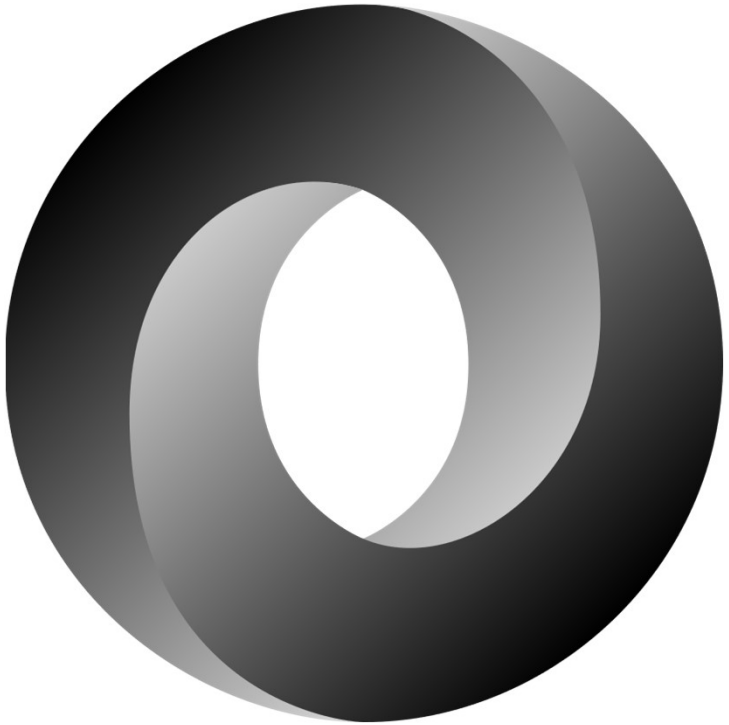
JSON



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Intro

- Now that we have JSON, we've escaped the rigid structure of SQL and can now freely describe any data.
- But in the real world, we want to be able to make some assertions about the data, to avoid runtime crashes due to invalid data being received or read from storage.

Validation

JSON Schema

- A 'language' to describe the structure of JSON documents.
- A JSON schema is itself a JSON object, whose keys are "keywords" and the values for those keys tell us something about the schema.

```
{"title": "Filesystem",
 "description": "A system for the organization of files",
 "type": "object" }
```

Why use a Schema?

- We use a schema to regain some structure, even though we're using a non-structured model.
- The schema tells us what to expect from the document, such as which parts are optional and which are required, and the general structure.
- Allows us to validate (at any time!) data coming from outside sources, such as user data, or external API data.

JSON Schemas

- A JSON schema is either a root schema or a subschema, with a root schema being the top level schema, and a subschema a schema that is within the root schema.
- A JSON schema is itself a JSON object.
- We use "keywords" as keys, and the value for each keyword tells us something about the schema.
- We use these keywords to define the schema.
- The empty object `{}` and `true` validates against anything, i.e. you don't provide any information about what it should contain. A schema that says `false` is always invalid, no matter what.

Example of a schema

- If we have the following schema, that says every branch has a name and a program:

```
{"type": "object", "title": "Branch",
 "properties": {"name": {"type": "string"},
                "program": {"type": "string"}},
 "required": ["name", "program"]}
```

- The following are valid:

```
{"name": "IT", "program": "IE"}
{"name": "MPALG", "program": "CS", "numStudents": 20}
```

- But the following are invalid:

```
{"name": "IT"}
{"name": "IT", "program": 5}
```

Keywords

- `title` and `description` are annotations that are used to identify the schema in question, but are not used for validation. Example:

  Schema: `{"title": "Character",`
  `"description": "A Lord of the Rings character"}`

  Valid: `everything`

  Invalid: `nothing`

  But it's a kind of documentation for the users

- `type` is used to define the type of the JSON within, and can be any of `array`, `boolean`, `integer`, `null`, `number`, `object`, or `string`. Example:

