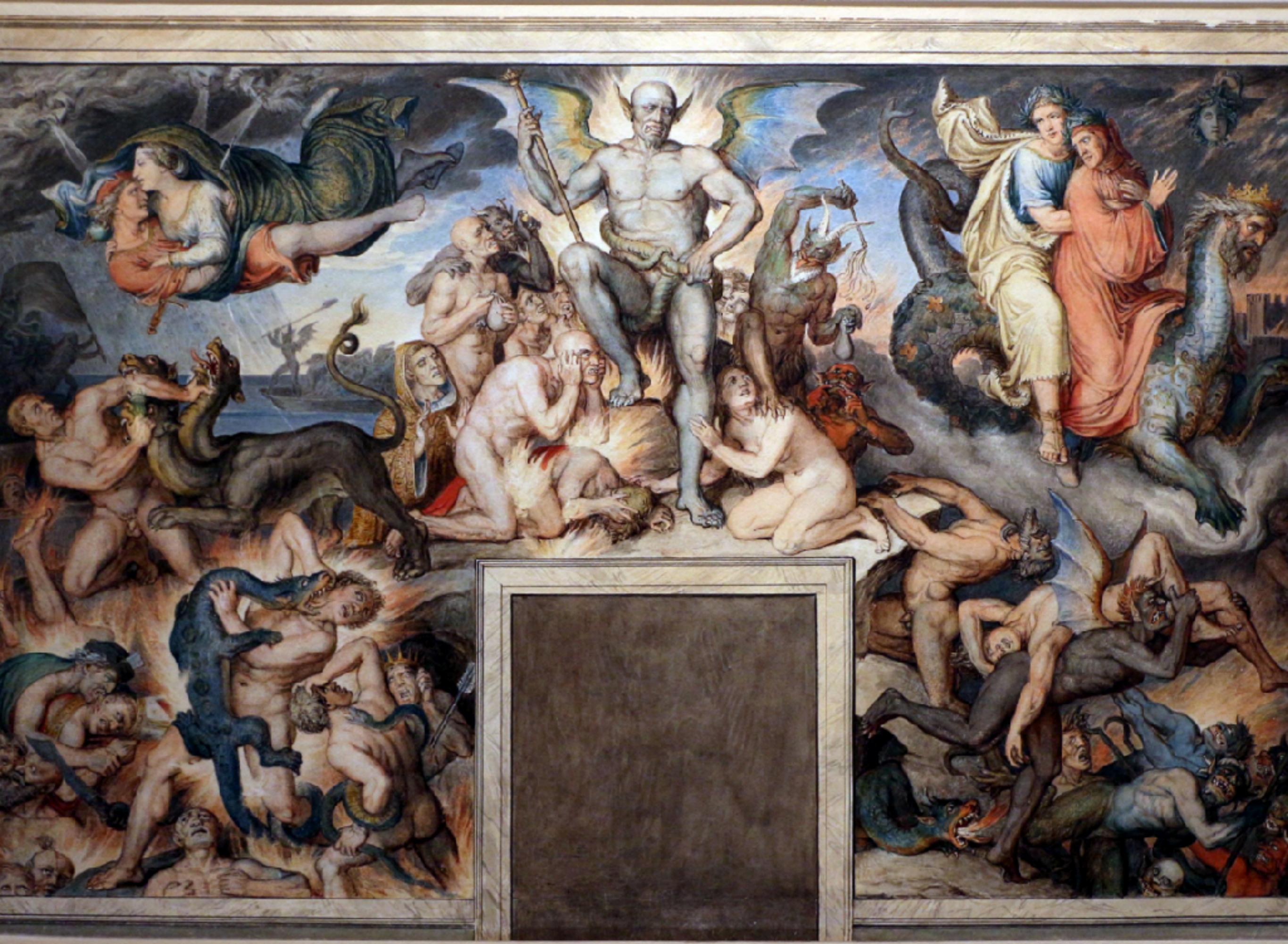




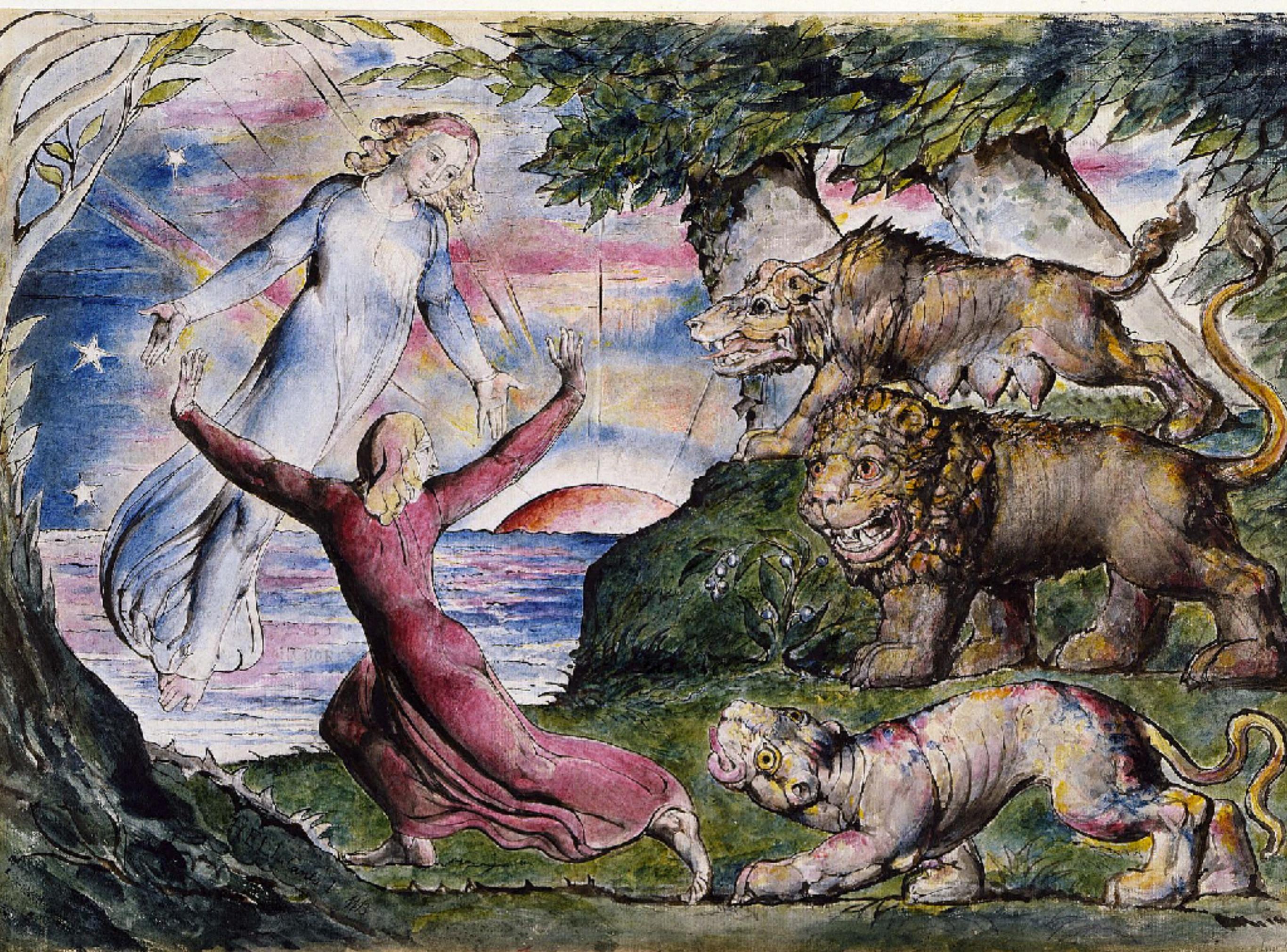
A Divine Data Comedy in JavaScript

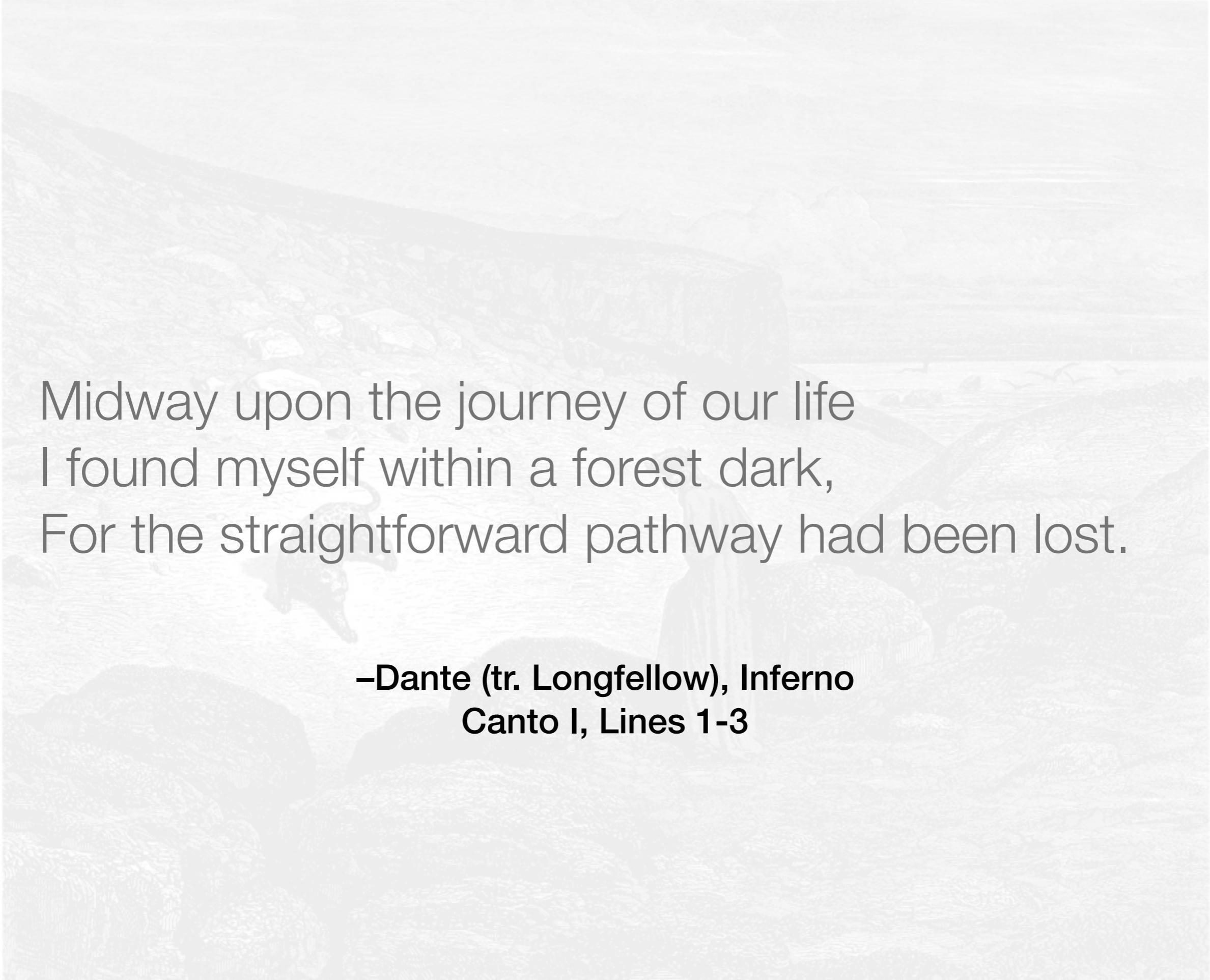
Mike Harris











Midway upon the journey of our life
I found myself within a forest dark,
For the straightforward pathway had been lost.

**—Dante (tr. Longfellow), Inferno
Canto I, Lines 1-3**

Canto

- Data Flow in a System
- The Language of Data Flow Manipulations
- Data Flow in Context

Canto

- **Data Flow in a System**
- The Language of Data Flow Manipulations
- Data Flow in Context

Example Data Set

```
create table stock_price (
    symbol varchar(5) not null
    , price_date date not null
    , price money not null
) ;

insert into stock_price
(symbol, price_date, price)
values
    ('ZVZZT', '2017-01-03', 10.02)
    , ('CBO' , '2017-01-03', 18.99)
    , ('ZVZZT', '2017-01-04', 9.99)
    , ('CBO' , '2017-01-04', 19.01)
;
```

Example Data Set

Symbol	Price Date	Price
ZVZZT	2017-01-03	10.02
CBO	2017-01-03	18.99
ZVZZT	2017-01-04	9.99
CBO	2017-01-04	19.01

SQL Statement

```
select symbol, price  
from stock_price  
where symbol = 'ZVZZT'  
order by price_date  
;
```

