

## Chapter 2

# Basic Manipulations

DRAFT

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Up to this point we have refrained from transforming any of the data that is being returned in our queries. In this module we being working on manipulating the data that is being returned via functions, renaming and other methods. Importantly, none of what we are doing changes the underlying data; it simply transforms what is being returned to the client.

Before manipulating, however, we need to understand data within a relational database and how it is represented. In particular, we need to understand “types”.

## 1 Types

- Relational databases are “strongly” typed, meaning that there are strict rules around what operations can be performed on what data.
- As in other computer languages, types determines both what operations are available and how operations behave as a function of the data contained therein.
- In Relational Databases, columns are typed and set when a table is created. A column can only be a single type.
- Relational databases support a variety of different data types. In this section we will discuss the most commonly used ones, a hierarchy of which can be found in Figure 2.1.

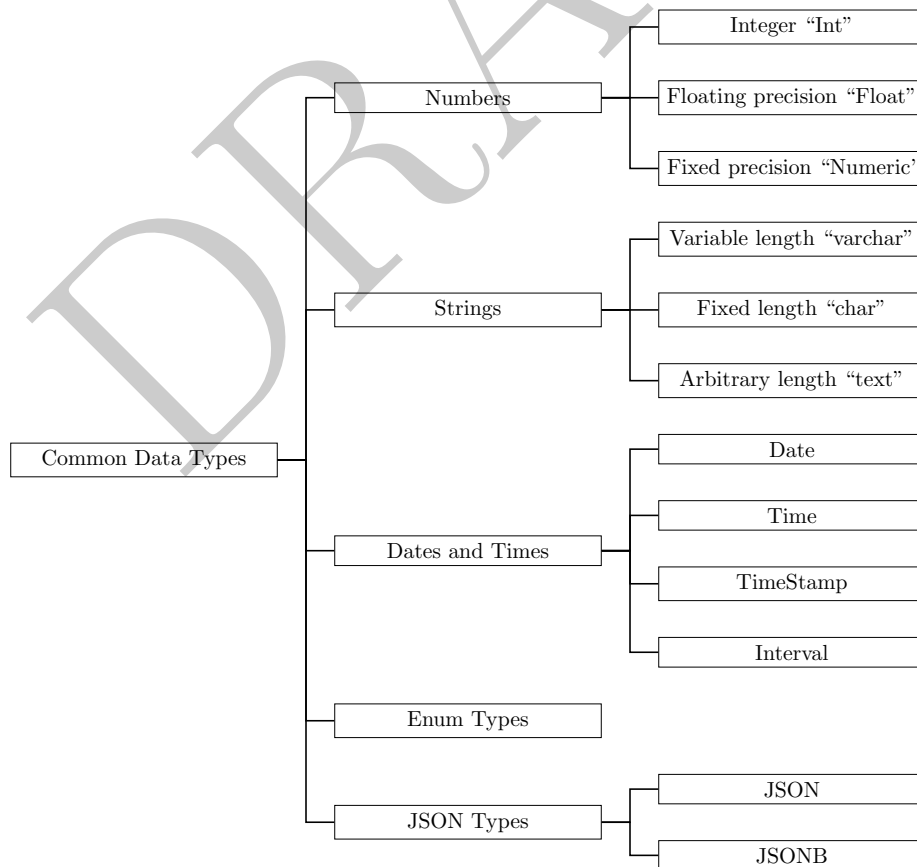


Figure 2.1: Common relational database data types

## Numbers

There are three “styles” of numbers:

1. **Integer:** These are whole numbers and there are actually 3 different types: smallint (2 bytes, can store -32,768 to +32,767 ( $2^{15}$ )), int (4 bytes, can store -2,147,483,648 to +2,147,483,647 ( $2^{31}$ )) and bigint (8 bytes, can store -9,223,372,036,854,775,808 to +9,223,372,036,854,775,807 ( $2^{63}$ )).
2. **Float:** A floating point number is an inexact, variable precision numeric type, usually coming in two flavors: real (4 bytes, 1E-37 to 1E+37 with a precision of at least 6 decimal digits) and double (8 bytes, 1E-307 to 1E+308 with a precision of at least 15 digit).
3. **Numeric:** A numeric has a user-defined fixed precision (like 2 decimal places). They vary in size and type depending on the amount of precision required. An example use of fixed precision is storing information about money; there is a fixed cut-off (penny) of precision.

In practice database administrators tend to stick to using integers and floats with an occasional numeric types.