  Schema: `{"type": "number"}`

  Valid:
  ```
  1
  2
  5.9
  6.022e+10
  …
  ```

  Invalid:
  ```
  "a"
  true
  {"as": "hey"}
  ["a", "b"]
  …
  ```

- `enum` is used to enforce that a field should be any of specifc values. Example:

  Schema: `{"type": "string","enum": ["u", "3", "4","5"]}`

  Valid: `"u"`
  `"3"`
  `"4"`
  `"5"`

  Invalid: `3`
  `4`
  `"uu"`
  …

- `const` is a special case of `enum` that allows exactly one value (a constant):

  Schema: `{"const":42}`

  Valid: `42` Invalid: `everything else`

- `minimum` and `maximum` are specific to numbers, and specify the minimum and maximum value that the number can take. Example:

  Schema: `{"type": "integer","minimum": 1,"maximum": 6}`

  Valid: `1`
  `2`
  `3`
  `4`
  `5`
  `6`

  Invalid: `0`
  `7`
  `100`
  `"asd"`
  `{"number": 5}`
  …

Strings

- `minLength` and `maxLength` are specific to strings, and specify the minimum and maximum length of the string. Example:

  Schema: `{"type": "string","minLength": 10,"maxLength": 10}`

  Valid: `"abde284320"`

  `"1234567890"`

  …

  Invalid: `"123"`

  `"1asd"`

  `25`

  `{"idnr": "1234567890"}`

  …

Objects

- `properties` is used to define the schema for the properties of an object. Example:

  Schema: `{"type": "object",`
  `"properties": {"name": {"type": "string"},`
  `"age": {"type":"integer"}}}`

  Valid: `{"name": "Matti", "age": 30}`
  `{"name": "Ana"}`
  `{"name": "Frodo", "age": 50, "location": "Shire"}`
  …

  Invalid: `{"name": 11, "age": 12}`
  `{"age": "23"}`
  `"1234"`
  …

- `additionalProperties` is used to define the schema for any properties not present in `properties`. Can be used to enforce that the properties in `properties` are the only properties present. Example:

  Schema:
  ```
  {"type": "object",
   "properties": {"name": {"type": "string"}},
   "additionalProperties": false}}
  ```
  Valid:
  ```
  {"name": "Ana"}
  {"name": "Matti"}
  …
  ```
  Invalid:
  ```
  {"name": 11, "age": 12}
  {"age": "23"}
  {"name": "Matti", "age": 30}
  {"name": "Frodo", "age": 50, "location": "Shire"}
  "1234"
  …
  ```

- `required` is used to define what properties a certain object must have. Example:

  Schema: `{"type": "object", "required": ["name", "age"]}`

  Valid: `{"name": "Matti", "age": 30}`
  `{"name": "Sauron", "age": "Not known"}`
  `{"name": 11, "age": "twelve", "favFood": "eggos"}`
  …

  Invalid: `{"name": "Matti"}`
  `{"age": 2}`
  `"asda"`
  …

- `minProperties` and `maxProperties` is used to define the maximum and minimum amount of properties and object must have. Example:

  Schema: `{"type": "object", "minProperties": 1, "maxProperties": 2}`

  Valid: `{"name": "Matti", "age": 30}`

  `{"name": 9}`

  `{"lottery": [7,9,13,17], "winner": "Ana" }`

  …

  Invalid: `{}`

  `{"name": "McCartney", "age": 79, "band": "The Beatles"}`

  `"asdad"`

  …

Arrays

- `items` allows you to specify a schema for the items in the array. Example:

  Schema: `{"type": "array", "items": {"type": "number"}}`

  Valid: `[1,2,3]`
  `[42,5,7e10]`
  `[323.8,2,1]`
  …

  Invalid: `["asd", "one"]`
  `[1,2,3,"four"]`
  `"asdf"`
  `24`
  …

- `uniqueItems` specifies that the items must be unique (i.e. no duplicates): Example:

