Lecture 4:
Introduction to Spark

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THE UNIVERSITY OF
TENNESSEE
KNOXVILLE

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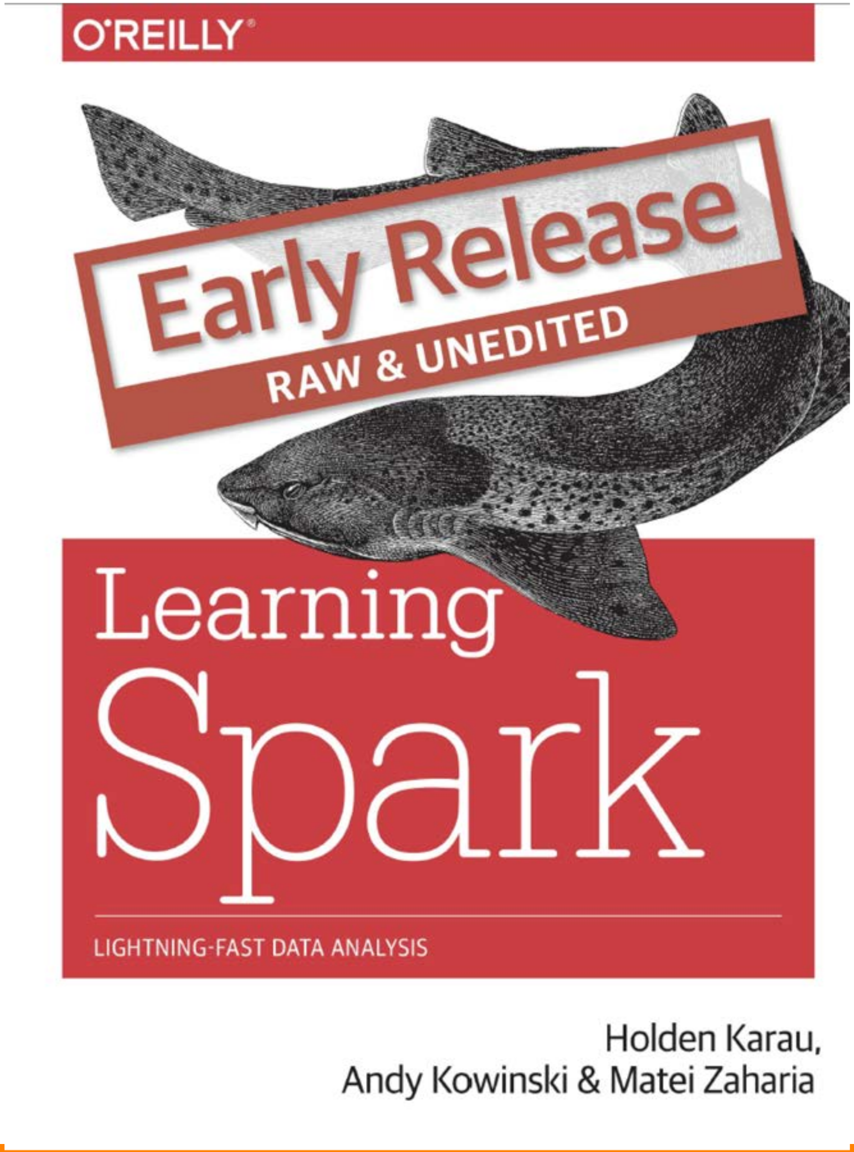
Today Outline

- Overview of Spark core concepts
- Create SparkContext and Resilient distributed datasets (RDDs)
- Run parallel operations on RDDS
- Assignment 4: create sequential Spark call:
  - *mapSequential,*
  - *reduceSequential*
  - *reduceByKeySequential*
- Work on Assignment 4
- Access our XSEDE Jetstream account
- Work on Assignment 4

Spark reference



O'REILLY

Early Release

RAW & UNEDITED

Learning Spark

LIGHTNING-FAST DATA ANALYSIS

Holden Karau,
Andy Kowinski & Matei Zaharia

Spark is …

- … a “computational engine that is responsible for scheduling, distributing, and monitoring applications consisting of many computational tasks across many **worker** machines, or a computing cluster.”

