

# Programming the SQL Way with Common Table Expressions

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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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# 1. Imperative vs. Declarative



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# 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](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**



## 2. Syntax



# Common Table Expression (CTE) Syntax

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

## Keep Your Eye on the Red (Text)



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# A Simple CTE

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

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
```

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
```

# Columns Can Be Renamed

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

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
```



# UNION Refresher

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

```
-----  
          1
```

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

```
-----  
          1  
          1
```

# 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
```

# 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

# 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	

# CTE Can Be Joined

```
WITH class 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		aggstoptop
pg_aggregate		aggtransfn

# 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;
```

### 3. Recursive CTEs



# Looping

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

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



# This Is an Infinite Loop

```
SET statement_timeout = '1s';

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;
```

# UNION without ALL Avoids Recursion

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

# 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
```

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 // 1;
    push @table, $arg;
    f($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).

## 4. 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

# 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
```

# 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

aaaaaaaaa



# 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

# 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;
```

# Output

?column?

```
-----
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
X           X
X           X
X           X
X           X
X           X
X           X
X           X
X           X
```

# 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

# ASCII Diamonds 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;
```

# A Diamond

?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  
X X  
X X  
X X  
X X  
X X  
X X  
X X  
X X  
XX



# 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;
```



# 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;
```

# Output

?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  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  X  X
    X  X  X  X  X  X  X
     X  X  X  X  X  X  X
      XX
```

# 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

# 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

# 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

# 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

# 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

# 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

# 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);
```

```
INSERT INTO part VALUES (1, 11);  
INSERT INTO part VALUES (1, 12);  
INSERT INTO part VALUES (1, 13);  
INSERT INTO part VALUES (2, 21);  
INSERT INTO part VALUES (2, 22);  
INSERT INTO part VALUES (2, 23);  
INSERT INTO part VALUES (11, 101);  
INSERT INTO part VALUES (13, 102);  
INSERT INTO part VALUES (13, 103);  
INSERT INTO part VALUES (22, 221);  
INSERT INTO part VALUES (22, 222);  
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
```

Using UNION without ALL here would avoid infinite recursion if there is a loop in the data, but it would also cause a part with multiple parents to appear only once.

# 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
```

# 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

# 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}

# 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



# CTE for SQL Object Dependency

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

# 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				

# 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 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_type	_deptest				
pg_type	deptest				

# Add a Primary Key

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

NOTICE: ALTER TABLE / ADD PRIMARY KEY will create implicit index  
"deptest\_pkey" for table "deptest"

# 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



# 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"

# 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 adsrsrc 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)

# 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			

## 5. Writable CTEs



# Writable CTEs

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

# Use INSERT, UPDATE, DELETE in WITH Clauses

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

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

```
-----  
0.00761545216664672  
0.85416117589920831  
0.10137318633496895
```

```
WITH source AS (  
    INSERT INTO retdemo  
    VALUES (random()), (random()), (random()) RETURNING x  
)  
SELECT AVG(x) FROM source;  
avg
```

```
-----  
0.46403147140517833
```



# Use INSERT, UPDATE, DELETE in WITH Clauses

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

# Supply Rows to INSERT, UPDATE, DELETE Using WITH Clauses

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

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

```
WITH source (average) AS (  
    SELECT AVG(x) FROM retdemo2  
)  
DELETE FROM retdemo2 USING source  
WHERE retdemo2.x < source.average;
```

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

```
-----  
0.777186767663807
```

# 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;
```

# Using Both Features

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

```
INSERT INTO retdemo3 VALUES (random()), (random()), (random());
```

```
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
```

# Chaining Modification Commands

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

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

```
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;
```

```
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;
```

# Mixing Modification Commands

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

## 6. 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



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