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.

https://momjian.us/presentations

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1. Imperative vs. declarative
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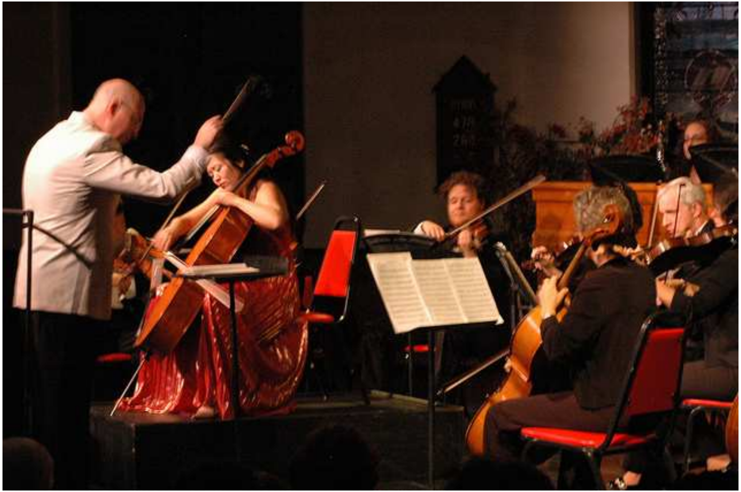
1. Imperative vs. Declarative



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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

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

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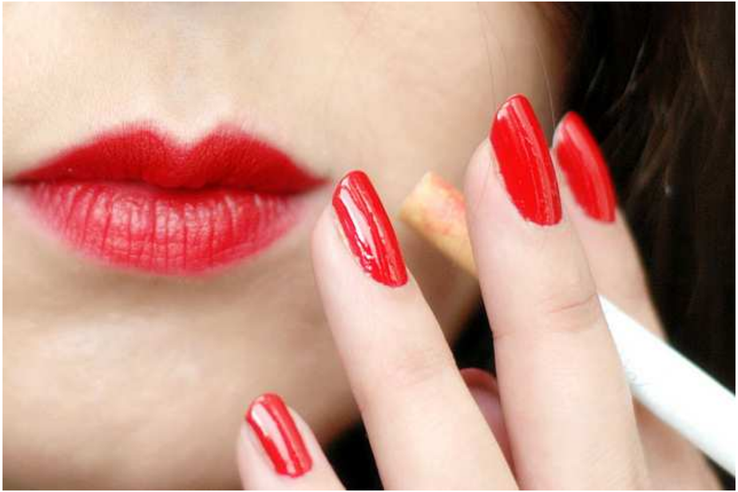
Common Table Expression (CTE) Syntax

```
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 `https://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

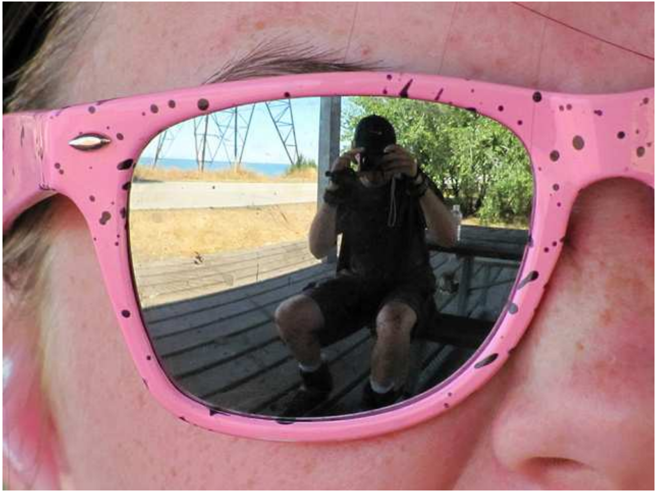
```
WITH class AS (
        SELECT oid, relname
        FROM pg_class
        WHERE relkind = 'r'
)
SELECT class.relname, attname
FROM pg_attribute, class
WHERE class.oid = attrelid
ORDER BY 1, 2
LIMIT 5;
   relname     |   attname
--------------+--------------
 pg_aggregate | aggfinalfn
 pg_aggregate | aggfnoid
 pg_aggregate | agginitval
 pg_aggregate | aggsortop
 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;
```



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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 ’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";
}
```