## Strings

The three most common string types used are:

1. **Variable length:** The “varchar” type is used for variable length strings, but with a maximum number of specified characters. For example, a varchar(10) can contain any string, as long as the number of characters is less than or equal to 10.
2. **Fixed length:** The “char” type is used for fixed length strings. For example, a char(10) can contain any string, as long as the number of characters is less than or equal to 10. The difference between char and varchar is that this type always reserves space for additional characters, up to the the max, while a varchar does not. So, to store the names “Nick”, “John” and “Reggie” as a varchar(6) would take (approximately)  $(4 + 4 + 6 = 16)$  bytes while storing those same names as a char(6) would take (approximately)  $6 + 6 + 6 = 18$  bytes.
3. **Arbitrary length:** The “text” type (sometimes called blob) is used for strings of arbitrary length. For example, if you wanted to store yelp comments you would use a text field, since the comments can be any length. Text fields are generally avoided when another type can be used due to storage efficiency.

## Enum

- For categorical data databases use what is called an “enum” or “enumerated” type.
- This type stores the data as an integer which also has a “map” that maps those numbers to specific values.
- The classic version of this is gender. Consider a survey with the following options:

	No. Chars	Enum Value
Woman	5	1
Man	3	2
Transgender	11	3
Non-binary/non-conforming	25	4
Prefer not to respond	21	5

- In this example, storing the data as an enum would save a ton of space over storing it as text.

- The downside is increased complexity and issues with comparisons (do you compare based on the map or on the text value)?
- All modern databases have a version of this, but we won't get too much into the details in this course.

## JSON

- Modern databases usually have two different options for storing JSON information: a raw representation and a binary representation.
- The raw representation is just a text blob that, by calling it “JSON” you get access to special functions only available to JSON objects, specifically functions around keys and values.
- The JSONB representation is a further parsed, binary representation of the JSON data. JSONB data (usually) is slower to load into the database due to the additional type conversions, but faster to do lookup operations on.
- All modern databases support JSON path (sometimes called JSONpath) syntax for accessing operators. This will be discussed later.

## Dates

We will hold off on discussing dates until Module 6.

## 2 Renaming a Column

- The first thing we will learn to do is change the name of tables and columns that are being returned.
- We sometimes want to rename columns. To do this, we use the AS operator:

```
select
    registrations as reg2
from
    cls.cars;

    reg2
-----
      5
     198
    5020
     366
    2507
    [...]
```

The query above will return a single column, with the name `reg2`.

- We can also use it to rename tables, though this won't be useful for a few weeks!

```

select
    registrations as reg2
from
    cls.cars as c2;

    reg2
    -----
         5
        198
       5020
        366
       2507
    [...]

```

- We can actually just skip the AS completely, though it isn't recommended since it can make the query more difficult to read.

```

select
    registrations reg2
from
    cls.cars c2;

    reg2
    -----
         5
        198
       5020
        366
       2507
    [...]

```

### 3 Basic Mathematical Manipulations, ABS and LEAST/GREATEST

- If, instead of selecting a column directly from the table, we put down a single value, then that value will be repeated for each row returned.
- For example, consider the following query:

```
select
  1 as v1, 2 as v2, 'Nick' as name, vehicletype
from
  cls.cars;
```

v1	v2	name	vehicletype
1	2	Nick	Bus
1	2	Nick	Moped
1	2	Nick	Truck
1	2	Nick	Travel Trailer
1	2	Nick	Truck
[...]			

- Note that the data is repeated once for each row and no rows are being generated.
- We can also manipulate the data that is being returned on a row-by-row basis by using functions within the select.
- For example, we can do basic math functions:

```
select
  registrations + 10 as reg2
, registrations
from
  cls.cars
```

reg2	registrations
15	5
208	198
5030	5020
376	366
2517	2507
[...]	

Note that what this does is create a synthetic column of the number ten (repeated for each row) and then adds that to the column “reg”. The result is that each entry in “reg2” is equal to “reg” plus 10.

- All standard mathematical operations (+, −, /, \*) are all supported and math can be done between columns, such as:

```

select
    registrations + 10 as reg2
    , annualfee * annualfee as annualfee_sq
    , registrations
from
    cls.cars;

```

reg2	annualfee_sq	registrations
15	462400	5
208	1.921e+06	198
5030	9.60083e+10	5020
376	3.39039e+08	366
2517	1.7873e+10	2507
[...]		

- What if we fail to rename the column with AS? The database will generate a column name for us:

```

select
    registrations + 10
    , annualfee * annualfee
    , registrations
from
    cls.cars;

```

?column?	?column?	registrations
15	462400	5
208	1.921e+06	198
5030	9.60083e+10	5020
376	3.39039e+08	366
2517	1.7873e+10	2507
[...]		