Symbol	Price Date	Price
ZVZZT	2017-01-03	10.02
ZVZZT	2017-01-04	9.99

Logical Order of a T-SQL Statement

1. FROM
2. ON
3. JOIN
4. WHERE
5. GROUP BY
6. WITH ROLLUP
7. HAVING
8. SELECT
9. DISTINCT
10. ORDER BY
11. TOP

Logical Order of a T-SQL Statement

1. FROM
2. ON
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11. TOP

Extract

Aggregate

Map

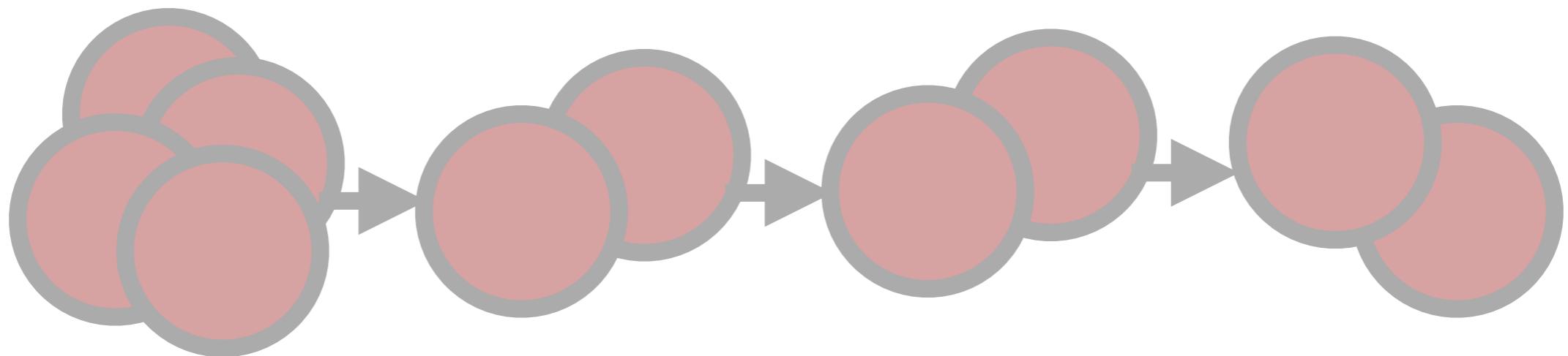
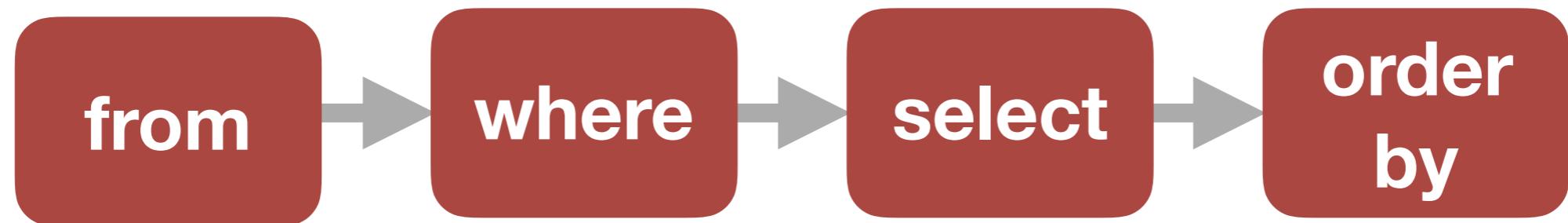
Order

Filter

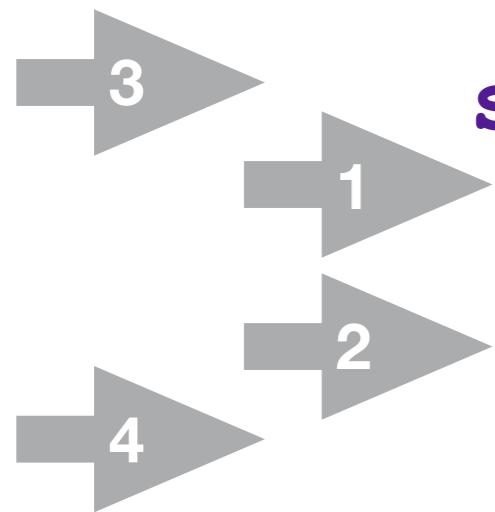
Logical Order of a T-SQL Statement

- 1. FROM**
2. ON
3. JOIN
- 4. WHERE**
5. GROUP BY
6. WITH ROLLUP
7. HAVING
- 8. SELECT**
9. DISTINCT
- 10. ORDER BY**
11. TOP

SQL Statement Data Flow



SQL Statement



```
3 select symbol, price  
1   from stock_price  
2 where symbol = 'ZVZZT'  
4 order by price_date  
;
```

Symbol	Price Date	Price
ZVZZT	2017-01-03	10.02
ZVZZT	2017-01-04	9.99

A faint, watermark-like illustration occupies the background. It depicts a man in a red, patterned robe and a hood, standing on the right side and holding a long staff or object. To his left, a woman in a flowing white dress stands in a field of tall grass. The scene is set outdoors with trees in the background.

Folded SQL

Folded SQL Statement

```
select max(price_date) as price_date  
from stock_price  
;
```

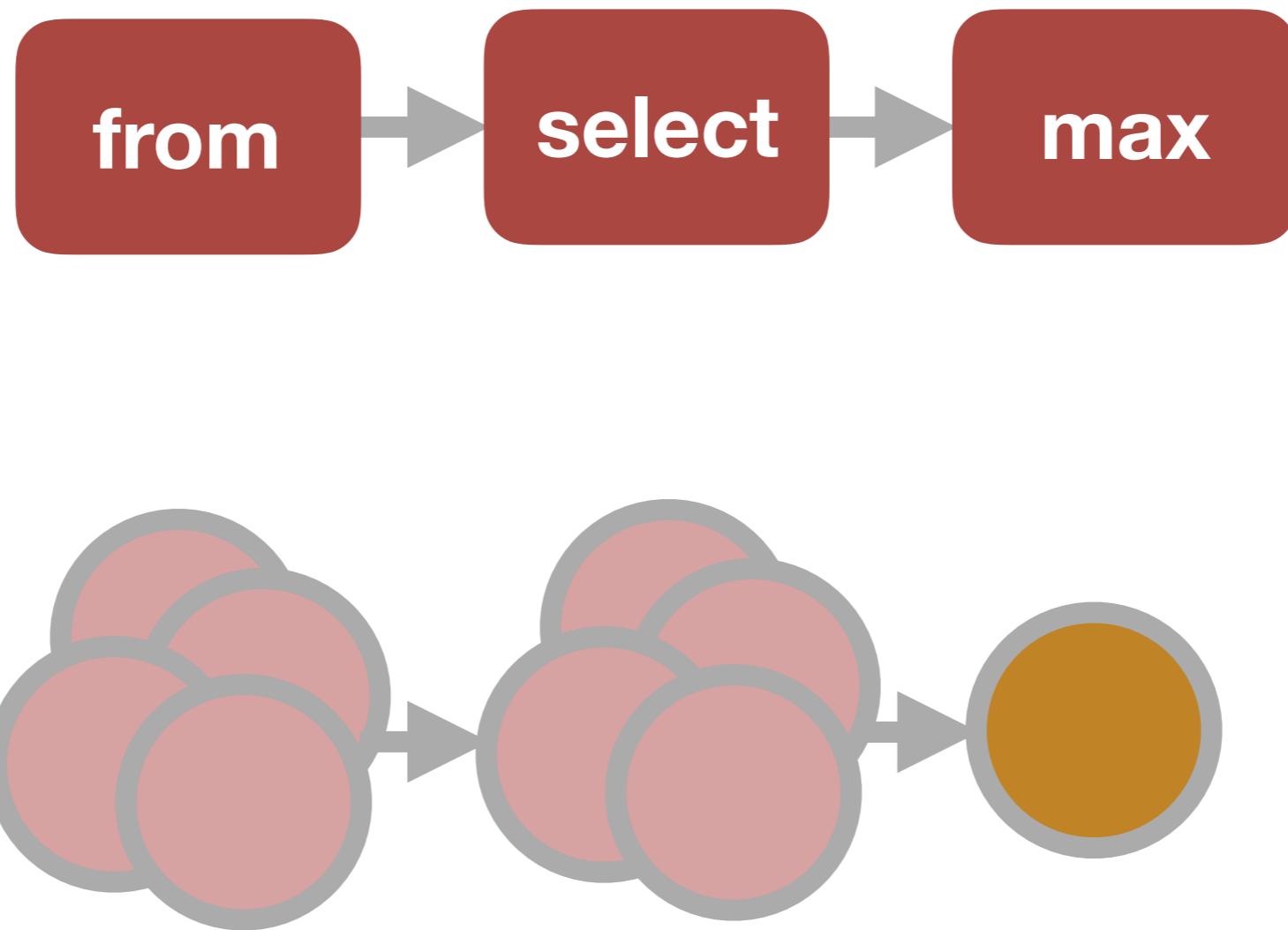
Price Date
2017-01-04

Logical Order of a T-SQL Statement

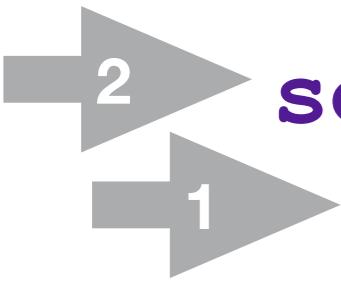
- 1. FROM**
2. ON
3. JOIN
4. WHERE
5. GROUP BY
6. WITH ROLLUP
7. HAVING

- 8. SELECT**
9. DISTINCT
10. ORDER BY
11. TOP

Folded SQL Statement Data Flow



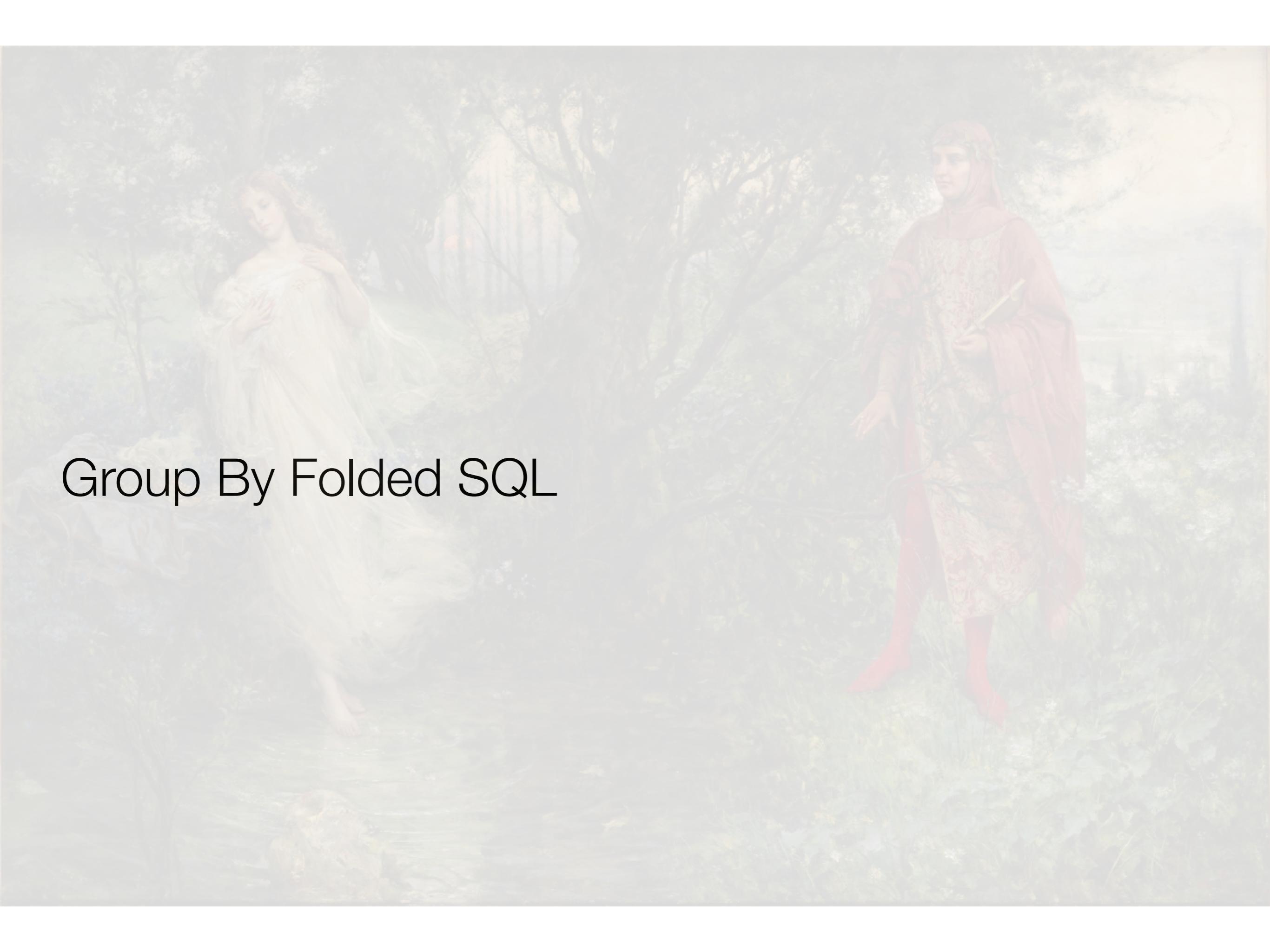
Folded SQL Statement



```
2 select max(price_date) as price_date  
1 from stock_price  
;
```