  Schema: `{"type": "array", "uniqueItems": true}`

  Valid: `[1,2,3]`
  `["a", "b", "c"]`
  `[1]`
  `[]`
  …

  Invalid: `[1,1]`
  `["a", "b", "a"]`
  `"asdf"`
  `1234`
  …

- `minItems` and `maxItems` specify the minimum and maximum number of items in the array. Example:

  Schema: `{"type": "array", "minItems": 3, "maxItems": 5}`

  Valid: `[1,2,3]`
  `["a","q","e","t"]`
  `[8,4,2,9,0]`
  …

  Invalid: `[]`
  `[1,2,3,5,6,7]`
  `["a","b"]`
  `"asdf"`
  …

- `contains` allows you to specify a schema that at least one item in the array must satisfy. Example:

  Schema: `{"type": "array", "contains": {"const": 42}}`

  Valid: `[1,2,3,42]`
  `[42]`
  `["a", 42, "b", "c", 42]`
  …

  Invalid: `[]`
  `[1, 2, 4]`
  `[[42]]`
  `{"contents": [12,2,3]}`
  `42`
  `"42"`
  …

Meta Keywords

- Subschemas can be combined using boolean logic operators:
  `allOf`, `anyOf`, `oneOf`, and `not`.
  Can also be written as `all-of`, `any-of`, `one-of`.
  Example:

```
Schema: {"title": "Grade",
         "oneOf": [{"type": "integer", "maximum": 5},
                   {"type": "integer", "minimum":3 }]}}
Valid:  -5
         2
        -15
         100
         …
Invalid: 3
         4
         5
         "asdf"
         5.8
         …
```

- `$ref` is a keyword you can use to refer and reuse schemas.

  `#` is used to refer to the schema itself. Example:

  Schema:

```
{"type": "object",
 "title": "A Non-empty linked list",
 "required": ["value", "next"],
 "properties": {
  "value": {"type": "integer"},
  "next": {"oneOf":[{"type": "null"},
                    {"$ref": "#"}]}}}
```

  Valid: `{"value": 1, "next": {"value":2, "next": null}}`
  `{"value": 1, "next": null}`
  …

  Invalid: `{"value": 2}`
  `{"next": {"value": 2, "next":null}}`
  `23, [1,2], "asdasd", …`

- `definitions` is used to define schemas to use with `$ref`. Example:

  Schema:

```
{"definitions": {"posInt": {"type": "integer","minimum":1}},
 "type": "array",
 "items": {"$ref": "#/definitions/posInt"}}
```

  Valid: `[1,2,3]`
  `[1]`
  `[]`
  `[1000,12]`
  …

  Invalid: `[-1]`
  `[0]`
  `[0,1,2]`
  `5`
  `"asd"`
  …

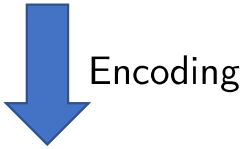
Additional Keywords (not covered in the course)

- JSON schema has more keywords than we use here, which allow for richer specification of valid schemas.
- You can find them on https://json-schema.org/
- Online validator available at https://www.jsonschemavalidator.net/
- In particular, the `$schema` and `$id` keywords are used to identify the document as a JSON schema, and where the definition of the schema can be found (using a URI). Example:

```
{"$schema": "http://json-schema.org/draft-07/schema#",
 "$id": "https://api.example.com/db.schema.json"}
```