In this case the database has no idea what to name the column so calls it ?column?.

- SQL also has more advanced functions, many of which are similar to Excel. For example, the absolute value function (ABS), which returns the magnitude of a number without regard for its sign, can be used to return a modified column:



```

SELECT
    abs( registrations - 1000 ) as abs_reg, registrations
FROM
    cls.cars;

```

abs_reg	registrations
995	5
802	198
4020	5020
634	366
1507	2507
[...]	

returns two columns from cars. The first is the absolute value of 1,000 subtracted from registrations and the second is the registrations number.

- As with the other SQL functions we have seen, these can be used within a WHERE clause:

```

SELECT
    *
FROM
    cls.cars
WHERE
    abs(registrations - 1000) <= 20;

```

year	countyname	motorvehicle	vehiclecat	vehicletype	tonnage	[...]
2005	Hardin	Yes	Motorcycle	Motorcycle		[...]
2013	Mahaska	No	Trailer	Regular Trailer		[...]
2008	Boone	No	Trailer	Travel Trailer		[...]
2016	Marion	No	Trailer	Semi Trailer		[...]
2012	Webster	No	Trailer	Semi Trailer		[...]
[...]						

which returns the 231 rows where the number of registrations are between 980 and 1,020.

- The functions LEAST and GREATEST do exactly what they say – they return the highest and lowest value in a particular set of observations. Note that LEAST and GREATEST only work within a single row:

```

select
    countyname
    , abs(registrations - 100) as c1
    , abs(registrations - 30) as c2
    , registrations
    , least( abs(registrations - 100), abs(registrations - 30)) as calc_1
    , greatest( abs(registrations - 100), abs(registrations - 30)) as calc_2
from cls.cars
where registrations >= 64 and registrations <= 66
and countyname = 'Wright';

```

countyname	c1	c2	registrations	calc_1	calc_2
Wright	36	34	64	34	36
Wright	34	36	66	34	36
Wright	35	35	65	35	35
Wright	36	34	64	34	36
Wright	36	34	64	34	36
[...]					

## 4 Queries without a FROM Clause and Singletons

- SQL allows for queries without a FROM. When doing this, no columns can be referenced, but the query will be executed as a single expression. This is handy when running tests, such as if we didn't understand the ABS function:

```
select abs( -5 ) as calc;
```

```

    calc
-----
      5

```

We can do this with almost any SQL function, including mathematical operations:

```
select 5 * 10 as calc;
```

```

    calc
-----
     50

```

- If a query returns a single value, which we will call a *singleton* in this class, then we can treat that value as what it returns. The code below, for example, returns twice the largest registrations:

```
select 2 * (select registrations from cls.cars order by 1 desc limit 1) as calc;
```

```

    calc
-----
437950

```

- We can also use this in a WHERE clause:

```
select registrations
from
  cls.cars
where
  registrations >
    10*(select registrations from cls.cars order by 1 asc limit 1)
order by registrations asc
limit 10;
```

```

  registrations
-----
                11
                11
                11
                11
                11
[...]
```

This query will return the registrations in `cls.cars` which are 10 times more than the smallest value. It will only return the smallest 10 of those rows.

## 5 String Functions: LEFT, RIGHT, LOWER, UPPER, LENGTH, TRIM and CONCAT

- The string operators LEFT and RIGHT behave just as in Excel: they take the left or right characters of a string. For example:

```
select left( 'THIS STRING', 4) as left_4;

left_4
-----
THIS
```

will return 'THIS' since it is the four left most letters of the string in question.

- Both the LEFT and RIGHT commands take the same inputs: a string and the number of characters to cut:

```
select
    countyname
    , left( countyname, 4) as left_4
    , right( countyname, 4) as right_4
from
    cls.cars;
```

countyname	left_4	right_4
-----	-----	-----
Ida	Ida	Ida
Jasper	Jasp	sper
Harrison	Harr	ison
Palo Alto	Palo	Alto
Adair	Adai	dair
[...]		

- Two other string functions that behave similarly to Excel are LOWER and UPPER, which return a lowercase and uppercase version of a string column:

```
select
    countyname
    , lower(countyname) as lc
    , upper(countyname) as uc
from
    cls.cars;
```

countyname	lc	uc
-----	-----	-----
Ida	ida	IDA
Jasper	jasper	JASPER
Harrison	harrison	HARRISON
Palo Alto	palo alto	PALO ALTO
Adair	adair	ADAIR
[...]		

will return the countyname (with capital casing, such as “Adair”) and also a lower- and upper-case version of the countyname.