Price Date
2017-01-04

Group By Folded SQL



Group By Folded SQL Statement

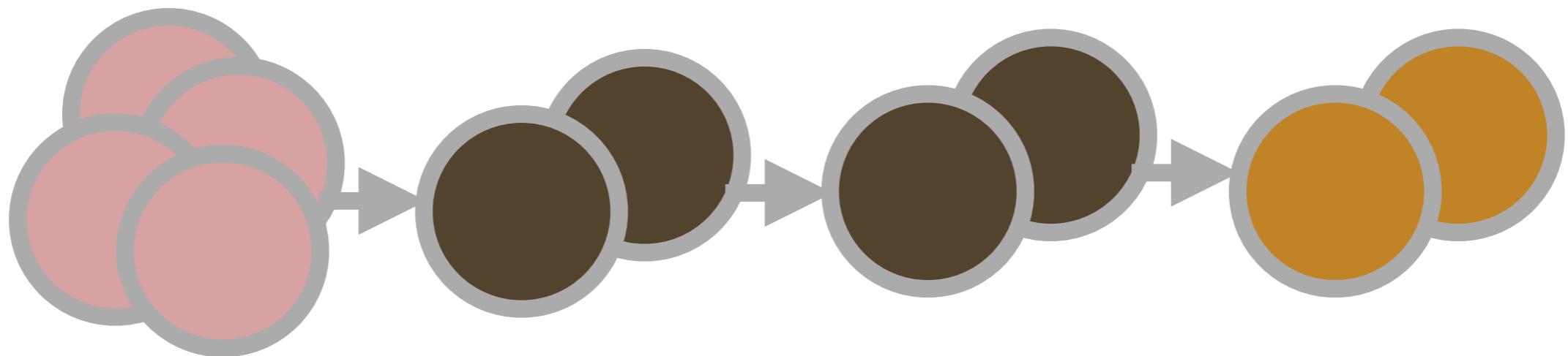
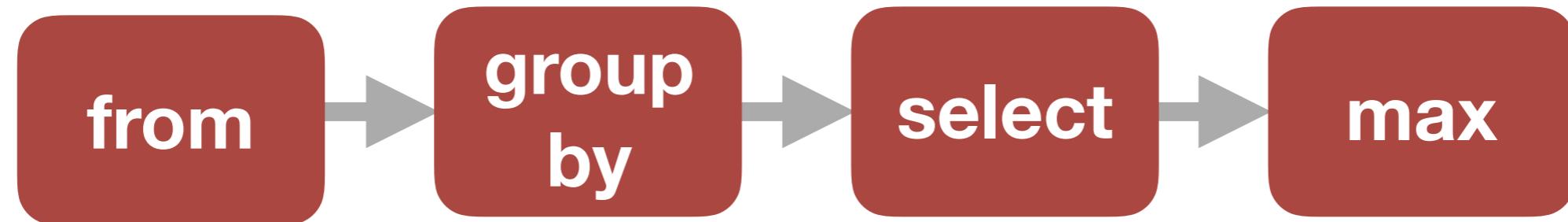
```
select
    symbol
    ,max(price_date) as price_date
from stock_price
group by symbol
;
```

Symbol	Price Date
CBO	2017-01-04
ZVZZT	2017-01-04

Logical Order of a T-SQL Statement

- 1. FROM**
2. ON
3. JOIN
4. WHERE
- 5. GROUP BY**
6. WITH ROLLUP
7. HAVING
- 8. SELECT**
9. DISTINCT
10. ORDER BY
11. TOP

Group By Folded SQL Statement Data Flow



Group By Folded SQL Statement

```
3  select
     symbol
     , max(price_date) as price_date
1  from stock_price
2  group by symbol
;

```

Symbol	Price Date
CBO	2017-01-04
ZVZZT	2017-01-04

Window Folded SQL



Window Folded SQL Statement

```
select distinct
    symbol
    , max(price_date) over(
        partition by symbol) as price_date
from stock_price
;
```

Symbol	Price Date
CBO	2017-01-04
ZVZZT	2017-01-04

Logical Order of a T-SQL Statement

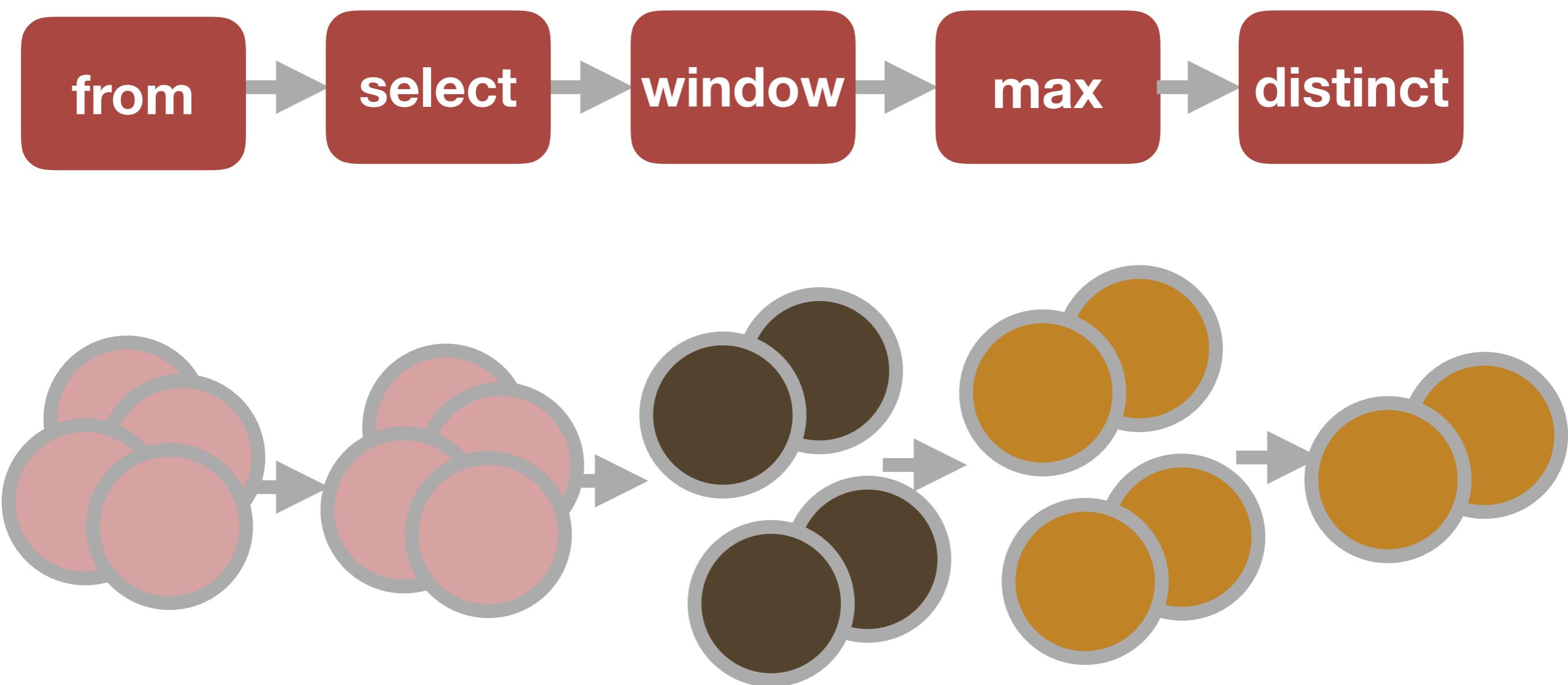
- 1. FROM**
2. ON
3. JOIN
4. WHERE
5. GROUP BY
6. WITH ROLLUP
7. HAVING
- 8. SELECT**
- 9. DISTINCT**
10. ORDER BY
11. TOP

Window SQL Statement Data View

```
max(price_date) over(  
partition by symbol) as price_date
```



Window SQL Statement Data Flow



Window Folded SQL Statement

```
select distinct  
    symbol  
    , max(price_date) over(  
        partition by symbol) as price_date  
from stock_price  
;  
2
```

Symbol	Price Date
CBO	2017-01-04
ZVZZT	2017-01-04

The background of the slide features a soft, out-of-focus illustration. On the right side, a man in a red robe with a patterned lining and a white head covering stands holding a long staff or object. On the left side, a woman in a flowing yellow dress with a floral pattern is seated or standing behind him. They appear to be in a field of tall grass and small flowers.

Window SQL

Window SQL Statement

```
select
    symbol
    ,price
    ,lag(price, 1) over (
        partition by symbol
        order by price_date) as prev_price
    ,price - lag(price, 1) over (
        partition by symbol
        order by price_date) as price_change
    ,lead(price, 1) over (
        partition by symbol
        order by price_date) as next_price
from stock_price
; 
```

Window SQL Statement

Symbol	Price	prev_price	price_change	next_price
CBO	18.99	(null)	(null)	19.01
CBO	19.01	18.99	0.02	(null)
ZVZZT	10.02	(null)	(null)	9.99
ZVZZT	9.99	10.02	-0.03	(null)

Window SQL Statement Data View

```
lag(price, 1) over (
    partition by symbol
    order by price_date) as prev_price
```

The diagram illustrates the transformation of a data table into a windowed view using the `lag` function. On the left, a table with columns `Symbol`, `Price_Date`, and `Price` contains two rows for symbol 'CBO'. An arrow points from this table to a vertical column on the right labeled `prev_price`, which shows the previous price for each row.

Symbol	Price_Date	Price	prev_price
CBO	2017-01-03	18.99	(null)
CBO	2017-01-04	19.01	18.99

Window SQL Statement Data View

```
lead(price, 1) over (
    partition by symbol
    order by price_date) as next_price
```

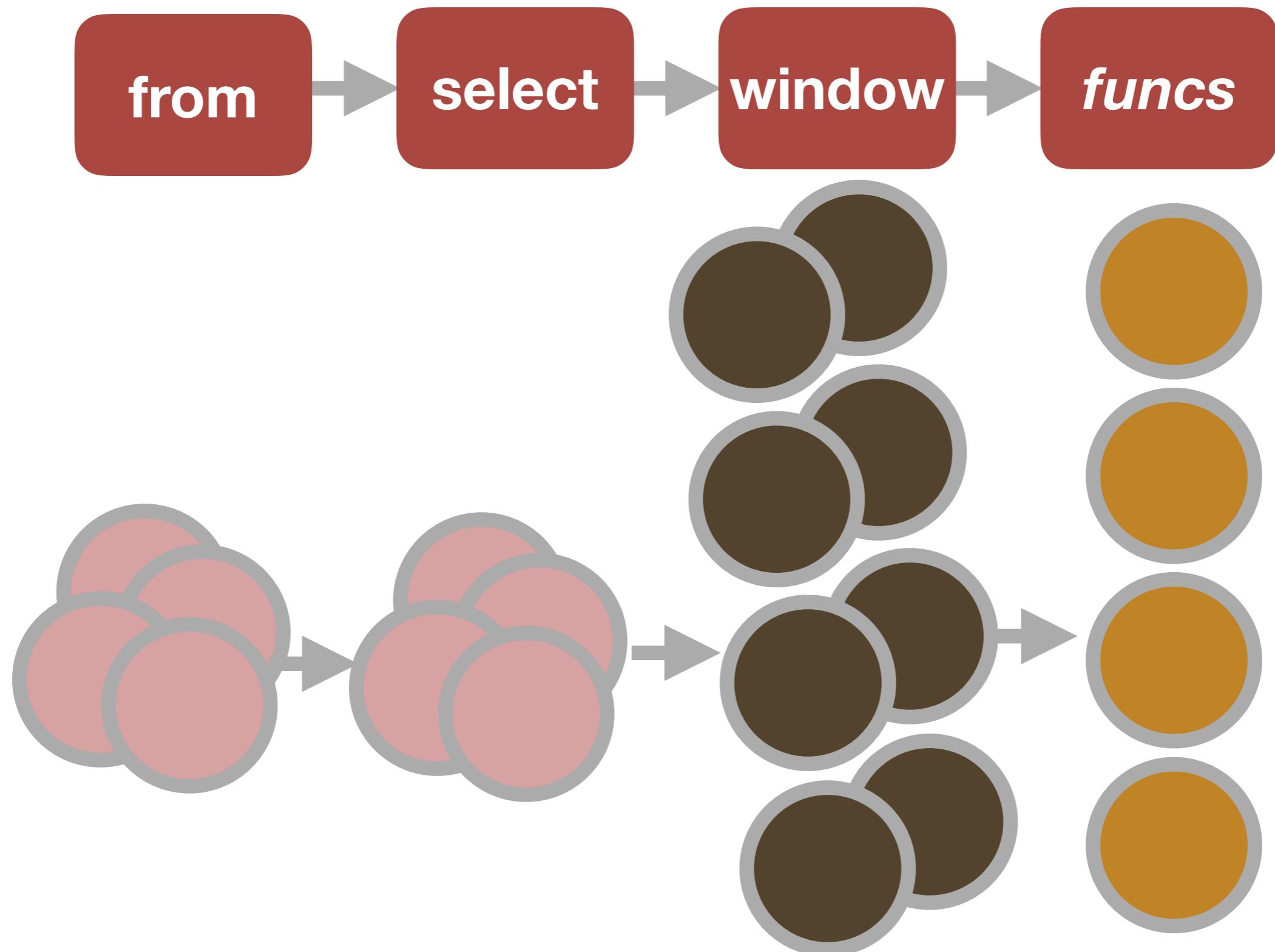
Symbol	Price_Date	Price	next_price
CBO	2017-01-03	18.99	19.01
CBO	2017-01-04	19.01	(null)

Logical Order of a T-SQL Statement

- 1. FROM**
2. ON
3. JOIN
4. WHERE
5. GROUP BY
6. WITH ROLLUP
7. HAVING

- 8. SELECT**
9. DISTINCT
10. ORDER BY
11. TOP

Window SQL Statement Data Flow



Window SQL Statement

```
select
→ 2 symbol
, price
, lag(price, 1) over (
    partition by symbol
    order by price_date) as prev_price
, price - lag(price, 1) over (
    partition by symbol
    order by price_date) as price_change
, lead(price, 1) over (
    partition by symbol
    order by price_date) as next_price
→ 1 from stock_price
;
```