A Filesystem

```
/file1.txt (100 bytes)
/a/file2.jpg (200 bytes)
/a/file3.mp4 (600 bytes)
/a/file4.png (300 bytes)
/b/c/file5.jpg (400 bytes)
```




```
{"name": "/", "contents": [
  {"name": "file1", "filetype": "txt", "size": 100},
  {"name": "a/", "contents": [
   {"name": "file2", "filetype": "jpg", "size": 200},
   {"name": "file3", "filetype": "mp4", "size": 600},
   {"name": "file4", "filetype": "png", "size": 300}]},
  {"name": "b/", "contents": [
   {"name": "c/", "contents": [
    {"name": "file5", "filetype": "jpg", "size": 400}]}]}]}
```

```
{"name": "/", "contents": [
  {"name": "file1", "filetype": "txt", "size": 100},
  {"name": "a/", "contents": [
   {"name": "file2", "filetype": "jpg", "size": 200},
   {"name": "file3", "filetype": "mp4", "size": 600},
   {"name": "file4", "filetype": "png", "size": 300}]},
  {"name": "b/", "contents": [
   {"name": "c/", "contents": [
    {"name": "file5", "filetype": "jpg", "size": 400}]}]}]}
```

```
{"title": "Filesystem",
 "$ref": "#/definitions/directory",
 "definitions": {
   "file": {
     "type": "object",
     "properties": {
       "name": {"type": "string", "minLength": 1},
       "filetype": {"type": "string"},
       "size": {"type": "integer"}},
     "required": ["name", "size"]},
   "directory": {
     "type": "object",
     "properties": {
       "name": {"type": "string","minLength": 1},
       "contents": {"type":"array",
                    "items": {"oneOf": [
                                {"$ref": "#/definitions/file"},
                                {"$ref": "#/definitions/directory"}]}}},
     "required": ["name","contents"]}}}
```

A User Filesystem

```
{"name": "/", "type": "dir",
  "contents": [
   {"name": "usr", "type": "dir",
    "contents": [
     {"name": "bin", "type": "dir",
      "contents": [
       {"name": "df", "type": "file", "filetype": "exe", "size": 42},
       {"name": "bash", "type": "file", "filetype": "exe", "size": 9},
       {"name": "imgviwr", "type": "file", "filetype": "exe", "size": 8},
       {"name": "vlc", "type": "file", "filetype": "exe", "size": 158}]},
     {"name": "vids", "type": "dir",
      "contents": [{"name": ”The.Mandalorian.S02E02.WEB.h264-TBS[eztv]”
                   ,"filetype": "mkv","size": 787, "type": "file"}]},
     {"name":"memes", "type":"dir",
      "contents":[
       {"name": "FellowKids", "filetype": "jpg", "size": 2, "type": "file"},
       {"name": "ItsAnOlderMeme", "filetype": "png", "size": 1, "type":"file"},
       {"name": "PikachuShocked", "filetype": "jpg", "size": 4, "type":"file"},
       {"name": "FellowKids-deepfried", "filetype": "jpg", "size":8, "type": "file"},
       {"name": "NyanCat", "filetype": "mp4", "size": 15, "type":"file"}]}]}]}
```

Querying JSON Documents

The JSON Path Language

- Now that we can validate that the data has a certain structure, what can we do with it?
- Answer: we can query it!
- In this course we use JSONPath to write queries for JSON documents.

The JSON Path Language

- **An extension to the dot syntax for accessing attributes of objects.**
- **What if we want to do more complex things than just access attributes? Filtering? Finding multiple separate values?**
- **We want to extend this into a query language**
- Inspired by xpath?
- Allows access to native execution engines?

The SQL/JSON Path Language

- A SQL specific JSON Path has been added to the SQL standard as defined in Oracle DB documentation, and is available in PostgreSQL **12.0** onwards.
- Defined at https://www.postgresql.org/docs/12/functions-json.html, in this course we use the '`strict`' mode to avoid confusion.
- Example: to get the sizes of all JPG files in the filesystem, we can write:

```
'strict $.**?(@.filetype == "jpg").size'
```

How to use JSON Path in Postgres

- Using the `jsonb_path_query`, we can use JSON Path expressions to query json documents and get all resulting JSON items as Postgres rows.
- Using `jsonb_path_query_array` does the same, except the results are wrapped into a single JSON array. This is what we use for our examples, so they'll all be arrays!
- Using `jsonb_path_query_first` returns only the first result.

```
WITH JsonEx AS (SELECT
'<json>':: jsonb AS val)
SELECT
jsonb_path_query_array(val,
 'strict <query>'
) FROM JsonEx;
```