Running Spark

- Apache Spark has four APIs: Java, Scala, R, and **Python**
- Ways to use the Python API:
  - Interactively, using **pyspark**
  - Non-interactively, using **spark-submit**
  - Within the **Jupyter Notebook**
- Run interactively: open the Python version of the Spark shell

  ```
  bin/pyspark
  ```
- Run non-interactively: Write Python scripts and run script:

  ```
  bin/spark-submit my_script.py
  ```
- Run in Jupyter Notebook: Assignment 5

Running Spark

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- Run interactively: open the Python version of the Spark shell

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  bin/pyspark
  ```
- Run non-interactively: Write Python scripts and run script:

  ```
  bin/spark-submit my_script.py
  ```
- Run in Jupyter Notebook: Assignment 5

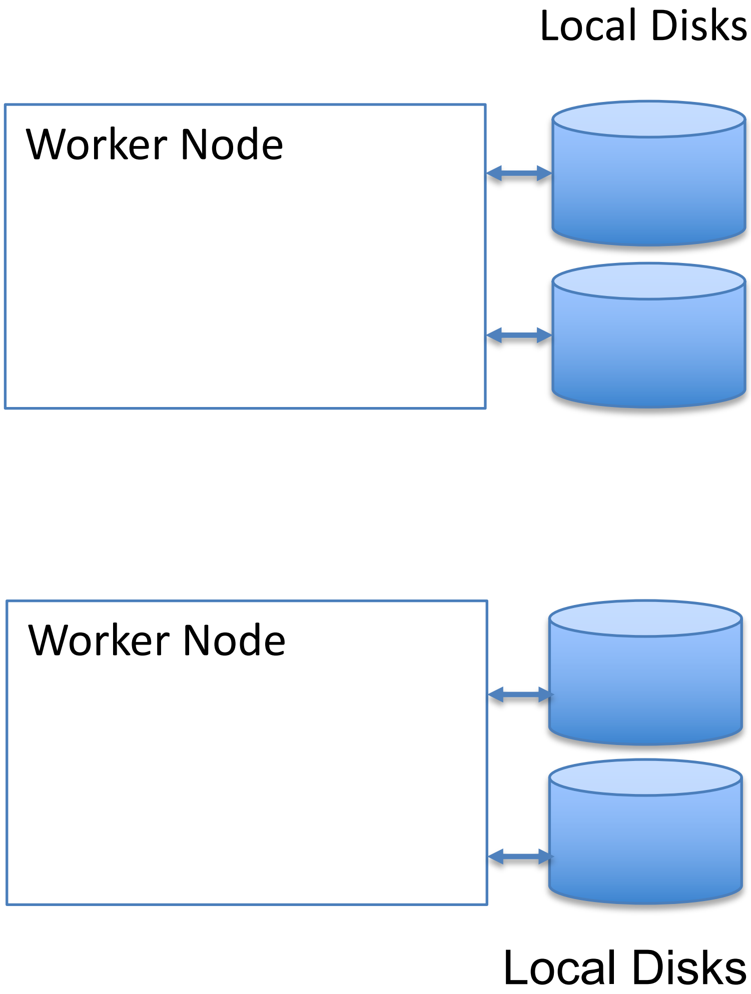
Installing pyspark