Canto

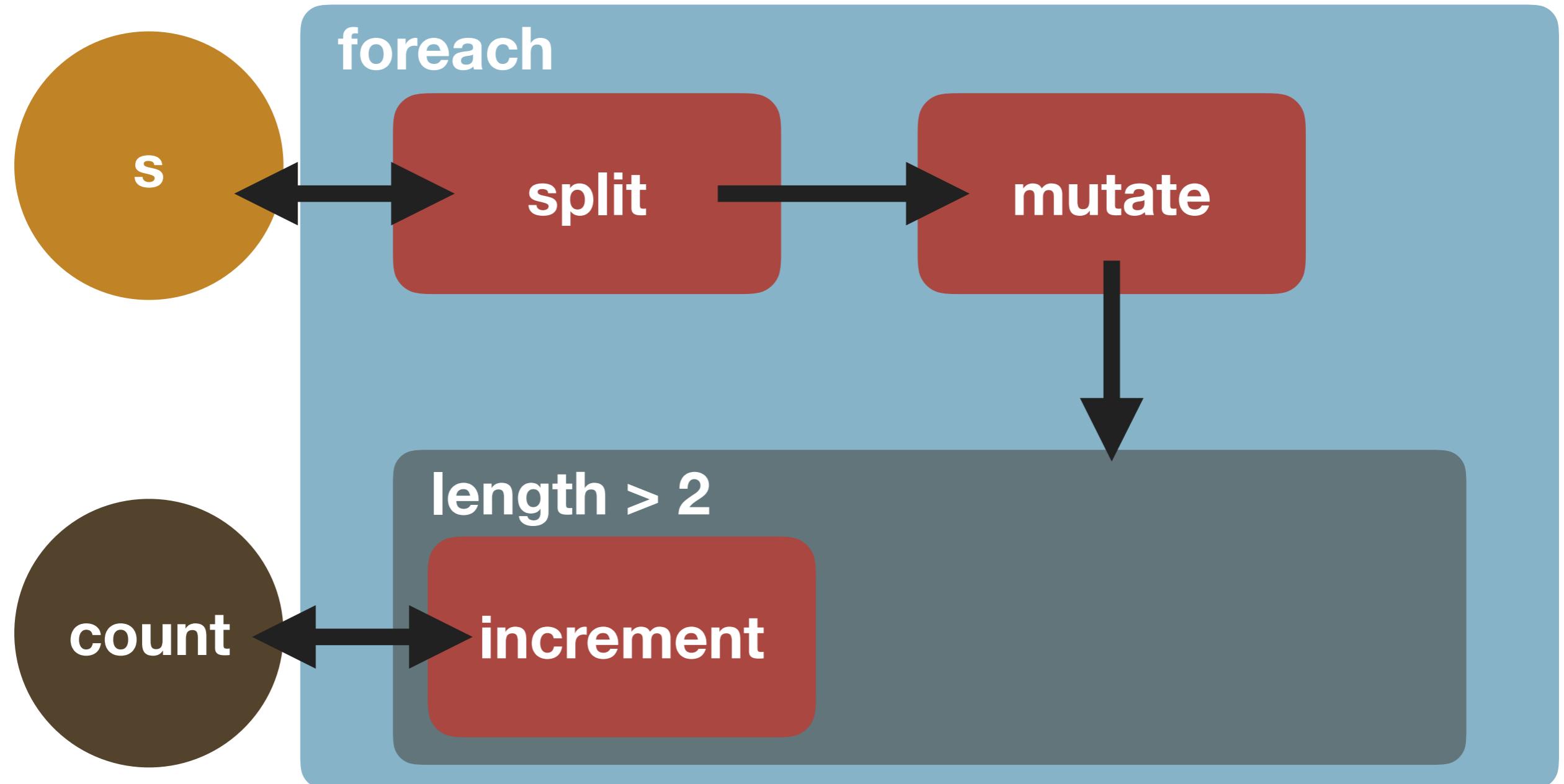
- Data Flow in a System
- **The Language of Data Flow Manipulations**
- Data Flow in Context

```
var _ = require('lodash');
```

Imperative Example

```
const s =
  'Midway in our life\'s journey, I went astray';
var count = 0;
for(var word of _.split(s, ' ')) {
  var stripped = _.replace(word, '(\\'s)|\w+', '');
  if (stripped.length > 2)
    count++;
}
```

Imperative Data Flow

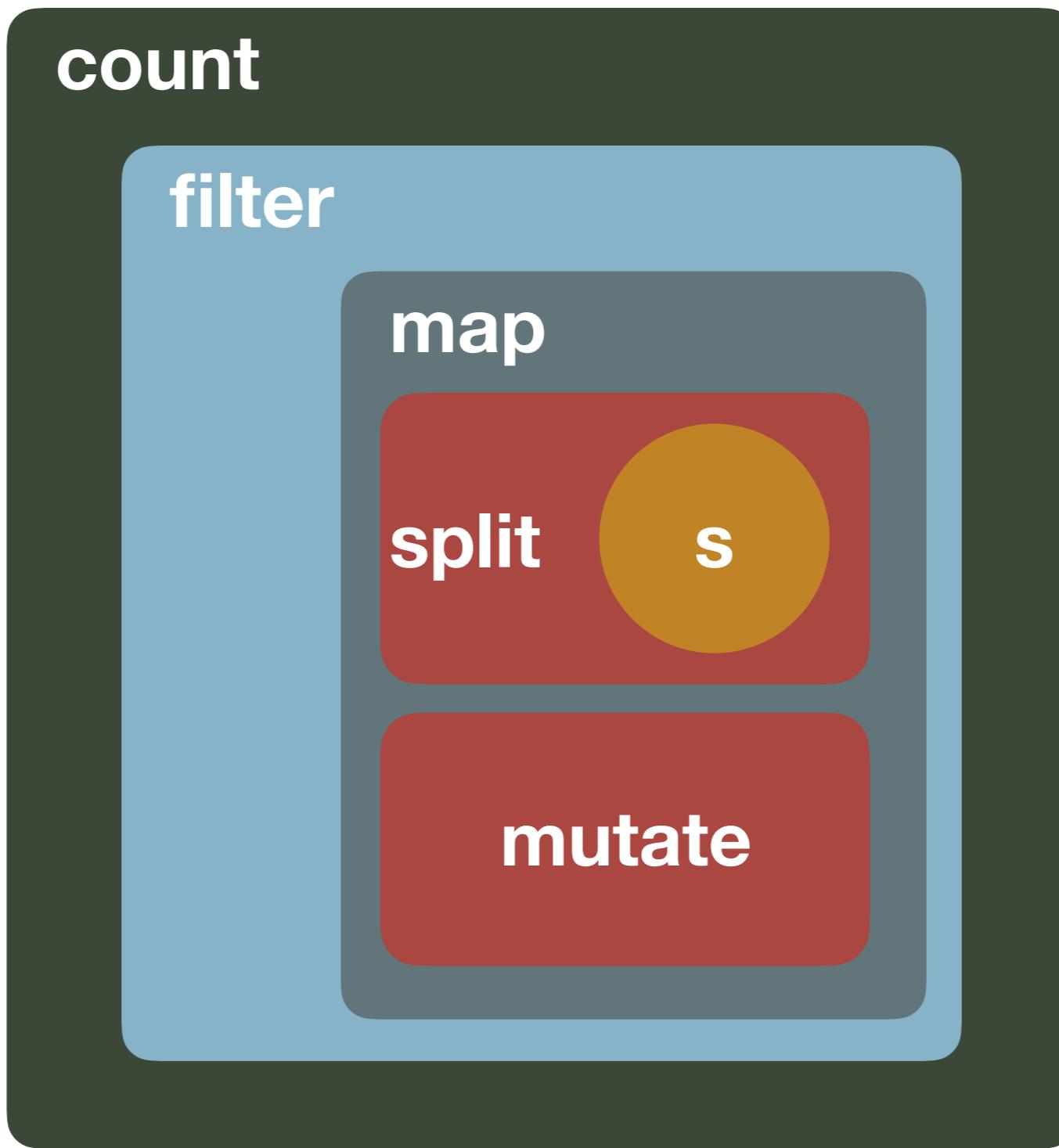


```
var _ = require('lodash');
```

Nested Example

```
const s =
  'Midway in our life\'s journey, I went astray';
const count = _.size(
  _.filter(
    _.map(
      _.split(s, ' '),
      word => _.replace(word, '(\\'s)|\w+', '')
    ),
    stripped => _.gt(stripped.length, 2)
  )
);
```

Nested Data Flow

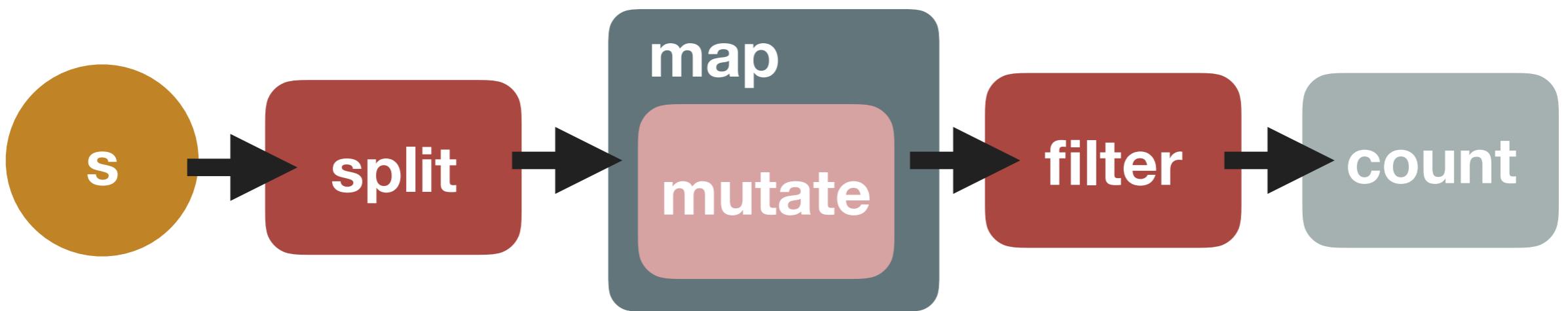


```
var { flow, map, filter, split, size, replace } = require('lodash/fp');
```

Piped Example

```
const count = flow([
  split(' '),
  map(
    replace('(\s)|\w+'(' ')),
    filter(
      stripped => _.gt(stripped.length, 2)),
    size
  )('Midway in our life\s journey, I went astray');
```

Piped Data Flow



The Language of Data Flow Manipulations

- map
- flat map
- filter
- fold
- mutate
- group by
- order by

The Language of Data Flow Manipulations

- map: **map**
- flat map: **flatMap**
- filter: **filter**
- fold: **reduce**
- mutate: **each**
- group by: **groupBy**
- order by: **orderBy**

The Language of Data Flow Manipulations

- **map**
- flat map
- filter
- fold
- mutate
- group by
- order by

Map

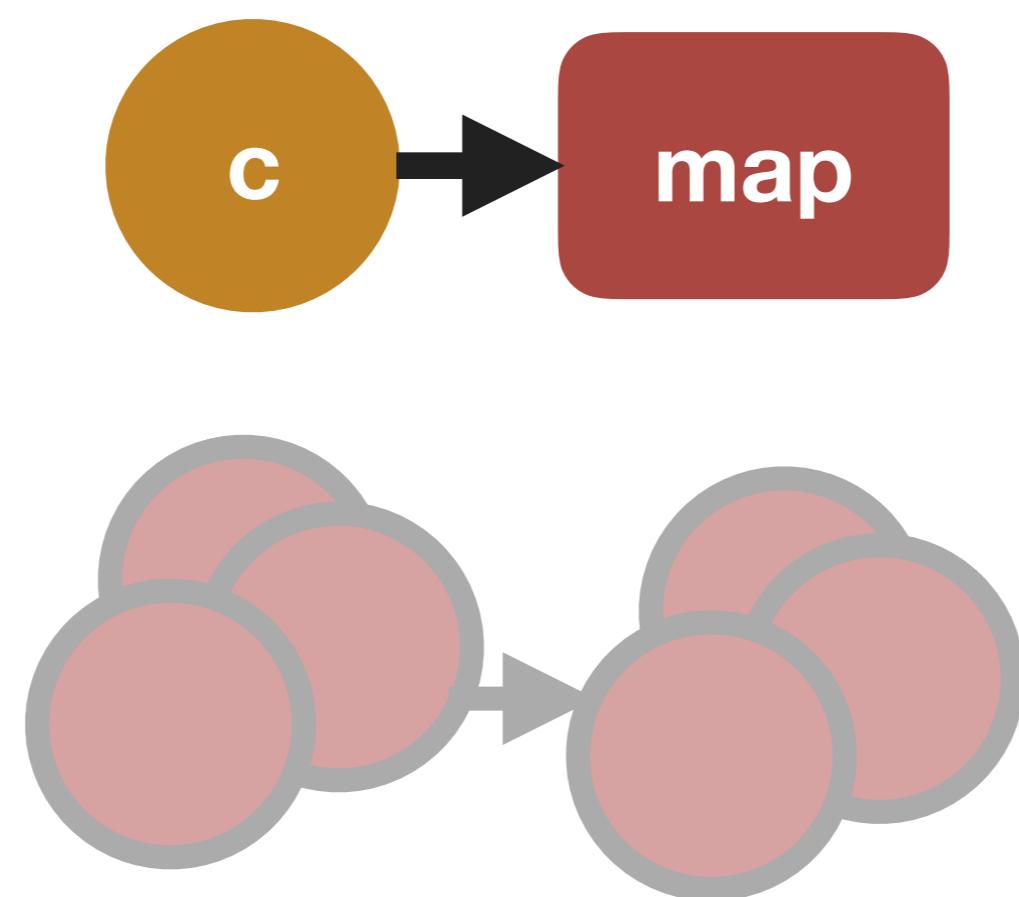


Map Example

```
const numbers =  
  _.map([3, 9, 10], x => x * 10);
```

output>
[30, 90, 100]

Map Data Flow



map Source Code

```
function map(array, iteratee) {
  let index = -1
  const length = array == null ? 0 : array.length
  const result = new Array(length)

  while (++index < length) {
    result[index] = iteratee(array[index], index, array)
  }
  return result
}
```

Map Example

```
const numbers =  
  _.map([3, 9, 10], x => x * 10);
```

output>
[30, 90, 100]