JSONPath operators

```
/file1.txt
/a/file2.jpg
/a/file3.mp4
/a/file4.png
/b/c/file5.jpg
```

```
{"name": "/", "contents": [
  {"name": "file1", "filetype": "txt", "size": 100},
  {"name": "a/", "contents": [
   {"name": "file2", "filetype": "jpg", "size": 200},
   {"name": "file3", "filetype": "mp4", "size": 600},
   {"name": "file4", "filetype": "png", "size": 300}]},
  {"name": "b/", "contents": [
   {"name": "c/", "contents": [
    {"name": "file5", "filetype": "jpg", "size": 400}]}]}]}
```

- '$' is the root object, which we usually start our expressions with:

```
SELECT jsonb_path_query_array(val,'strict $') FROM JsonEx
[{"name": "/", "contents": […]}]
```

- '.' is the child operator, used to access a property of an object:

```
'strict $.name'
["/"]
```

```
/file1.txt
/a/file2.jpg
/a/file3.mp4
/a/file4.png
/b/c/file5.jpg
```

```
{"name": "/", "contents": [
  {"name": "file1", "filetype": "txt", "size": 100},
  {"name": "a/", "contents": [
   {"name": "file2", "filetype": "jpg", "size": 200},
   {"name": "file3", "filetype": "mp4", "size": 600},
   {"name": "file4", "filetype": "png", "size": 300}]},
  {"name": "b/", "contents": [
   {"name": "c/", "contents": [
    {"name": "file5", "filetype": "jpg", "size": 400}]}]}]}
```

- '[]' is the subscript operator, which is used to access elements in arrays or objects (counting from 0), or iterate over them:

```
'strict $.contents[1].contents[0].name'
["file2"]
```

```
'strict $.contents[2].contents[0].contents[0].size'
[400]
```

Using * lets you iterate over all the elements!

```
/file1.txt
/a/file2.jpg
/a/file3.mp4
/a/file4.png
/b/c/file5.jpg
```

```
{"name": "/", "contents": [
  {"name": "file1", "filetype": "txt", "size": 100},
  {"name": "a/", "contents": [
   {"name": "file2", "filetype": "jpg", "size": 200},
   {"name": "file3", "filetype": "mp4", "size": 600},
   {"name": "file4", "filetype": "png", "size": 300}]},
  {"name": "b/", "contents": [
   {"name": "c/", "contents": [
    {"name": "file5", "filetype": "jpg", "size": 400}]}]}]}
```

- '*' is the wild card operator, which returns everything in the current object. Example:

```
'strict $.*'
["/", [{"name": "file1", "filetype": "txt", size: 100}, {"name": "a/", …},
 {"name": "b/",…}]]
```

```
'strict $.contents[1].*'
["a/", [{"name": "file2",…}, {"name": "file3",…}, {"name": "file4",…}]]
```

```
'lax $.contents[1].*[0]'
["a/", {"name": "file2", "filetype": "jpg", "size": 200}]
```

Note the use of `'lax'` here, it allows us to ignore the fact that not all the results are subscriptable!

```
/file1.txt
/a/file2.jpg
/a/file3.mp4
/a/file4.png
/b/c/file5.jpg
```

```
{"name": "/", "contents": [
  {"name": "file1", "filetype": "txt", "size": 100},
  {"name": "a/", "contents": [
   {"name": "file2", "filetype": "jpg", "size": 200},
   {"name": "file3", "filetype": "mp4", "size": 600},
   {"name": "file4", "filetype": "png", "size": 300}]},
  {"name": "b/", "contents": [
   {"name": "c/", "contents": [
    {"name": "file5", "filetype": "jpg", "size": 400}]}]}]}
```

- '**' is the recursive descent operator, which goes into all the children of the element, and then into all children of that element, and so on...

