Object Dependency

```
WITH RECURSIVE dep (classid, obj) AS (  
    SELECT (SELECT oid FROM pg_class WHERE relname = 'pg_class'),  
           oid  
    FROM pg_class  
    WHERE relname = 'deptest'  
    UNION ALL  
    SELECT pg_depend.classid, objid  
    FROM pg_depend JOIN dep ON (refobjid = dep.obj)  
)  
SELECT (SELECT relname FROM pg_class WHERE oid = classid) AS class,  
       (SELECT typname FROM pg_type WHERE oid = obj) AS type,  
       (SELECT relname FROM pg_class WHERE oid = obj) AS class,  
       (SELECT relkind FROM pg_class where oid = obj::regclass) AS kind,  
       (SELECT adsrc FROM pg_attrdef WHERE oid = obj) AS attrdef,  
       (SELECT conname FROM pg_constraint WHERE oid = obj) AS constraint  
FROM dep  
ORDER BY obj;
```

Output

class	type	class	kind	attrdef	constraint
pg_class		deptest	r		
pg_type	_deptest				
pg_type	deptest				

(3 rows)

Do Not Show *deptest*

```
WITH RECURSIVE dep (classid, obj) AS (  
    SELECT classid, objid  
    FROM pg_depend JOIN pg_class ON (refobjid = pg_class.oid)  
    WHERE relname = 'deptest'  
    UNION ALL  
    SELECT pg_depend.classid, objid  
    FROM pg_depend JOIN dep ON (refobjid = dep.obj)  
)  
SELECT (SELECT relname FROM pg_class WHERE oid = classid) AS class,  
       (SELECT typename FROM pg_type WHERE oid = obj) AS type,  
       (SELECT relname FROM pg_class WHERE oid = obj) AS class,  
       (SELECT relkind FROM pg_class where oid = obj::regclass) AS kind,  
       (SELECT adsrc FROM pg_attrdef WHERE oid = obj) AS attrdef,  
       (SELECT conname FROM pg_constraint WHERE oid = obj) AS constraint  
FROM dep  
ORDER BY obj;
```

Output

class	type	class	kind	attrdef	constraint
pg_type	_deptest				
pg_type	deptest				

(2 rows)

Add a Primary Key

```
ALTER TABLE deptest ADD PRIMARY KEY (x1);
```

```
NOTICE: ALTER TABLE / ADD PRIMARY KEY will create implicit index "deptest_pkey" fo  
ALTER TABLE
```

Output With Primary Key

```
WITH RECURSIVE dep (classid, obj) AS (  
    SELECT (SELECT oid FROM pg_class WHERE relname = 'pg_class'),  
           oid  
    FROM pg_class  
    WHERE relname = 'deptest'  
    UNION ALL  
    SELECT pg_depend.classid, objid  
    FROM pg_depend JOIN dep ON (refobjid = dep.obj)  
)  
SELECT (SELECT relname FROM pg_class WHERE oid = classid) AS class,  
       (SELECT typname FROM pg_type WHERE oid = obj) AS type,  
       (SELECT relname FROM pg_class WHERE oid = obj) AS class,  
       (SELECT relkind FROM pg_class where oid = obj::regclass) AS kind,  
       (SELECT adsrc FROM pg_attrdef WHERE oid = obj) AS attrdef,  
       (SELECT conname FROM pg_constraint WHERE oid = obj) AS constraint  
FROM dep  
ORDER BY obj;
```

Output

class	type	class	kind	attrdef	constraint
pg_class		deptest	r		
pg_type	_deptest				
pg_type	deptest				
pg_class		deptest_pkey	i		
pg_constraint					deptest_pkey

(5 rows)

Add a SERIAL Column

```
ALTER TABLE deptest ADD COLUMN x2 SERIAL;
```

NOTICE: ALTER TABLE will create implicit sequence "deptest_x2_seq" for serial column "deptest.x2"
ALTER TABLE

Output with SERIAL Column

```
WITH RECURSIVE dep (classid, obj) AS (  
    SELECT (SELECT oid FROM pg_class WHERE relname = 'pg_class'),  
           oid  
    FROM pg_class  
    WHERE relname = 'deptest'  
    UNION ALL  
    SELECT pg_depend.classid, objid  
    FROM pg_depend JOIN dep ON (refobjid = dep.obj)  
)  
SELECT (SELECT relname FROM pg_class WHERE oid = classid) AS class,  
       (SELECT typname FROM pg_type WHERE oid = obj) AS type,  
       (SELECT relname FROM pg_class WHERE oid = obj) AS class,  
       (SELECT relkind FROM pg_class where oid = obj::regclass) AS kind,  
       (SELECT adsrc FROM pg_attrdef WHERE oid = obj) AS attrdef  
       -- column removed to reduce output width  
FROM dep  
ORDER BY obj;
```

Output

class	type	class	kind	attrdef
pg_class		deptest	r	
pg_type	_deptest			
pg_type	deptest			
pg_class		deptest_pkey	i	
pg_constraint				
pg_class		deptest_x2_seq	S	
pg_type	deptest_x2_seq			
pg_attrdef				nextval('deptest_x2_seq'::regclass)
pg_attrdef				nextval('deptest_x2_seq'::regclass)

(9 rows)

Show Full Output

```
WITH RECURSIVE dep (level, tree, classid, obj) AS (  
    SELECT 0, array_append(null, oid)::oid[],  
           (SELECT oid FROM pg_class WHERE relname = 'pg_class'),  
           oid  
    FROM pg_class  
    WHERE relname = 'deptest'  
    UNION ALL  
    SELECT level + 1, array_append(tree, objid),  
           pg_depend.classid, objid  
    FROM pg_depend JOIN dep ON (refobjid = dep.obj)  
)  
SELECT tree,  
       (SELECT relname FROM pg_class WHERE oid = classid) AS class,  
       (SELECT typename FROM pg_type WHERE oid = obj) AS type,  
       (SELECT relname FROM pg_class WHERE oid = obj) AS class,  
       (SELECT relkind FROM pg_class where oid = obj::regclass) AS kind  
       -- column removed to reduce output width  
FROM dep  
ORDER BY tree, obj;
```