```
$ python
Python 3.6.5 |Anaconda, Inc.| (default, Apr 26 2018,
08:42:37)
[GCC 4.2.1 Compatible Clang 4.0.1
(tags/RELEASE_401/final)] on darwin
Type "help", "copyright", "credits" or "license" for
more information.
>>> import pyspark
Traceback (most recent call last):
File "<stdin>", line 1, in <module>ModuleNotFoundError:
No module named 'pyspark’
$ pip install pyspark
```

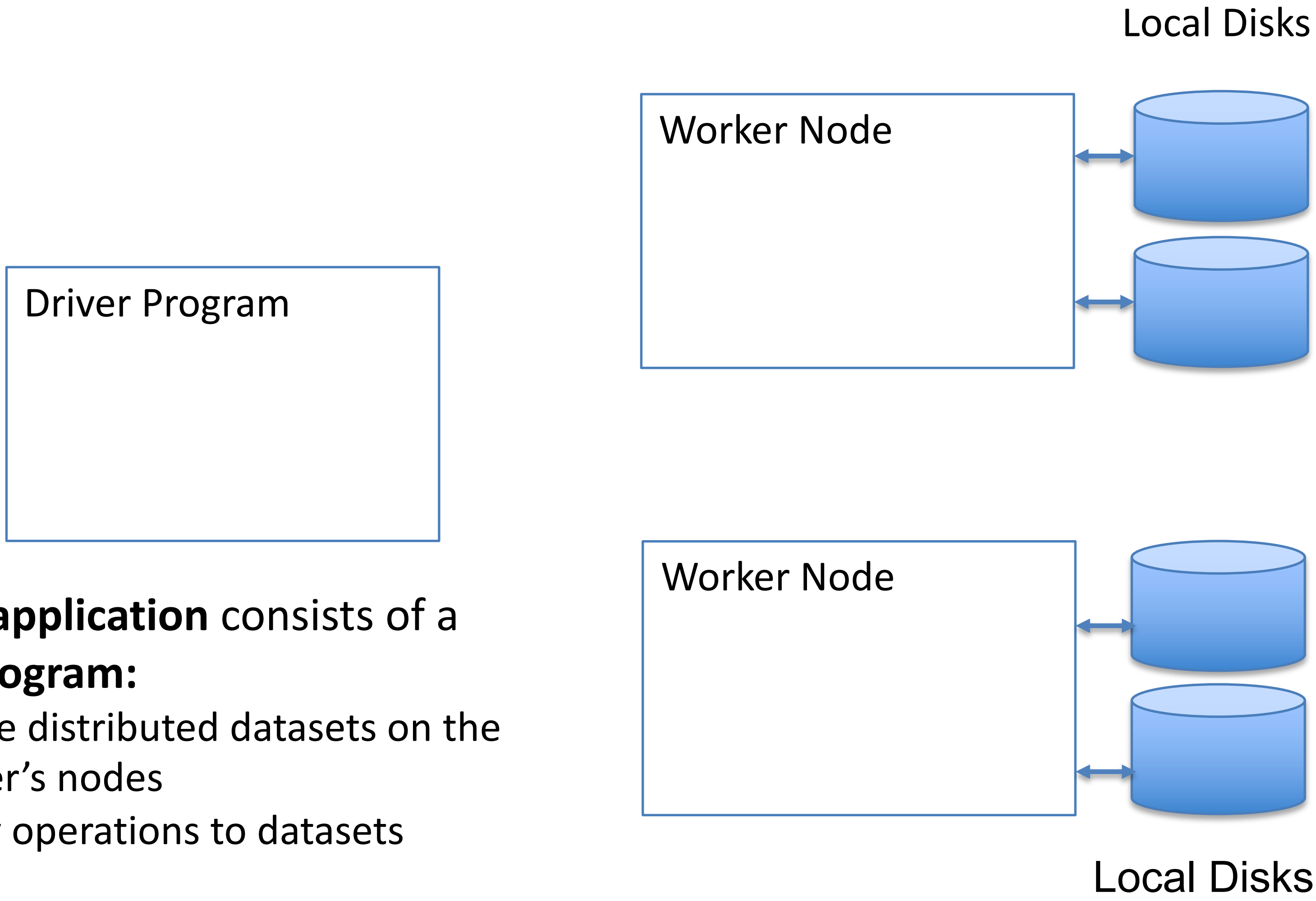