  Example:

```
'strict $.**.name'
["/", "file1", "a/", "file2", "file3", "file4", "b/","c/","file5"]


'strict $.contents[1].**.name'
["a/",  "file2", "file3", "file4"]
```

/file1.txt
/a/file2.jpg
/a/file3.mp4
/a/file4.png
/b/c/file5.jpg

```
{"name": "/", "contents": [
  {"name": "file1", "filetype": "txt", "size": 100},
  {"name": "a/", "contents": [
   {"name": "file2", "filetype": "jpg", "size": 200},
   {"name": "file3", "filetype": "mp4", "size": 600},
   {"name": "file4", "filetype": "png", "size": 300}]},
  {"name": "b/", "contents": [
   {"name": "c/", "contents": [
    {"name": "file5", "filetype": "jpg", "size": 400}]}]}]}
```

- '@' is used to refer to the current element in expressions.
- '?(<expr>)' allows you to apply a filter expression. Example:

```
'strict $.**?(@.filetype == "jpg").size'
[200, 400]

'strict $.**?(@.size < 300).name'
["file1","file2"]
```

How do we use these operators in practice?

```
[{"category":"Starters",
  "contents":[
    {"dish":"Calamari", "price":8.50}]},
 {"category":"Salads",
  "contents":[
    {"dish":"Caesar",   "price":8.50},
    {"dish":"Chicken", "price":9.25}]},
 {"category":"Burgers",
  "contents":[
    {"dish":"Standard", "price":9},
    {"dish":"Bacon",    "price":10},
    {"category":"Vegetarian Burgers",
     "contents":[
       {"dish":"Haloumi",  "price":13},
       {"dish":"Mushroom", "price":10}]}]}]
```

- Say we had a JSON document representing a menu at a restaurant
- How would we use JSON path to get the sum of the prices of hamburgers on the menu?
- One way to go about it is to think about successively expanding and shrinking the documents.

We start off with

```
'strict $',
```

which gives us the entire document.

```
[{"category":"Starters",
  "contents":[
    {"dish":"Calamari", "price":8.50}]},
 {"category":"Salads",
  "contents":[
    {"dish":"Caesar",  "price":8.50},
    {"dish":"Chicken", "price":9.25}]},
 {"category":"Burgers",
  "contents":[
    {"dish":"Standard", "price":9},
    {"dish":"Bacon",    "price":10},
    {"category":"Vegetarian Burgers",
     "contents":[
       {"dish":"Haloumi",  "price":13},
       {"dish":"Mushroom", "price":10}]}]}]
```

Since the document is an array, and the category we want is one of the elements, we use

```
'strict $[*]',
```

to operate on each of the elements

```
{"category":"Starters",
 "contents":[
   {"dish":"Calamari", "price":8.50}]}

{"category":"Salads",
 "contents":[
   {"dish":"Caesar",  "price":8.50},
   {"dish":"Chicken", "price":9.25}]}

{"category":"Burgers",
 "contents":[
   {"dish":"Standard", "price":9},
   {"dish":"Bacon",    "price":10},
   {"category":"Vegetarian Burgers",
    "contents":[
      {"dish":"Haloumi",  "price":13},
      {"dish":"Mushroom", "price":10}]}]}
```

Since the document is an array, and the category we want is one of the elements, we use

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```
{"category":"Starters",
 "contents":[
   {"dish":"Calamari", "price":8.50}]}

{"category":"Salads",
 "contents":[
   {"dish":"Caesar",  "price":8.50},
   {"dish":"Chicken", "price":9.25}]}

{"category":"Burgers",
 "contents":[
   {"dish":"Standard", "price":9},
   {"dish":"Bacon",    "price":10},
   {"category":"Vegetarian Burgers",
    "contents":[
      {"dish":"Haloumi",  "price":13},
      {"dish":"Mushroom", "price":10}]}]}
```


We only want the prices of burgers,
so we apply a filter to the previous results

```
'strict $[*]?(@.category == "Burgers")'
```

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so we apply a filter to the previous results

```
'strict $[*]?(@.category == "Burgers")'
```


```
{"category":"Burgers",
 "contents":[
   {"dish":"Standard", "price":9},
   {"dish":"Bacon",    "price":10},
   {"category":"Vegetarian Burgers",
    "contents":[
      {"dish":"Haloumi",  "price":13},
      {"dish":"Mushroom", "price":10}]}]}
```

Now, we have the right category.

But how do we get the prices of all the different dishes? The easiest way is to expand the results into **ALL THE ELEMENTS**