Output

tree	class	type	class	kind
{16458}	pg_class		deptest	r
{16458,16460}	pg_type	deptest		
{16458,16460,16459}	pg_type	_deptest		
{16458,16462}	pg_constraint			
{16458,16462,16461}	pg_class		deptest_pkey	i
{16458,16463}	pg_class		deptest_x2_seq	S
{16458,16463,16464}	pg_type	deptest_x2_seq		
{16458,16463,16465}	pg_attrdef			
{16458,16465}	pg_attrdef			

(9 rows)

Writable CTEs

- ▶ Allow data-modification commands (INSERT/UPDATE/DELETE) in WITH clauses (Marko Tiikkaja, Hitoshi Harada)
 - ▶ These commands can use RETURNING to pass data up to the containing query.
- ▶ Allow WITH clauses to be attached to INSERT, UPDATE, DELETE statements (Marko Tiikkaja, Hitoshi Harada)
- ▶ Added in Postgres 9.1

Use INSERT, UPDATE, DELETE in WITH Clauses

```
CREATE TEMPORARY TABLE retdemo (x NUMERIC);
```

```
CREATE TABLE
```

```
INSERT INTO retdemo VALUES (random()), (random()), (random()) RETURNING x;
```

```
x
```

```
-----
```

```
0.00761545216664672
```

```
0.85416117589920831
```

```
0.10137318633496895
```

```
(3 rows)
```

```
INSERT 0 3
```

```
WITH source AS (
```

```
    INSERT INTO retdemo
```

```
    VALUES (random()), (random()), (random()) RETURNING x
```

```
)
```

```
SELECT AVG(x) FROM source;
```

```
avg
```

```
-----
```

```
0.46403147140517833
```

```
(1 row)
```

Use INSERT, UPDATE, DELETE in WITH Clauses

```
WITH source AS (  
    DELETE FROM retdemo RETURNING x  
)  
SELECT MAX(x) FROM source;  
      max  
-----  
0.93468171451240821  
(1 row)
```

Supply Rows to INSERT, UPDATE, DELETE Using WITH Clauses

```
CREATE TEMPORARY TABLE retdemo2 (x NUMERIC);
```

```
CREATE TABLE
```

```
INSERT INTO retdemo2 VALUES (random()), (random()), (random());
```

```
INSERT 0 3
```

```
WITH source (average) AS (  
    SELECT AVG(x) FROM retdemo2  
)
```

```
DELETE FROM retdemo2 USING source  
WHERE retdemo2.x < source.average;
```

```
DELETE 2
```

```
SELECT * FROM retdemo2;  
      x
```

```
-----  
0.777186767663807  
(1 row)
```

Recursive WITH to Delete Parts

```
WITH RECURSIVE source (part_no) AS (  
    SELECT 2  
    UNION ALL  
    SELECT part.part_no  
    FROM source JOIN part ON (source.part_no = part.parent_part_no)  
)  
DELETE FROM part  
USING source  
WHERE source.part_no = part.part_no;  
DELETE 6
```

Using Both Features

```
CREATE TEMPORARY TABLE retdemo3 (x NUMERIC);
CREATE TABLE

INSERT INTO retdemo3 VALUES (random()), (random()), (random());
INSERT 0 3

WITH source (average) AS (
    SELECT AVG(x) FROM retdemo3
),
    source2 AS (
        DELETE FROM retdemo3 USING source
        WHERE retdemo3.x < source.average
        RETURNING x
    )
SELECT * FROM source2;
      x
-----
0.185174203012139
0.209731927141547
(2 rows)
```

Chaining Modification Commands

```
CREATE TEMPORARY TABLE orders (order_id SERIAL, name text);  
CREATE TABLE
```

```
CREATE TEMPORARY TABLE items (order_id INTEGER, part_id SERIAL, name text);  
CREATE TABLE
```

```
WITH source (order_id) AS (  
    INSERT INTO orders VALUES (DEFAULT, 'my order') RETURNING order_id  
)  
INSERT INTO items (order_id, name) SELECT order_id, 'my part' FROM source;  
INSERT 0 1
```

```
WITH source (order_id) AS (  
    DELETE FROM orders WHERE name = 'my order' RETURNING order_id  
)  
DELETE FROM items USING source WHERE source.order_id = items.order_id;  
DELETE 1
```

Mixing Modification Commands

```
CREATE TEMPORARY TABLE old_orders (order_id INTEGER);
CREATE TABLE

WITH source (order_id) AS (
    DELETE FROM orders WHERE name = 'my order' RETURNING order_id
), source2 AS (
    DELETE FROM items USING source WHERE source.order_id = items.order_id
)
INSERT INTO old_orders SELECT order_id FROM source;
INSERT 0 0
```


Why Use CTEs

- ▶ Allows imperative processing in SQL
- ▶ Merges multiple SQL queries and their connecting application logic into a single, unified SQL query
- ▶ Improves performance by issuing fewer queries
 - ▶ reduces transmission overhead, unless server-side functions are being used
 - ▶ reduces parsing/optimizing overhead, unless prepared statements are being used
- ▶ Uses the same row visibility snapshot for the entire query, rather than requiring serializable isolation mode
- ▶ Adds an optimizer barrier between each CTE and the outer query
 - ▶ helpful with writable CTEs
 - ▶ can hurt performance when a join query is changed to use CTEs

Conclusion