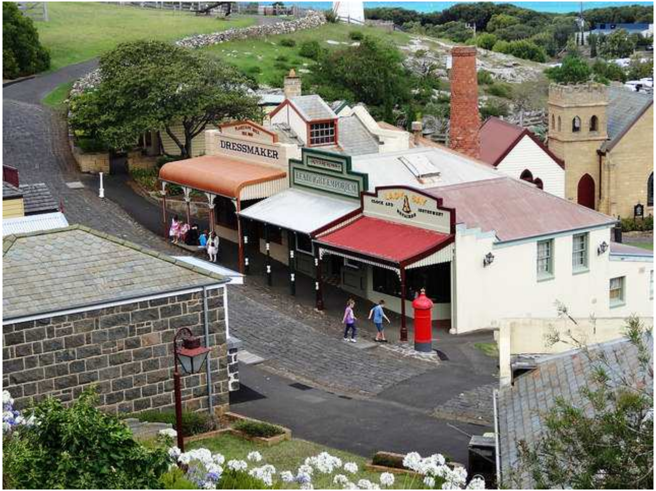
Perl Using Recursion

```
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 accumultes results in an array (similar to a table result).



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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
 aaaaaaaaaa
```

Characters Can Be Computed

```
WITH RECURSIVE source (str) AS (
        SELECT 'a'
        UNION ALL
        SELECT str || chr(ascii(right(str, 1)) + 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
      XX
      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
      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;
```

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

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
                     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 pg_get_expr(adbin, classid) 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 pg_get_expr(adbin, classid) 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 pg_get_expr(adbin, classid) 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 pg_get_expr(adbin, classid) 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)
```

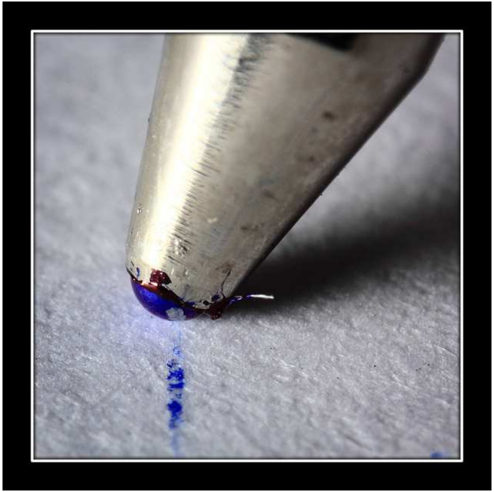
Show Full Output

```
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 typname FROM pg_type WHERE oid = obj) AS type,
        (SELECT relname FROM pg_class WHERE oid = obj) AS class,
        (SELECT pg_get_expr(adbin, classid) FROM pg_attrdef WHERE oid = obj) AS attrdef
        -- 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



https://www.flickr.com/photos/dmelchordiaz//

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
-------------------
 0.77186767663807
```

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

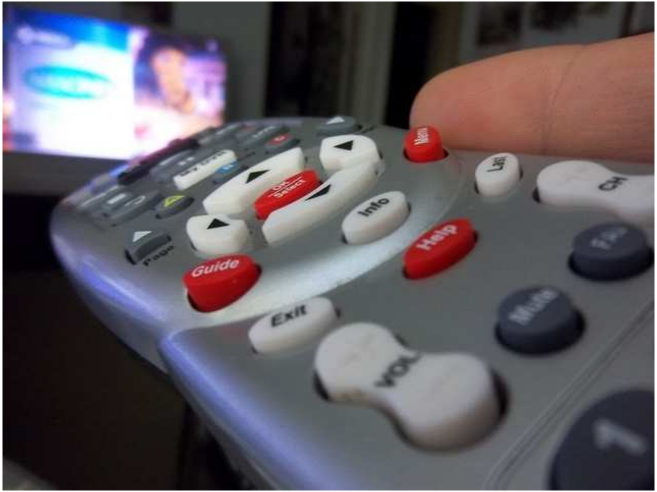
```
CREATE TEMPORARY TABLE old_orders (order_id INTEGER, delete_user TEXT, delete_time TIMESTAMPTZ);

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, CURRENT_USER, CURRENT_TIMESTAMP 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 repeatable read isolation mode
- Possible optimization barrier after each CTE
  - necessary for recursion and writable CTEs
  - can hurt performance when a join query is changed to use CTEs
  - pre-Postgres 12, CTEs are always an optimization barrier
  - Postgres 12 and later, a barrier only when useful
    - can be forced by keyword MATERIALIZED
    - see https://www.postgresql.eu/events/pgconfeu2022/sessions/session/3902/slides/354/CTEsAndTheirMaterialization-DivyaSharma.pdf

Conclusion



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