The Language of Data Flow Manipulations

- map
- **flat map**
- filter
- fold
- mutate
- group by
- order by

Flat Map



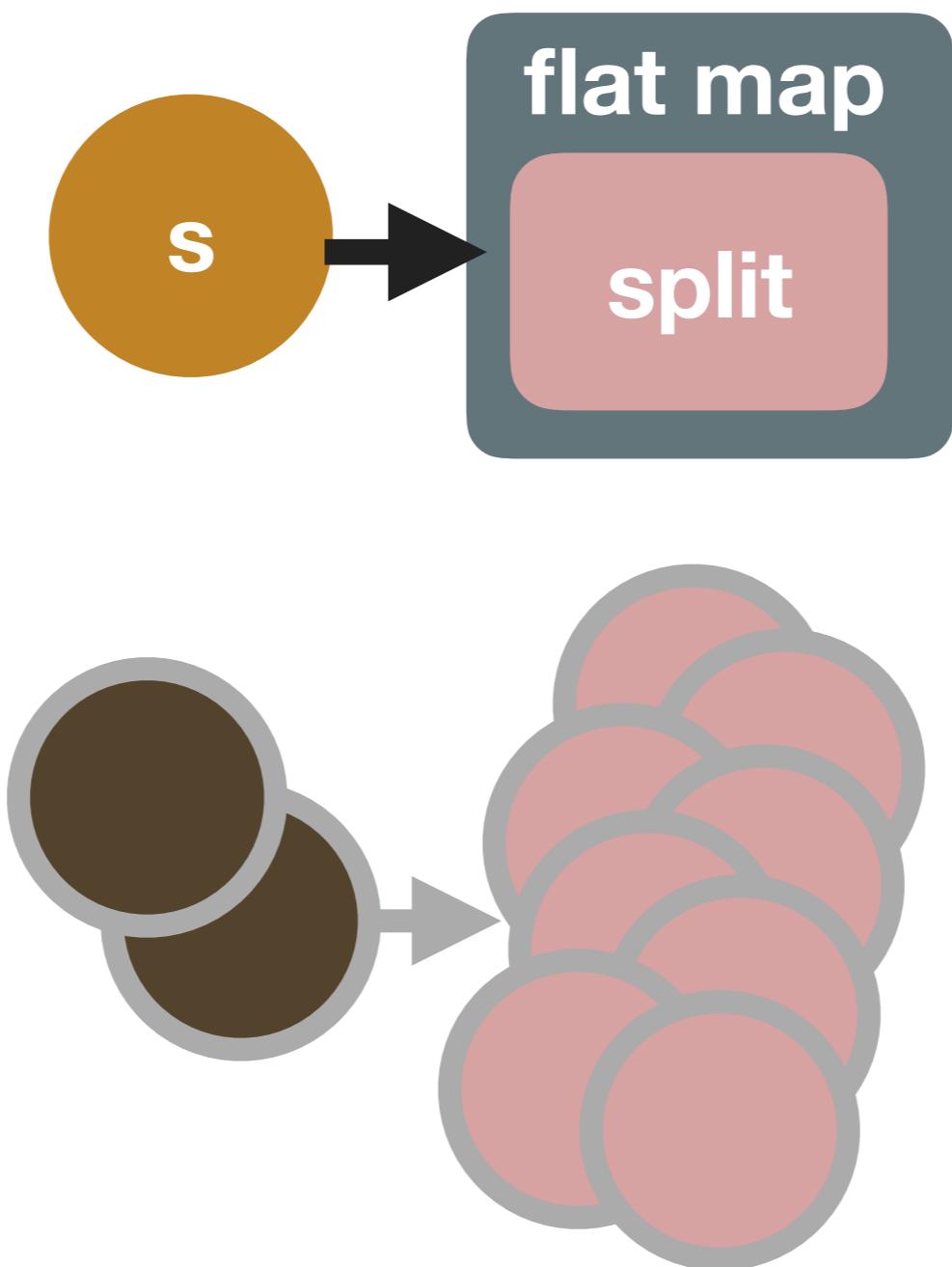
Flat Map Example

```
const list = _.flatMap([
  'Midway in our life\'s journey',
  'I went astray'
],  
  s => _.split(s, ' ')
);
```

output>

```
[ 'Midway', 'in', 'our',
  'life\'s', 'journey',
  'I', 'went', 'astray' ]
```

Flat Map Query Syntax Data Flow



flatMap Source Code

```
function flatMap(collection, iteratee) {  
  return baseFlatten(map(collection, iteratee), 1)  
}
```

baseFlatten Source Code

```
function baseFlatten(array, depth, predicate, isStrict, result) {
  predicate || (predicate = isFlattenable)
  result || (result = [])

  if (array == null) {
    return result
  }

  for (const value of array) {
    if (depth > 0 && predicate(value)) {
      if (depth > 1) {
        // Recursively flatten arrays (susceptible to call stack limits).
        baseFlatten(value, depth - 1, predicate, isStrict, result)
      } else {
        result.push(...value)
      }
    } else if (!isStrict) {
      result[result.length] = value
    }
  }
  return result
}
```

baseFlatten Source Code

```
function baseFlatten(array, depth, predicate, isStrict, result) {
  predicate || (predicate = isFlattenable)
  result || (result = [])
  // check for null ..

  for (const value of array) {
    if (depth > 0 && predicate(value)) {
      if (depth > 1) {
        baseFlatten(value, depth - 1, predicate, isStrict, result)
      } else {
        result.push(...value)
      }
    }
  } // else ..
}

return result
```

Flat Map Example

```
const list = _.flatMap([
  'Midway in our life\'s journey',
  'I went astray'
],  
  s => _.split(s, ' ')
);
```

output>

```
[ 'Midway', 'in', 'our',
  'life\'s', 'journey',
  'I', 'went', 'astray' ]
```

The Language of Data Flow Manipulations

- map
- flat map
- **filter**
- fold
- mutate
- group by
- order by

Filter

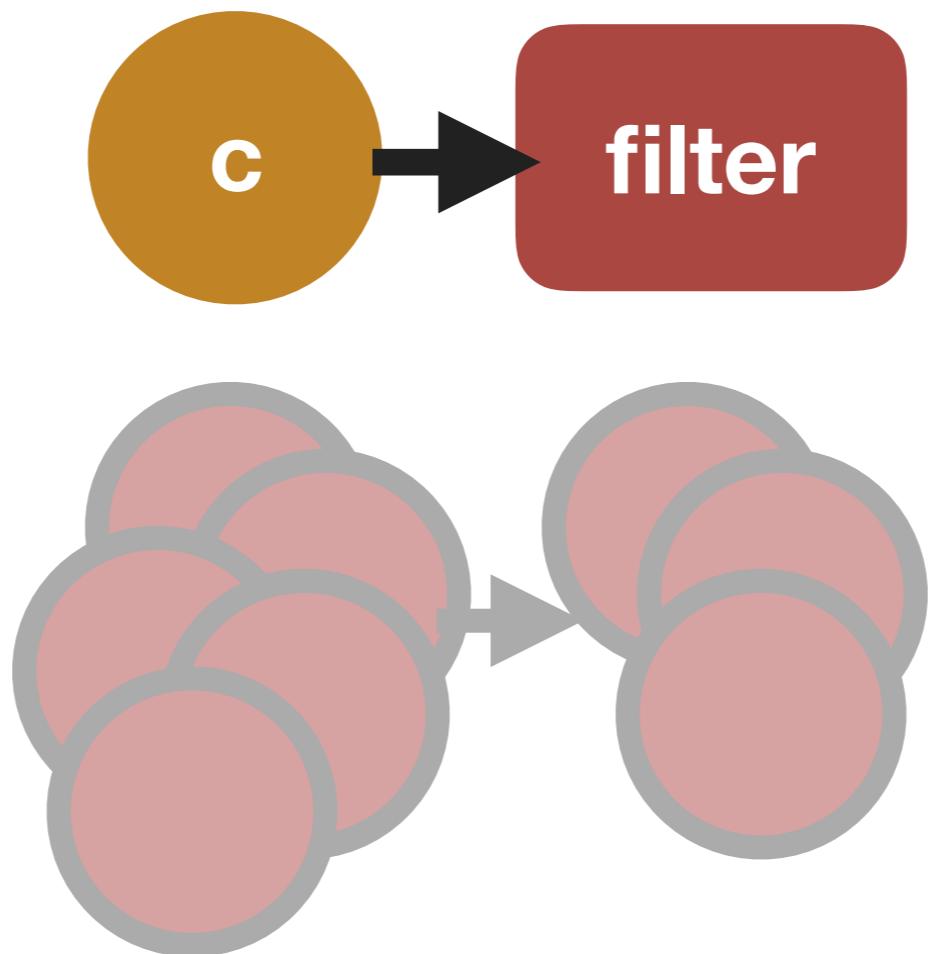


Filter Example

```
const numbers =  
  _.filter([3, 9, 10, 33, 100], n => n % 2 != 0);
```

output>
[3, 9, 33]

Filter Data Flow



filter Source Code

```
function filter(array, predicate) {
  let index = -1
  let resIndex = 0
  const length = array == null ? 0 : array.length
  const result = []

  while (++index < length) {
    const value = array[index]
    if (predicate(value, index, array)) {
      result[resIndex++] = value
    }
  }
  return result
}
```

Filter Example

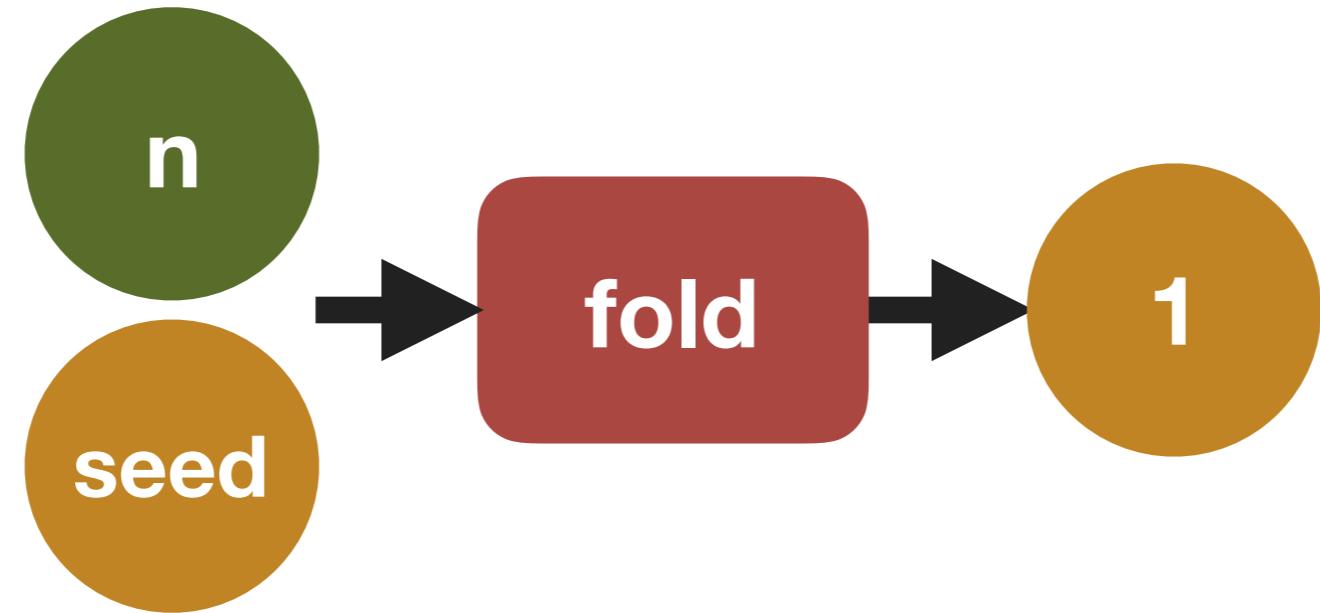
```
const numbers =  
  _.filter([3, 9, 10, 33, 100], n => n % 2 != 0);
```

output>
[3, 9, 33]

The Language of Data Flow Manipulations

- map
- flat map
- filter
- **fold**
- mutate
- group by
- order by

Fold



Fold Example

```
const sum =  
  _.reduce(  
    [3, 9, 10, 33, 100],  
    (m, x) => m + x,  
    0  
  );
```