```
'strict $[*]?(@.category == "Burgers").**'
```


```
{"category":"Burgers",
 "contents":[
   {"dish":"Standard", "price":9},
   {"dish":"Bacon",    "price":10},
   {"category":"Vegetarian Burgers",
    "contents":[
      {"dish":"Haloumi",  "price":13},
      {"dish":"Mushroom", "price":10}]}]}
```

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```
'strict $[*]?(@.category == "Burgers").**'
```

```
{"category":"Burgers",
 "contents":[
   {"dish":"Standard", "price":9},
   {"dish":"Bacon",    "price":10},
   {"category":"Vegetarian Burgers",
    "contents":[
      {"dish":"Haloumi",  "price":13},
      {"dish":"Mushroom", "price":10}]}]}

"Burgers"

[{"dish":"Standard", "price":9},
 {"dish":"Bacon",    "price":10},
 {"category":"Vegetarian Burgers",
  "contents":[
    {"dish":"Haloumi",  "price":13},
    {"dish":"Mushroom", "price":10}]}]

{"dish":"Standard", "price":9}

"Standard"

9

{"dish":"Bacon",    "price":10}

"Bacon"

10

{"category":"Vegetarian Burgers",
 "contents":[
   {"dish":"Haloumi",  "price":13},
   {"dish":"Mushroom", "price":10}]}

"Vegetarian Burgers"

[{"dish":"Haloumi",  "price":13},
 {"dish":"Mushroom", "price":10}]

{"dish":"Haloumi",  "price":13}

"Haloumi"

13

{"dish":"Mushroom", "price":10}

"Mushroom"

10
```

We see that the prices we want are all available from elements which have the `price` attribute... so we simply use the `.price` accessor, which gives us the prices!

```
'strict $[*]?(@.category == "Burgers").**.price'
```

```
{"category":"Burgers",
 "contents":[
   {"dish":"Standard", "price":9},
   {"dish":"Bacon",    "price":10},
   {"category":"Vegetarian Burgers",
    "contents":[
      {"dish":"Haloumi",  "price":13},
      {"dish":"Mushroom", "price":10}]}]}

"Burgers"

[{"dish":"Standard", "price":9},
 {"dish":"Bacon",    "price":10},
 {"category":"Vegetarian Burgers",
  "contents":[
    {"dish":"Haloumi",  "price":13},
    {"dish":"Mushroom", "price":10}]}]

{"dish":"Standard", "price":9}

"Standard"

9

{"dish":"Bacon",    "price":10}

"Bacon"

10

{"category":"Vegetarian Burgers",
 "contents":[
   {"dish":"Haloumi",  "price":13},
   {"dish":"Mushroom", "price":10}]}

"Vegetarian Burgers"

[{"dish":"Haloumi",  "price":13},
 {"dish":"Mushroom", "price":10}]

{"dish":"Haloumi",  "price":13}

"Haloumi"

13

{"dish":"Mushroom", "price":10}

"Mushroom"

10

9

10

13

10
```

The full query is then

```
SELECT jsonb_path_query(val, 'strict $[*]?(@.category == "Burgers").**.price')
FROM JsonEx;
```

And since we're in Postgres, we can aggregate and sum up the numbers!

... but we need to do an explicit type cast, since the resulting numbers are still `jsonb` values.

```
SELECT SUM(query.value :: int)
FROM (SELECT jsonb_path_query(val,
     'strict $[*]?(@.category == "Burgers").**.price') AS value
      FROM JsonEx) as query;
```

9

10

13

10

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- Expand into more examples for e.g. burgers
- Add exercise, show entire burger thing.
- Ask ourselves, does this contain the information that we want?
- Applying successive filters is a good way to think about it
- Map-reduce thinking. Map -> expand into more stuff, reduce -> filter the stuff we expanded (not useful analogy?)