- Note that we can nest functions:

```
select
    lower( left(countyname, 4)) as ll4
    ,countyname
from
    cls.cars;
```

ll4	countyname
ida	Ida
jasp	Jasper
harr	Harrison
palo	Palo Alto
adai	Adair
[...]	

- the LENGTH command returns the length of a string.<sup>1</sup> For example:

```
select
    countyname, length(countyname) as len
from
    cls.cars;
```

countyname	len
Ida	3
Jasper	6
Harrison	8
Palo Alto	9
Adair	5
[...]	

- The TRIM command can be used to remove letters from a string. The default behavior is to remove spaces, but it is possible to use it for other things.

```
select '      aaaa' as vall, trim('      aaa      ') as trm;
```

vall	trm
aaaa	aaa

Importantly the leading and trailing spaces have been removed from the string. Note that the commands LTRIM and RTRIM do what they are expected to do – trim from only a single side.

- To put two strings together, similar to an “&” in Excel, we can use a concatenation operator, “||”. For example, the following query will return a single column with the countyname twice.

---

<sup>1</sup>In MS-SQL this is LEN, not LENGTH.

```

select
    countyname || countyname as str_calc
from
    cls.cars;

str_calc
-----
IdaIda
JasperJasper
HarrisonHarrison
Palo AltoPalo Alto
AdairAdair
[...]
```

- We can also put a constant into the string concatenation to modify it, as in the following example:

```

select
    'County Name = ' || countyname as str_calc
from
    cls.cars;

str_calc
-----
County Name = Ida
County Name = Jasper
County Name = Harrison
County Name = Palo Alto
County Name = Adair
[...]
```

Different variants of SQL use different operators for string concatenation:

SQL Variant	Syntax	Example
MySQL	concat()	select concat( col1, col2 ) from tablename;
MS-SQL	+	select col1 + col2 from tablename;

- A final useful command for parsing strings is LENGTH, which returns the length of a string. We can use this with right and left to uppercase the last letter of a string:

```

select
    left(countyname, length(countyname) - 1)
    || upper( right( countyname, 1) ) as lastUpper
from
    cls.cars;

lastupper
-----
IdA
JaspeR
Harrison
Palo Alto
AdaiR
[...]
```

which returns a list of countynames with both the first and last letter upper-cased!

## 6 ROUND and Changing Types (CAST)

### 7 CAST and changing types

- It can be the case that you want to switch data types and then do operations on them.
- To do this we use the “CAST” operator, which takes a column and a target data type as its inputs. Unlike other functions, however, the word “as” is used to split the inputs. Consider the following examples:

```
select 125.5 + 4 as ans;
```

```

ans
-----
129.5
```

```

select '125.5' + 4 as ans;
ERROR:  invalid input syntax for integer: "125.5"
LINE 1: select '125.5' + 4 as ans;
         ^
```

```
select cast( '125.5' as float) + 4 as ans;
```

```

ans
-----
129.5
```

The first query returns the expected answer while the second errors out because it tries to add a string and an integer. The third query uses the cast operator to change the data type.

- Rather than using CAST PostgreSQL provides a double colon operator to do the same thing:

```
select '123.5'::float + 4 as ans;
```

```

      ans
-----
    127.5

```

- Finally, keep in mind that PostgreSQL will attempt to do many conversions, even if you don't explicitly specify them. For example:

```
select '123' + 4 as ans;
```

```

      ans
-----
     127

```

Surprisingly, the database is able to make this conversion and thus does the math correctly.

- One commonly used function is the ROUND command which rounds a number.
- Lets say that we wanted to get the annualfee and registrations rounded to the nearest 100. In this case we could start by doing the following:

```
select
    round( registrations, -2 ) as rounded_reg
    , registrations
from
    cls.cars;
```

rounded_reg	registrations
-----	-----
0	5
200	198
5000	5020
400	366
2500	2507
[...]	

As from the results above, the ROUND commands rounds numbers to the place specified in the integer following the value to be rounded. In this example the rounding occurs to the  $-2$  position which is the hundreds place.

Moving to annualfee, we could write it as:



```
select
    round( annualfee, -2 ) as rounded_af
    , annualfee
from
    cls.cars;
```

which would return:

```
ERROR:  function round(double precision, integer) does not exist
LINE 4:      , round( annualfee, -2 ) as rounded_af
              ^
HINT:  No function matches the given name and argument types. You might need to add explicit type casts.
```

Why does this return an error?!?