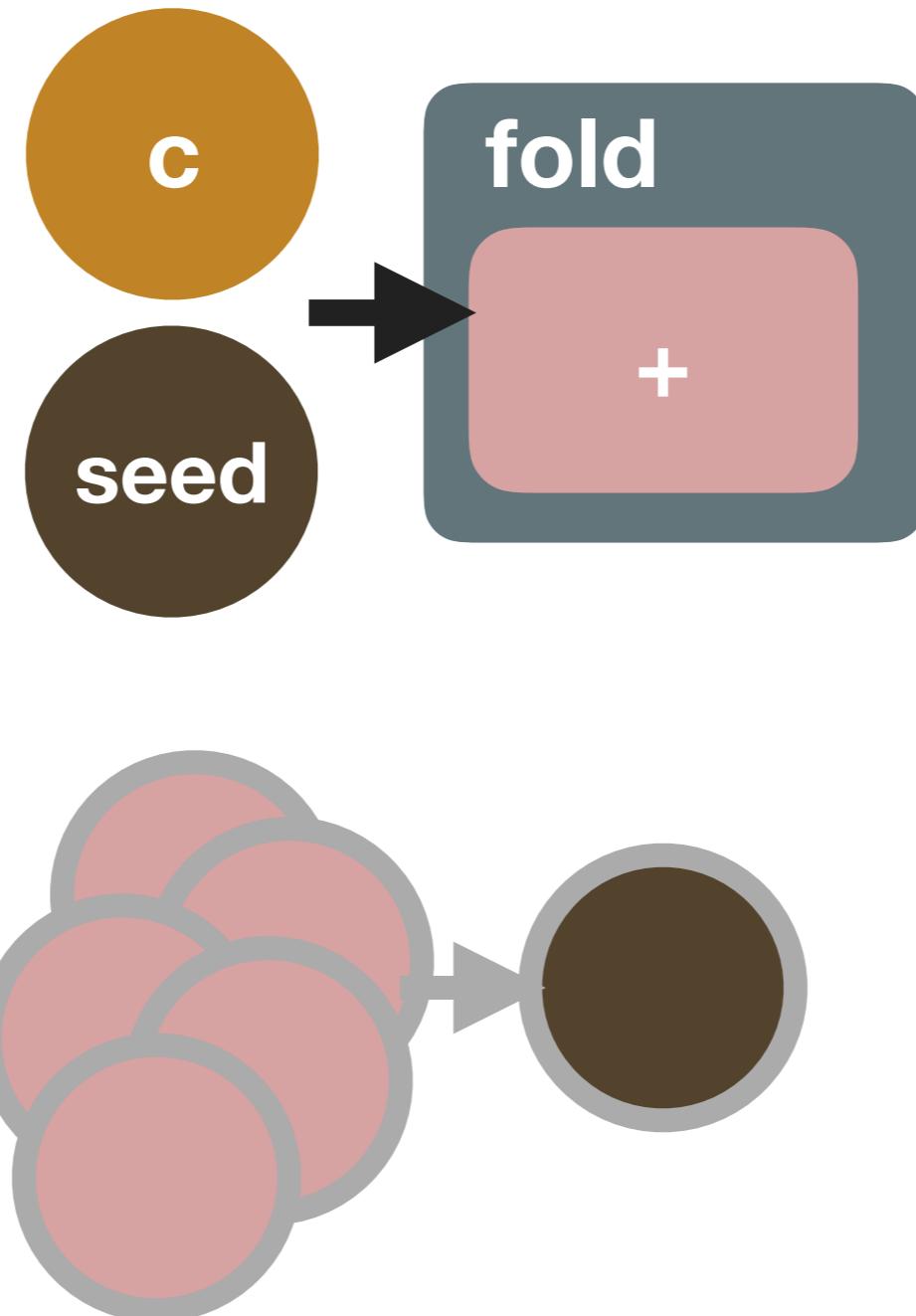
output>
155

Fold Example

```
const sum =  
  _.reduce([3, 9, 10, 33, 100], _.add);
```

output>
155

Fold Data Flow



reduce Source Code

```
function reduce(collection, iteratee, accumulator) {  
  const func = Array.isArray(collection)  
    ? arrayReduce : baseReduce  
  const initAccum = arguments.length < 3  
  return func(collection, iteratee, accumulator,  
              initAccum, baseEach)  
}
```

arrayReduce Source Code

```
function arrayReduce(array, iteratee, accumulator, initAccum) {  
  let index = -1  
  const length = array == null ? 0 : array.length  
  
  if (initAccum && length) {  
    accumulator = array[++index]  
  }  
  while (++index < length) {  
    accumulator = iteratee(  
      accumulator, array[index], index, array)  
  }  
  return accumulator  
}
```

Fold Example

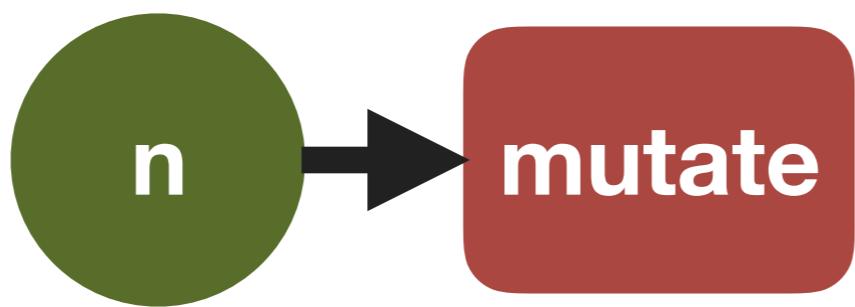
```
const sum =  
  _.reduce(  
    [3, 9, 10, 33, 100],  
    (m, x) => m + x,  
    0  
  );
```

output>
155

The Language of Data Flow Manipulations

- map
- flat map
- filter
- fold
- **mutate**
- group by
- order by

Mutate



Mutate Example

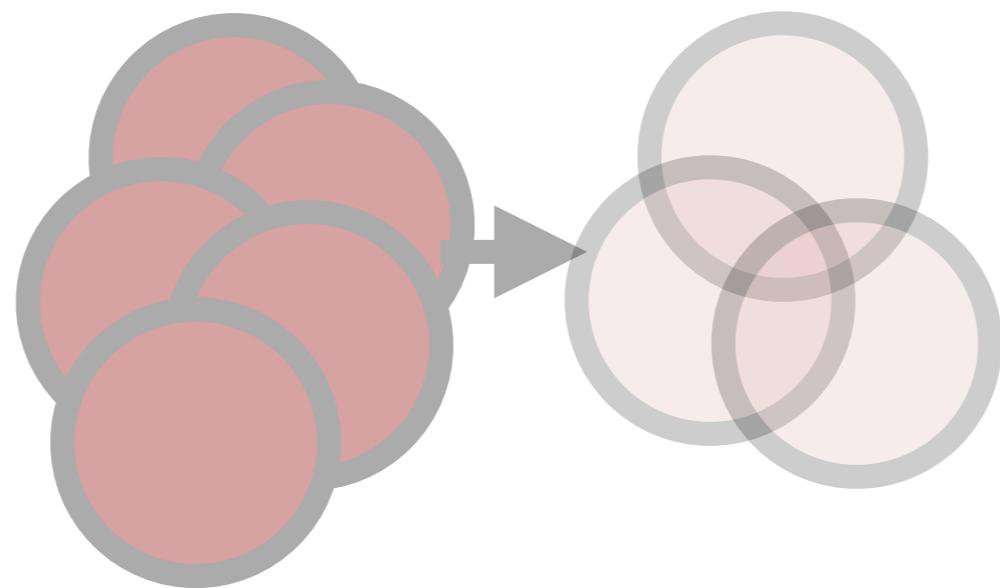
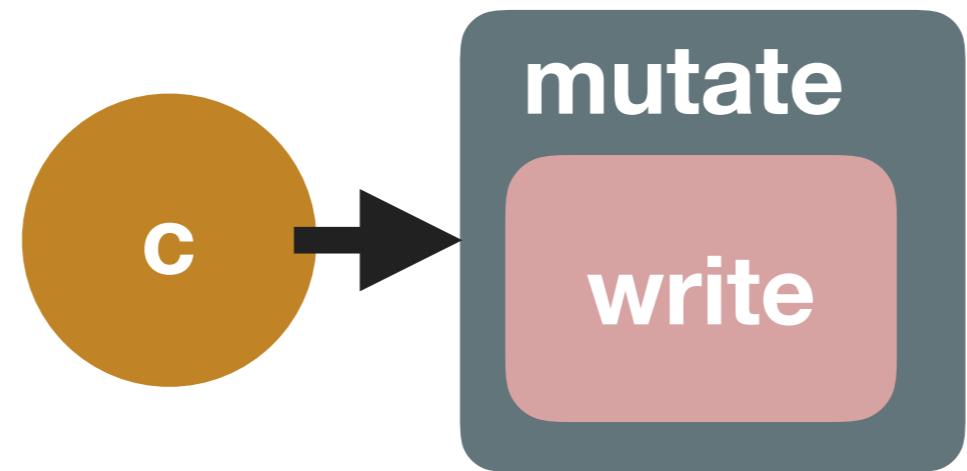
```
let r = [];
_.each(
  [3, 9, 10, 33, 100],
  n => { if (n % 3 === 0) { r.push(n); } }
);
```

output>

// void

r = [3, 9, 33]

Mutate Data Flow



forEach Source Code

```
function forEach(collection, iteratee) {
  const func =
    Array.isArray(collection) ? arrayEach : baseEach
  return func(collection, iteratee)
}
```

arrayEach Source Code

```
function arrayEach(array, iteratee) {
  let index = -1
  const length = array == null ? 0 : array.length

  while (++index < length) {
    if (iteratee(array[index], index, array)
        === false) {
      break
    }
  }
  return array
}
```

Mutate Example

```
let r = [];
_.each(
  [3, 9, 10, 33, 100],
  n => { if (n % 3 === 0) { r.push(n); } }
);
```

output>

// void

r = [3, 9, 33]

The Language of Data Flow Manipulations

- map
- flat map
- filter
- fold
- mutate
- **group by**
- order by

Group By



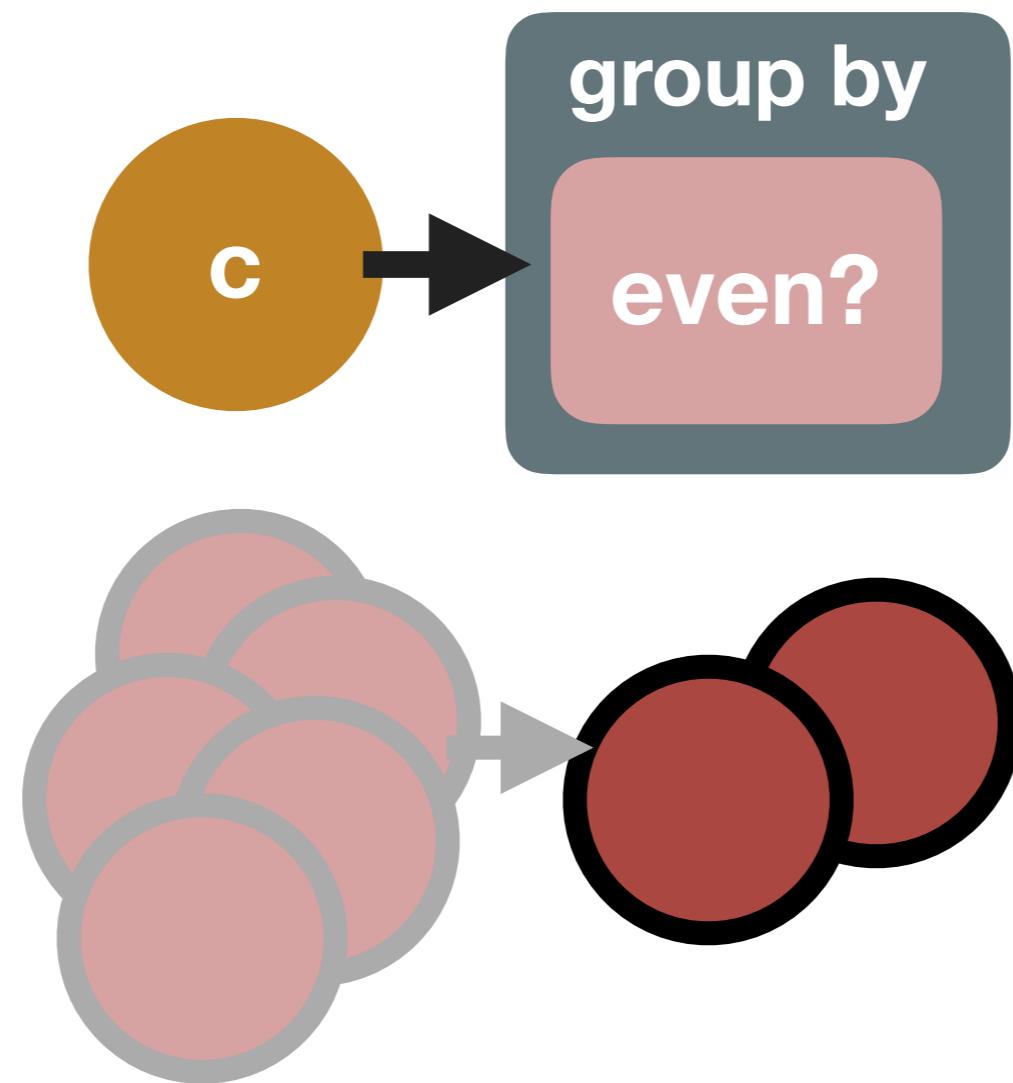
Group By Example

```
const groups =  
  _.groupBy(  
    [3, 9, 10, 33, 100],  
    n => n % 2 === 0  
  );
```

output>

```
{'true': [10, 100],  
 'false': [3, 9, 33]}
```

Group By Data Flow



groupBy Source Code

```
function groupBy(collection, iteratee) {
  return reduce(collection, (result, value, key) => {
    key = iteratee(value)
    if (hasOwnProperty.call(result, key)) {
      result[key].push(value)
    } else {
      baseAssignValue(result, key, [value])
    }
    return result
  }, [])
}
```