Spark Core Concepts

- A **Spark application** consists of a **driver program**
- A drive program:
  - Defines distributed datasets on the cluster
  - Applies operations to datasets
- A driver program accesses Spark through a SparkContext object
- A **SparkContext** represents a connection to a computing cluster
- Spark uses SparkContext to build resilient **distributed datasets (RDDS)**

Spark Core Concepts



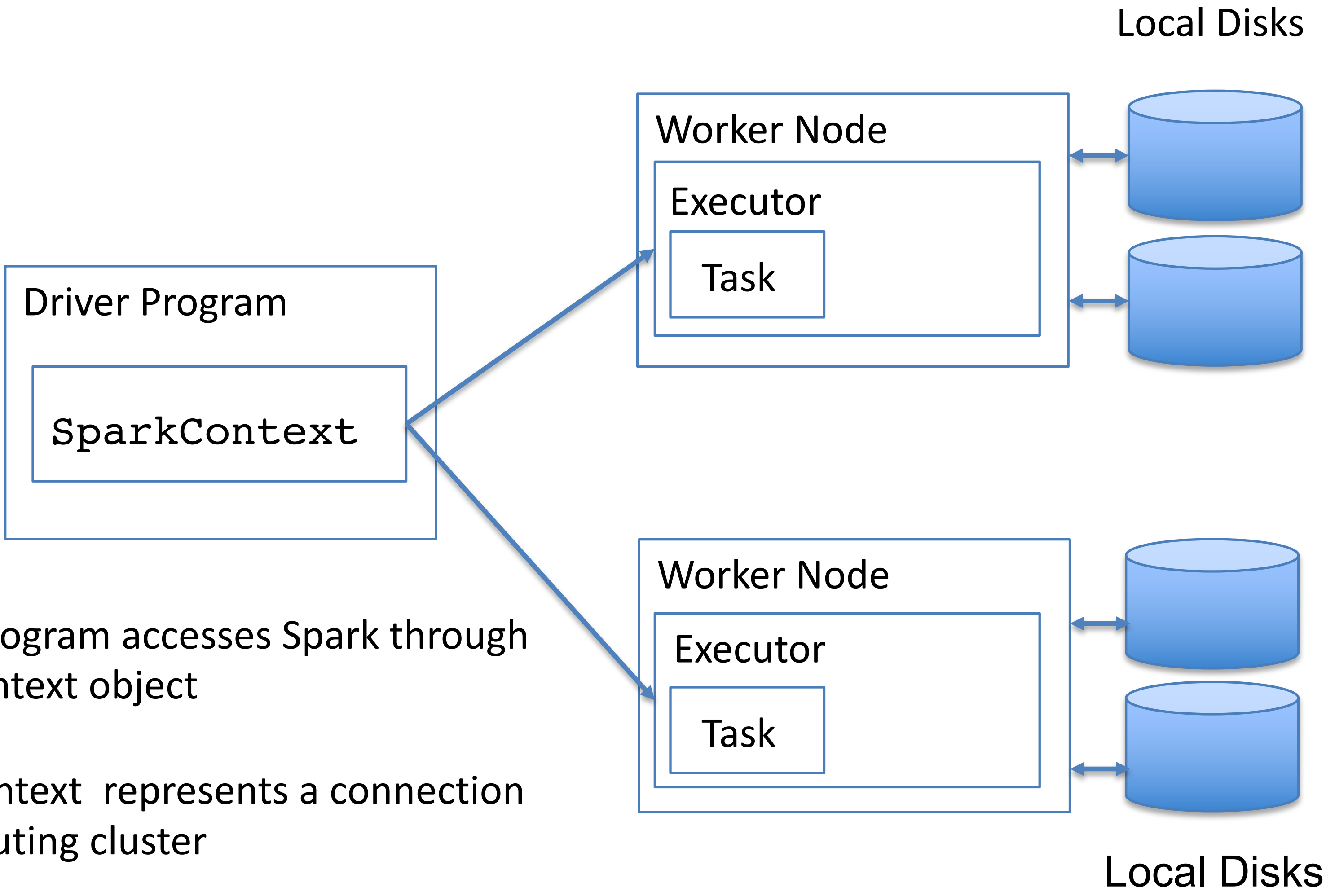
Spark Core Concepts



A **Spark application** consists of a **driver program:**

- Define distributed datasets on the cluster's nodes
- Apply operations to datasets

Spark Core Concepts



A driver program accesses Spark through a SparkContext object

A SparkContext represents a connection to a computing cluster

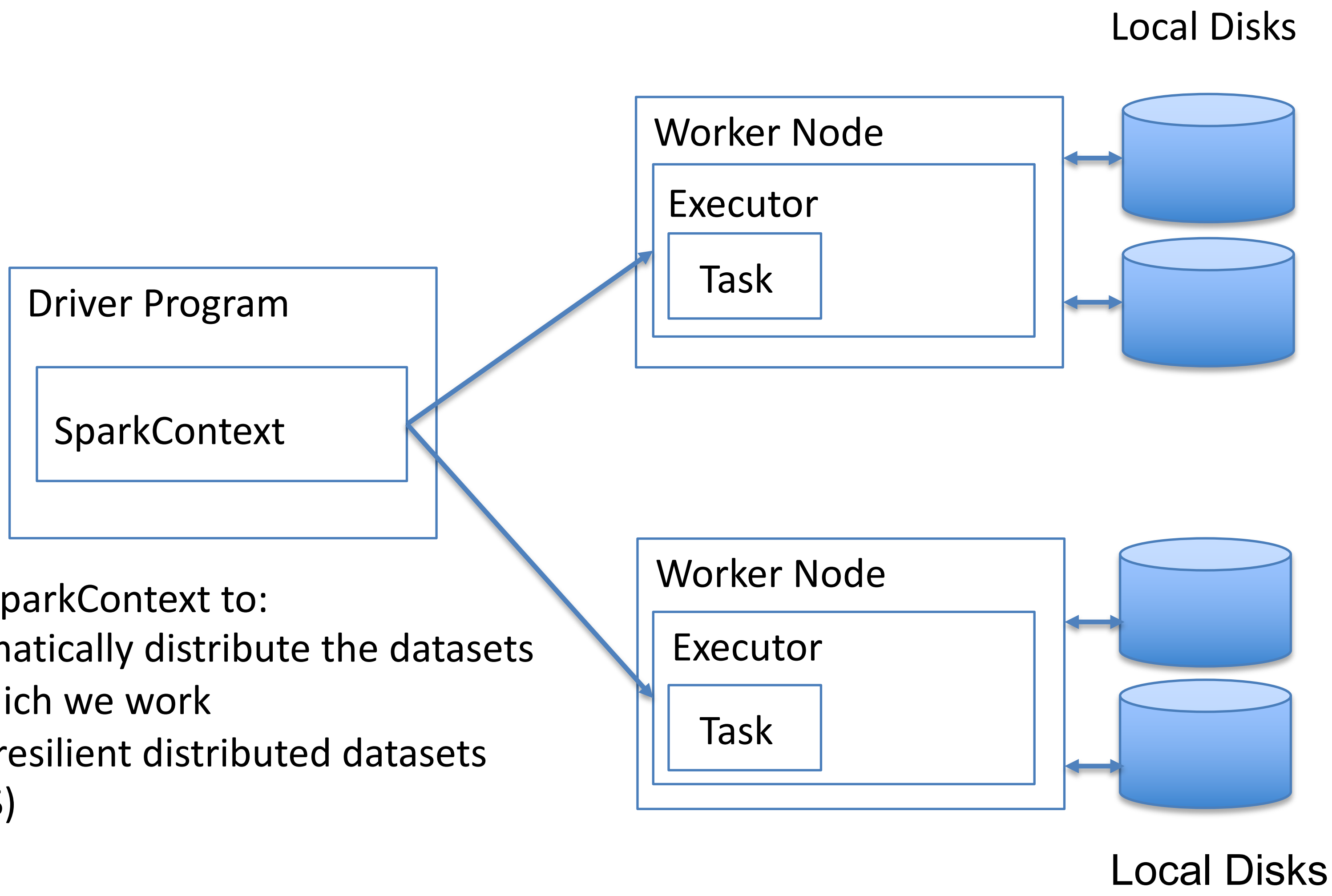
Create a SparkContex

In [1]