The round command is *type* dependent. If you have an integer or a numeric type, the syntax is `ROUND( column, integer )` where the integer determines where to round the value. If the integer is positive, it will round to values *after* the decimal while negative integers in the ROUND will return values rounded to places before the decimal, as in the example above. On the other hand, floats (called “double precision” in the error) do not accept a second argument and will only round to the nearest integer!

- So how do we handle rounding to the nearest hundreds for a float? There are two options: we either transform the column to use the ROUND command on floats or we CAST the float as a different type (either numeric or integer) and then use the available parameters therein.
- The first option:

```
select
    round(registrations, -2) as rounded_reg
    , registrations
    , 100*round( annualfee/100) as rounded_af
    , annualfee
from
    cls.cars;
```

rounded_reg	registrations	rounded_af	annualfee
0	5	700	680
200	198	1400	1386
5000	5020	309900	309852
400	366	18400	18413
2500	2507	133700	133690
[...]			

In the example above the column `annualfee/100` is a floating point type which does not take an additional argument in the function and instead just rounds to the nearest whole number. Since it's been divided by 100, this will return the number rounded to the nearest 100. We then multiply it against 100 to get the original scale.

- The second option is to cast, or change the variables type, in a few different ways:
  1. **Use the CAST function** We can use the CAST command in order to explicitly change the

type. The CAST command is a bit awkward syntactically, as can be seen below:

```
select
    round(registrations, -2) as rounded_reg
    , registrations
    , round( cast( annualfee as int), -2) as rounded_af
    , annualfee
from
    cls.cars;
```

rounded_reg	registrations	rounded_af	annualfee
0	5	700	680
200	198	1400	1386
5000	5020	309900	309852
400	366	18400	18413
2500	2507	133700	133690
[...]			

rather than using standard parameters, a more sentence like construction occurs.

2. **Conversion with ::** We can use **::** to explicitly cast a variable from one type to another. **This is Postgres only!**

```
select
    round(registrations, -2) as rounded_reg
    , registrations
    , round( annualfee::int, -2) as rounded_af
    , annualfee
from
    cls.cars;
```

rounded_reg	registrations	rounded_af	annualfee
0	5	700	680
200	198	1400	1386
5000	5020	309900	309852
400	366	18400	18413
2500	2507	133700	133690
[...]			

3. **Implicit conversion:** While not possible in every situation, Postgres will implicitly convert between types when operators are applied. For example, if you multiply a float against an integer, the result will be a float:

```

select
    annualfee / 5.0 as af
from
    cls.cars;

    af
-----
    136
    277.2
61970.4
    3682.6
26738
[...]
```

In this case, annualfee has been converted from an integer to a float.

- There is a big “gotcha” when using implicit conversion – when doing it the database attempts to determine which type you want if you aren’t careful you may end with an unanticipated result. Consider the following:
- Look at what following returns, given that there are 659 rows where registrations is equal to 5:

```

select registrations / 10 as calc
from cls.cars where registrations = 5;

    calc
-----
        0
        0
        0
        0
        0
[...]
```

- Why is this occurring? Because the database sees a query which divides two integers and thus assumes that the result is also going to be an integer. Importantly – this isn’t rounding, it is simply cutting off the value.
- We can use implicit methods of conversion in order to solve this. Consider the following:

```
select registrations *1.0 / 10 as calc
from cls.cars where registrations = 5;
```

```
    calc
-----
    0.5
    0.5
    0.5
    0.5
    0.5
[...]
```

or

```
select registrations /10.0 as calc
from cls.cars where registrations = 5;
```

```
    calc
-----
    0.5
    0.5
    0.5
    0.5
    0.5
[...]
```

or

```
select registrations::float /10 as calc
from cls.cars where registrations = 5;
```

```
    calc
-----
    0.5
    0.5
    0.5
    0.5
    0.5
[...]
```

The first two solutions work because they introduce a number with a decimal component. When the database attempts to do math between decimals and integers it presumes that the answer is going to be decimal and we get the expected result. The third answer uses the “::” operator to convert the integer into a floating point number.

There is one important difference between the first two solutions and the final solution. The final solution converts the data into a floating point number, not a numeric type. As we will learn later, these are not equivalent and there can be strong reasons to prefer one data type over the other.

- Finally, we could use the CAST function in order to complete this operation:

```
select
    CAST( registrations as float)/10 as calc
from
    cls.cars
where
    registrations = 5;
```

```
    calc
-----
    0.5
    0.5
    0.5
    0.5
    0.5
[...]
```

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