Group By Example

```
const groups =  
  _.groupBy(  
    [3, 9, 10, 33, 100],  
    n => n % 2 === 0  
  );
```

output>

```
{'true': [10, 100],  
 'false': [3, 9, 33]}
```

The Language of Data Flow Manipulations

- map
- flat map
- filter
- fold
- mutate
- group by
- **order by**

Order By

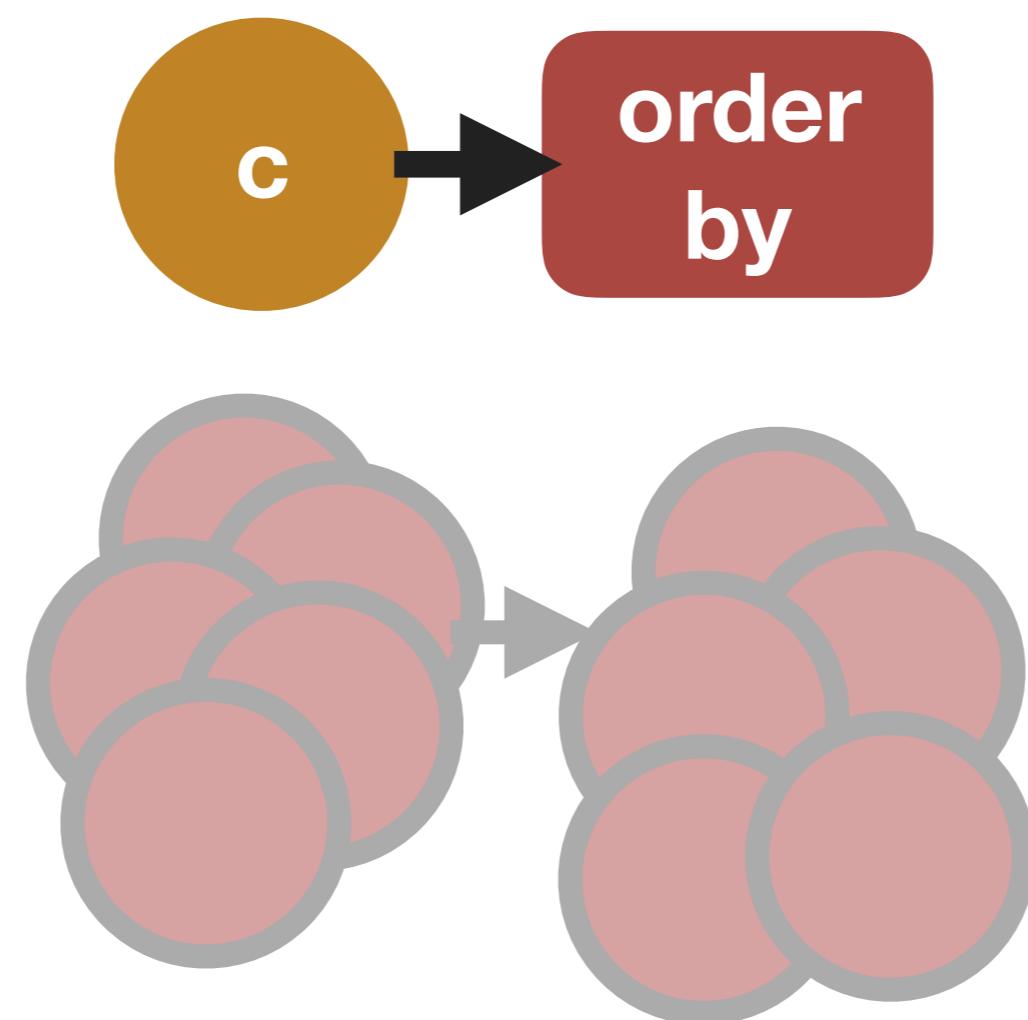


Order By Example

```
const ordered =  
  _.orderBy( [33, 9, 100, 3, 10]);
```

output>
[3, 9, 10, 33, 100]

Order By Data Flow



orderBy Source Code

```
function orderBy(collection, iteratees, orders) {
  if (collection == null) {
    return []
  }
  if (!Array.isArray(iteratee)) {
    iteratees = iteratees == null ? [] : [iteratee]
  }
  if (!Array.isArray(orders)) {
    orders = orders == null ? [] : [orders]
  }
  return baseOrderBy(collection, iteratees, orders)
}
```

baseOrderBy Source Code

```
function baseOrderBy(collection, iteratees, orders) {
  let index = -1
  iteratees = iteratees.length ? iteratees : [(value) => value]

  const result = baseMap(collection, (value, key, collection) => {
    const criteria = iteratees.map((iteratee) => iteratee(value))
    return { 'criteria': criteria, 'index': ++index, 'value': value }
  })

  return baseSortBy(result, (object, other)
    => compareMultiple(object, other, orders)))
}
```

baseSortBy Source Code

```
function baseSortBy(array, comparer) {
  let { length } = array

  array.sort(comparer)
  while (length--) {
    array[length] = array[length].value
  }
  return array
}
```

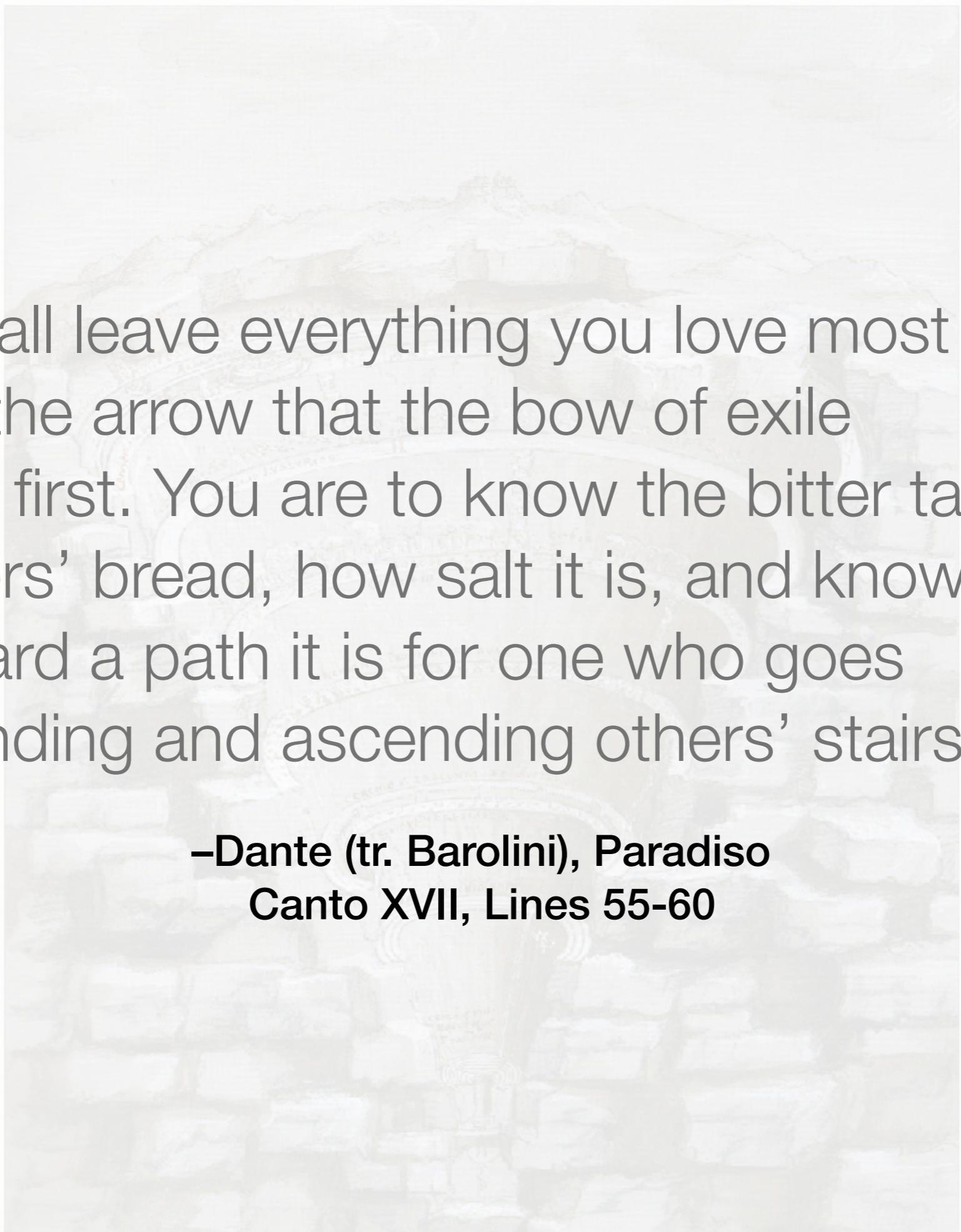
Order By Example

```
const ordered =  
  _.orderBy( [33, 9, 100, 3, 10]);
```

output>
[3, 9, 10, 33, 100]

Canto

- Data Flow in a System
- The Language of Data Flow Manipulations
- **Data Flow in Context**



You shall leave everything you love most dearly:
this is the arrow that the bow of exile
shoots first. You are to know the bitter taste
of others' bread, how salt it is, and know
how hard a path it is for one who goes
descending and ascending others' stairs.

**—Dante (tr. Barolini), Paradiso
Canto XVII, Lines 55-60**

Domain and Codomain



Domain and Codomain



Symbols

$$x \in X$$

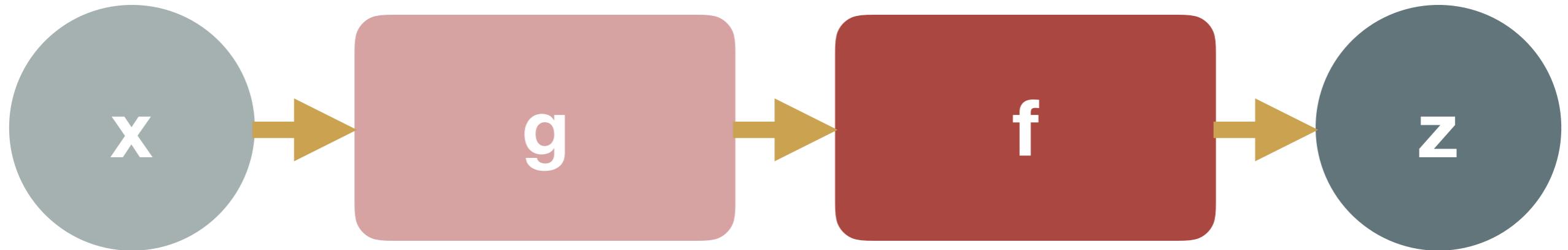
$$y \in Y$$

Natural
Language

X is domain of **f**

Y is codomain of **f**

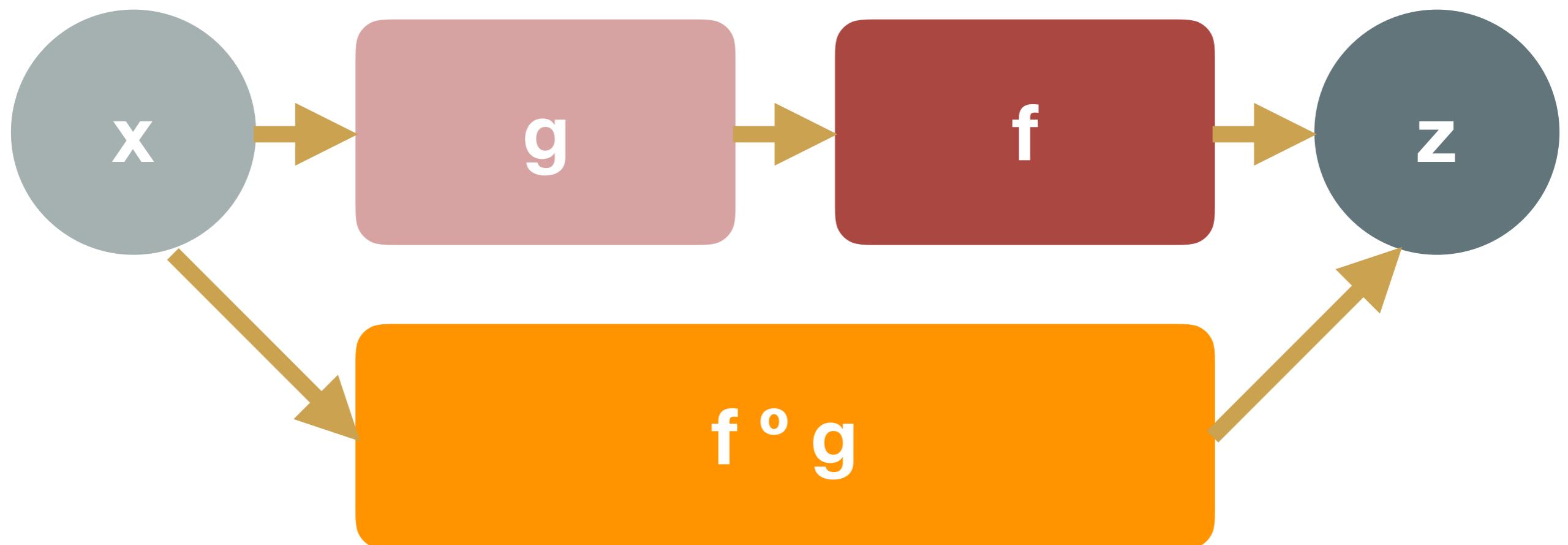
Functional Composition



```
Y g (X x)
{
    return y;
}
```

```
Z f (Y y)
{
    return z;
}
```