```
from pyspark import SparkContext


sc = SparkContext.getOrCreate()
```

Spark Core Concepts



We use SparkContext to:

- Automatically distribute the datasets on which we work
- Build resilient distributed datasets (RDDS)

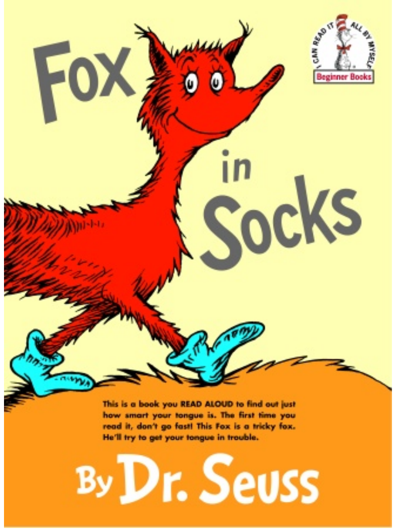
Resilient Distributed Datasets

- Spark operates on a distributed collections of data called Resilient Distributed Datasets (or RDDs)
- We express Spark computation through operations on RDDs
- Datasets are automatically distributed across a cluster
- Operations are automatically parallelized across a cluster

→ RDDs are Spark’s fundamental abstraction for distributed data and computation

```
# Given the file “FoxInSocks.txt”
```

When tweetle beetles fight,
it’s called a tweetle beetle battle.
And when they battle in a puddle,
it’s a tweetle beetle puddle battle.
And when tweetle beetles battle with paddles in a puddle,
They call it a tweetle beetle puddle paddle battle.

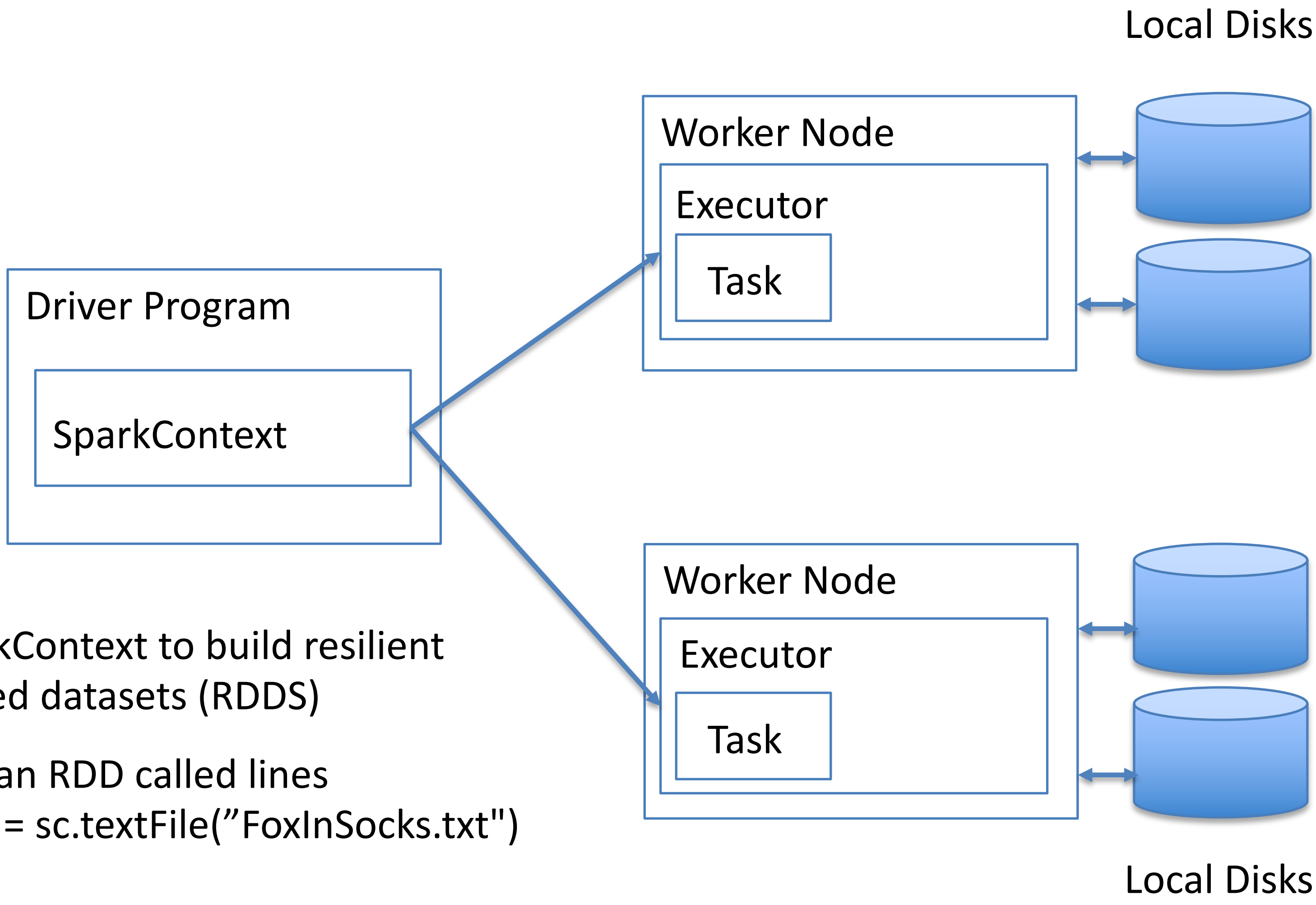

Fox
in
Socks
I CAN READ IT ALL BY MYSELF
Beginner Books
This is a book you READ ALOUD to find out just how smart your tongue is. The first time you read it, don't go fast! This Fox is a tricky fox. He'll try to get your tongue in trouble.
By Dr. Seuss