Functional Composition

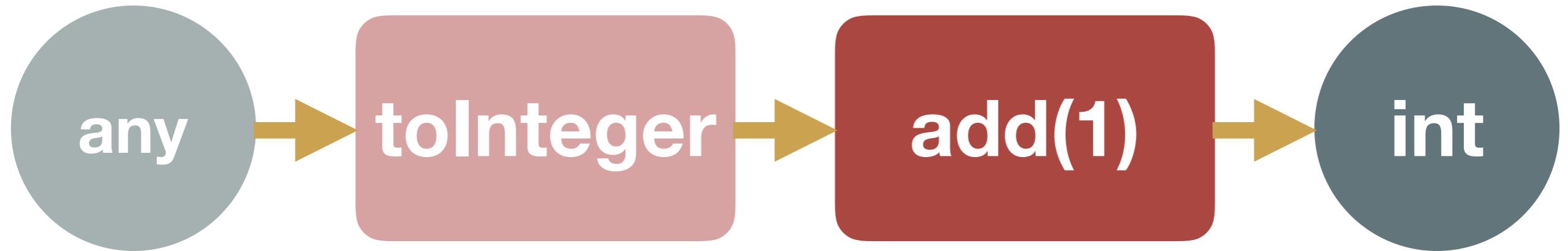


Example of Composed Functions

toInteger: (value: any) => number

var **add:** (augend: number, addend: number) => number

Example of Composed Functions



Example of Composed Functions

```
const inc = flow( [  
  toInteger,  
  add(1)  
] );  
  
inc('5');
```

output>
6

Functions in Context



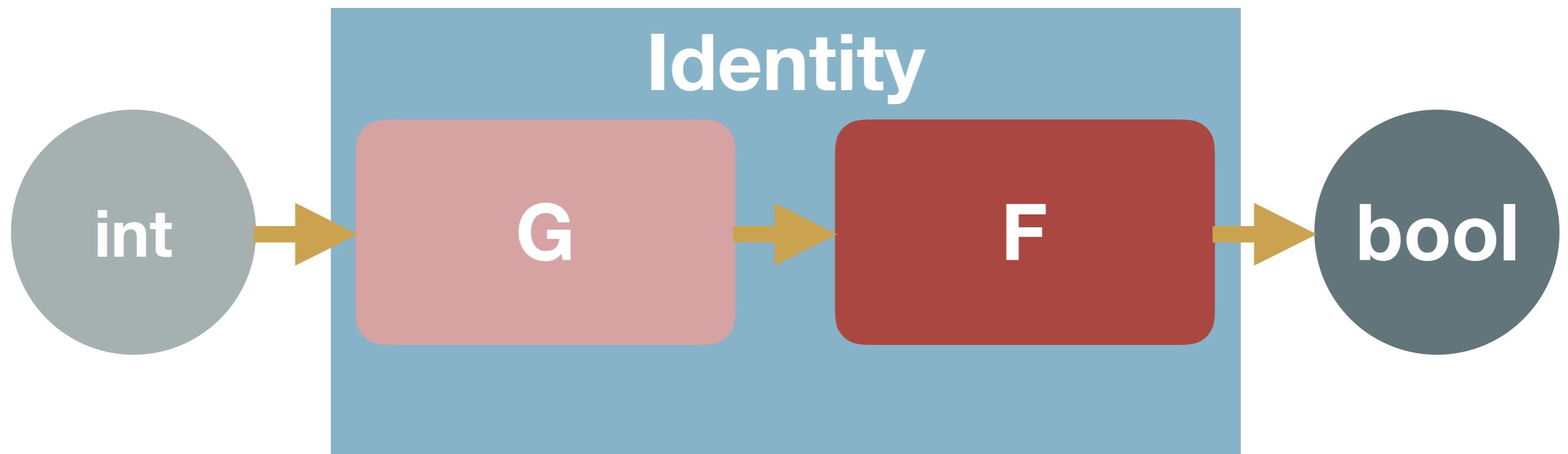
Example of Composed Functions

```
class Identity {  
    static of(value) { return [value]; }  
}
```

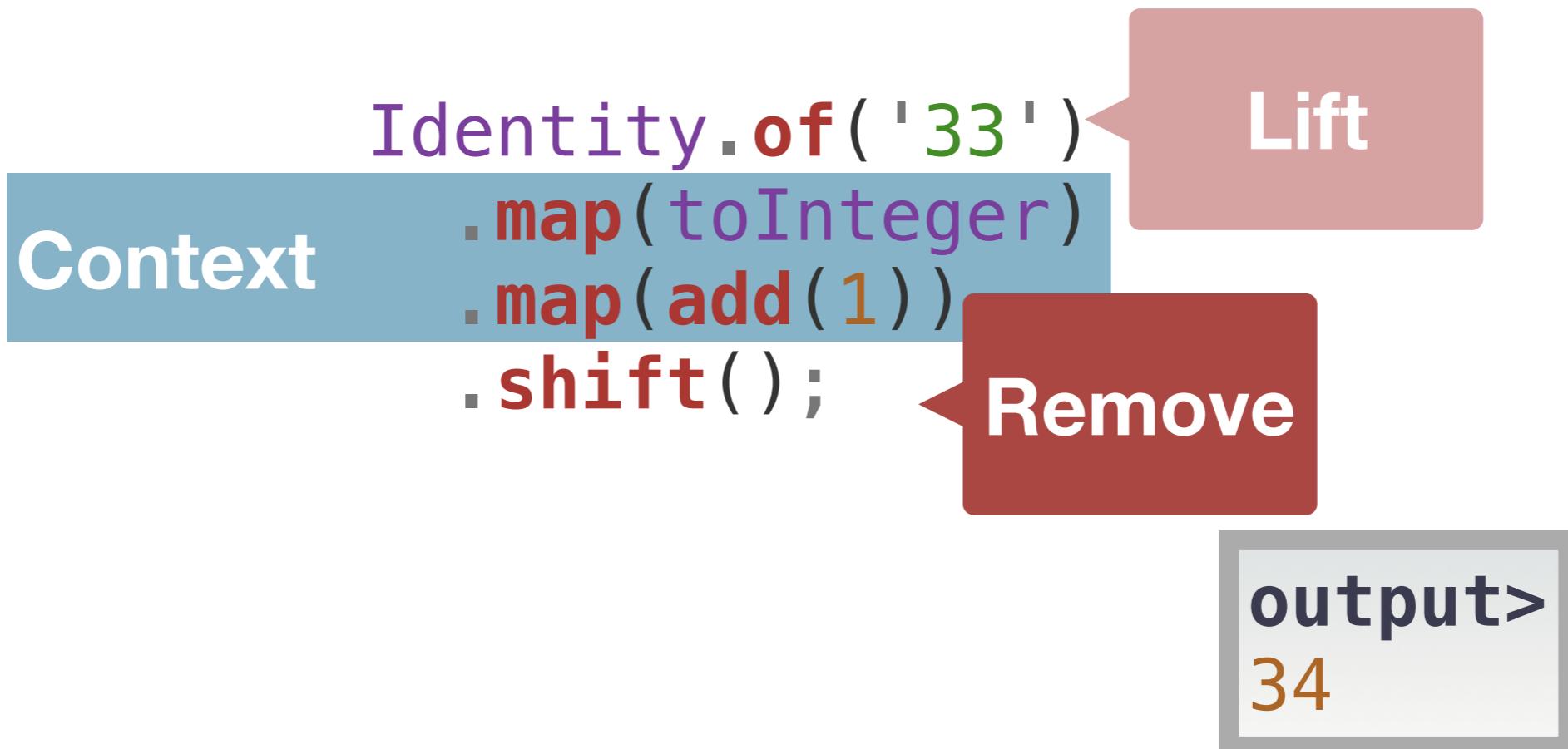
```
Identity.of('33')  
    .map(toInteger)  
    .map(add(1))  
    .shift();
```

output>
34

Example of Composed Functions



Example of Composed Functions

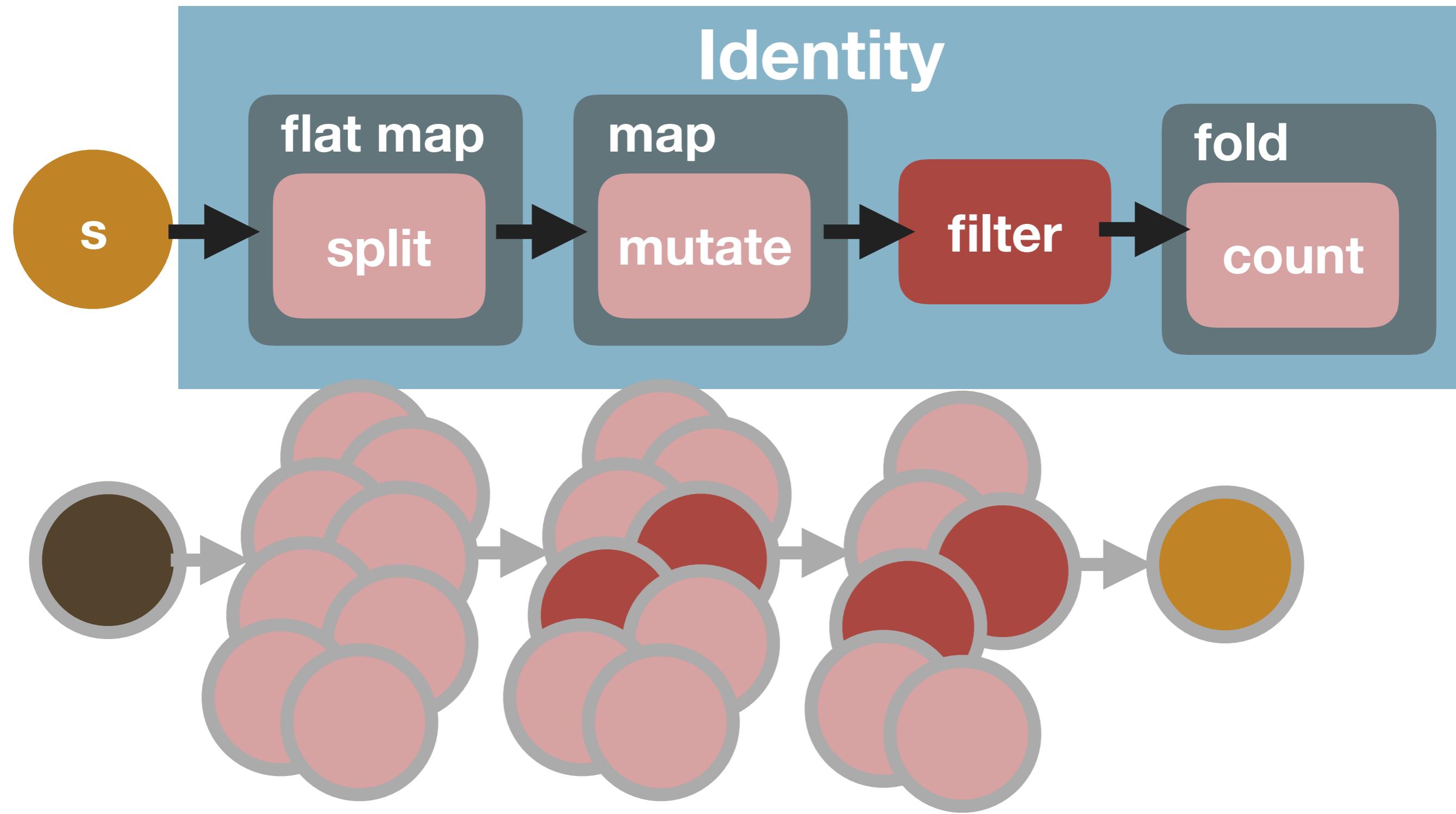


Functions in Context Example

```
const count = Identity.of(  
  'Midway in our life\'s journey, I went astray'  
  .map(split(' '))  
  .reduce(concat)  
  .map(replace('(\\'s)|\\w+')(''))  
  .filter(word => _.gt(word.length, 2))  
  .reduce(number => ++number, 0);
```

output>
6

Functions in Context Data Flow



Functions in Context Example

```
const count = Identity.of(Lift  
  'Midway in our life\'s journey, I went astray'  
  .map(split(' '))  
  .reduce(concat)  
  .map(replace('(\\'s)|\w+')(''))  
  .filter(word => _.gt(word.length, 2))  
  .reduce(number => ++number, 0);Context
```

Remove

output>
6

String in Context Example

```
const count =  
  'Midway in our life\'s journey, I went astray'  
    .split(' ')  
    .map(replace('(\\'s)|\W+')(''))  
    .filter(word => _.gt(word.length, 2))  
    .reduce(number => ++number, 0);
```

output>
6

String in Context Example

Lift

```
const count =  
  'Midway in our life\'s journey, I went astray'  
    .split(' ')  
    .map(replace('(\\'s)|\W+')(''))  
    .filter(word => _gt(word.length, 2))  
    .reduce(number => ++number, 0);
```

Context

Remove

output>
6



OVI COELVM DEONIT MEDIVMOVE IMMVOQUE TRIBUNALE
SENSIT CONSILIS AC PLEIADE PATRIGM
LVSTRAVIT QVE ANIMO CVNCTA POETA SVO¹⁴ DOCTVS AEST DANTES SVA QVEM FLORENTIA SAEPE
NIL POTVIT TANTO MORS SAEVA NOCERE POETA E¹⁵ QVEM VIVVM VIRTUS GARMEN IMAGO FACIE

Thank you!

Mike Harris

@MikeMKH

<http://comp-phil.blogspot.com/>



Next Steps

- StrangeLoop (conference)
<https://www.thestrangeloop.com/>
- Brian Lonsdorf - Professor Frisby Introduces Composable Functional JavaScript (video series)
<https://egghead.io/courses/professor-frisby-introduces-composable-functional-javascript>
- Aditya Bhargava - Functors, Applicatives, And Monads In Pictures (blog post)
http://adit.io/posts/2013-04-17-functors,_applicatives,_and_monads_in_pictures.html
- Luis Atencio - Functional Programming in JavaScript (book)
<https://www.manning.com/books/functional-programming-in-javascript>
- Reginald Braithwaite - JavaScript Allongé, The “Six” Edition (book)
<https://leanpub.com/javascriptallongesix/read>

Code from Lodash Source Code

- map
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/map.js#L19-L28>
- flatMap
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/flatMap.js#L24-L26>
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/.internal/baseFlatten.js#L14-L35>
- filter
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/filter.js#L24-L37>
- reduce
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/reduce.js#L38-L42>
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/.internal/arrayReduce.js#L12-L23>

Code from Lodash Source Code

- foreach
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/forEach.js#L28-L31>
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/.internal/arrayEach.js#L9-L19>
- groupBy
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/groupBy.js#L24-L34>
- orderBy
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/orderBy.js#L30-L41>
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/.internal/baseOrderBy.js#L14-L24>
 - <https://github.com/lodash/lodash/blob/6ad829fa90af199150b11ba1d3c944b648a39ce5/.internal/baseSortBy.js#L11-L19>

Code

- SQL Code, <http://sqlfiddle.com/#!6/50442/6>
- C# Code, <https://gist.github.com/MikeMKH/cabd17faa9290d6f15592c5df8ed9f>

Yes, Lodash's source code does not have ;

- [https://github.com/lodash/lodash/commit/
6cb3460fcefe66cb96e55b82c6feb2153c992cc](https://github.com/lodash/lodash/commit/6cb3460fcefe66cb96e55b82c6feb2153c992cc)

Biography

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