```
# Create an RDD called lines
>>> lines = sc.textFile(”FoxInSocks.txt")
```

```
# File lines automatically distributed across nodes  of 2-node cluster
```

Node 1	When tweetle beetles fight, it’s called a tweetle beetle battle. And when they battle in a puddle,
Node 2	it’s a tweetle beetle puddle battle. And when tweetle beetles battle with paddles in a puddle, They call it a tweetle beetle puddle paddle battle.

Spark Core Concepts



Use SparkContext to build resilient distributed datasets (RDDS)

# Create an RDD called lines
>>> lines = sc.textFile(”FoxInSocks.txt")

Create a SparkContex

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
# Load list of words
lines = sc.textFile('FoxInSocks.txt')
```

Count Number of Lines

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
# Load list of words
lines = sc.textFile('FoxInSocks.txt')
# Count the number of items in this RDD
print(lines.count())
```

Print First Line

In [1]

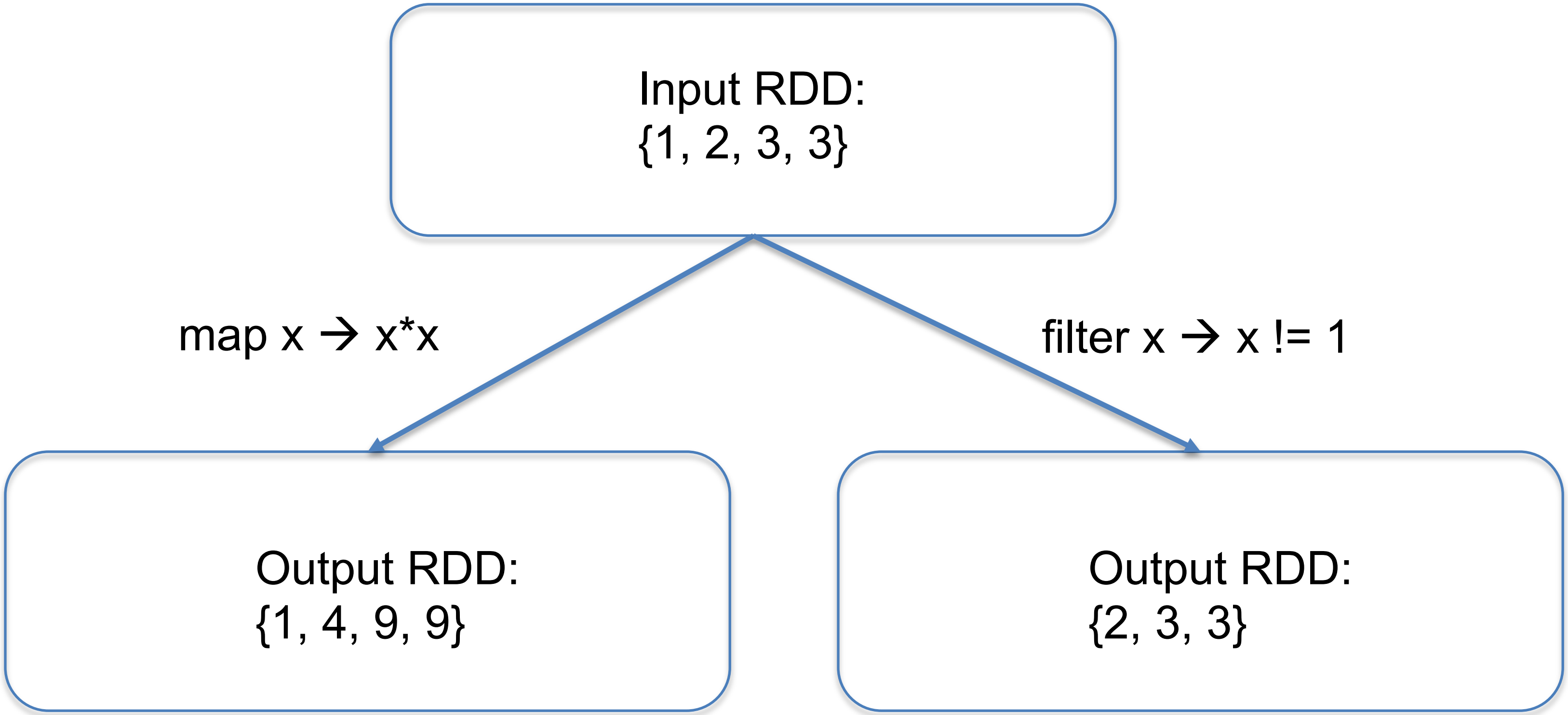
```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
# Load list of words
lines = sc.textFile('FoxInSocks.txt')
# First item in this RDD, i.e. first line of FoxInSocks.txt
print( lines.first())
```

Operations

- **Transformations:** lazily evaluated—no immediate computation
  - “Return” new RDDs obtained by transforming an old RDD
  - Input: **RDD type** → OPERATION → Output: **RDD type**
- **Actions:** cause all *queued* transformations to be applied
  - Return a list or value to the driver (serial) process
  - Input: **RDD type** → OPERATION → Output: **NOT a RDD type** (e.g., integer)

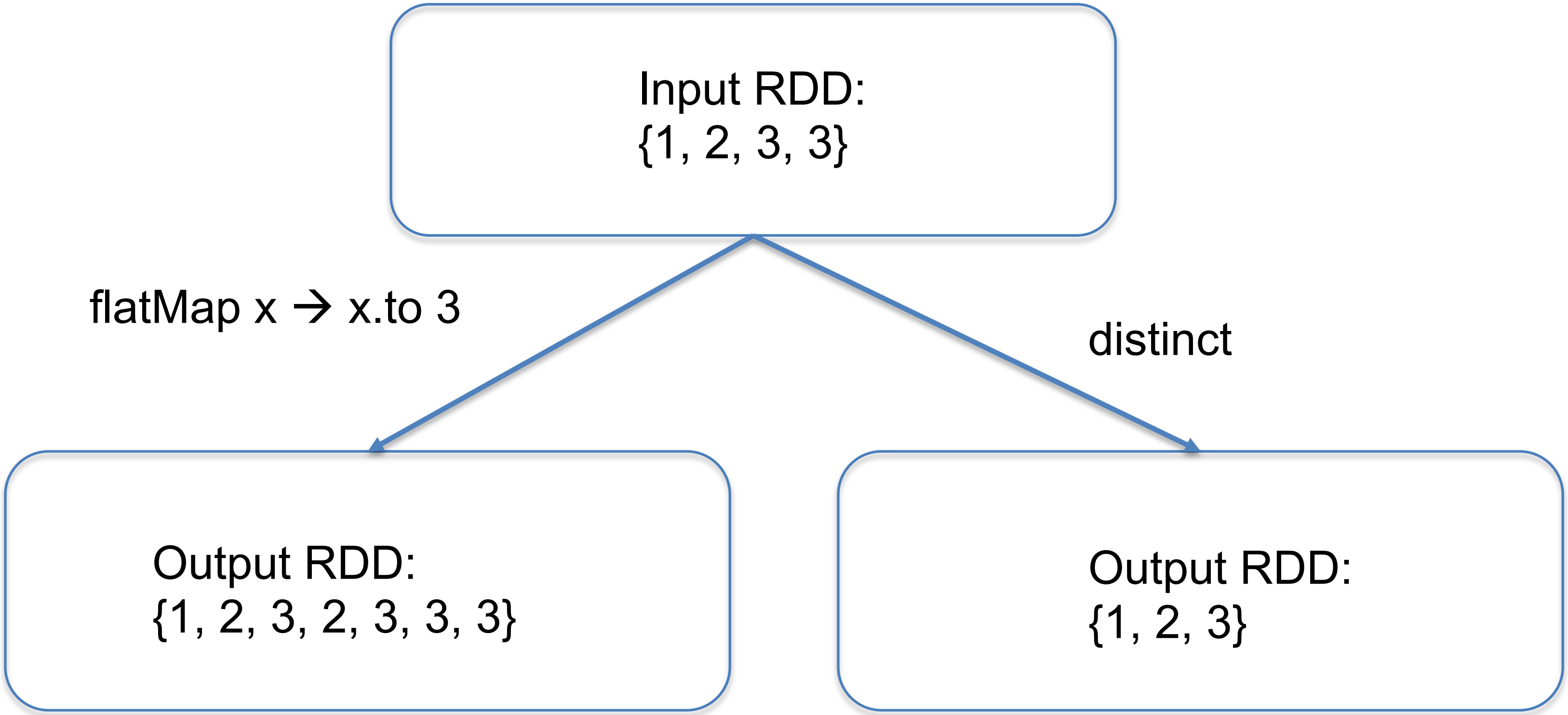
Transformations I

- Transformations (lazily evaluated—no immediate computation)



Transformations I (Cont.)

- Transformations (lazily evaluated—no immediate computation)



Input RDD:
{1, 2, 3, 3}

flatMap x → x.to 3

distinct

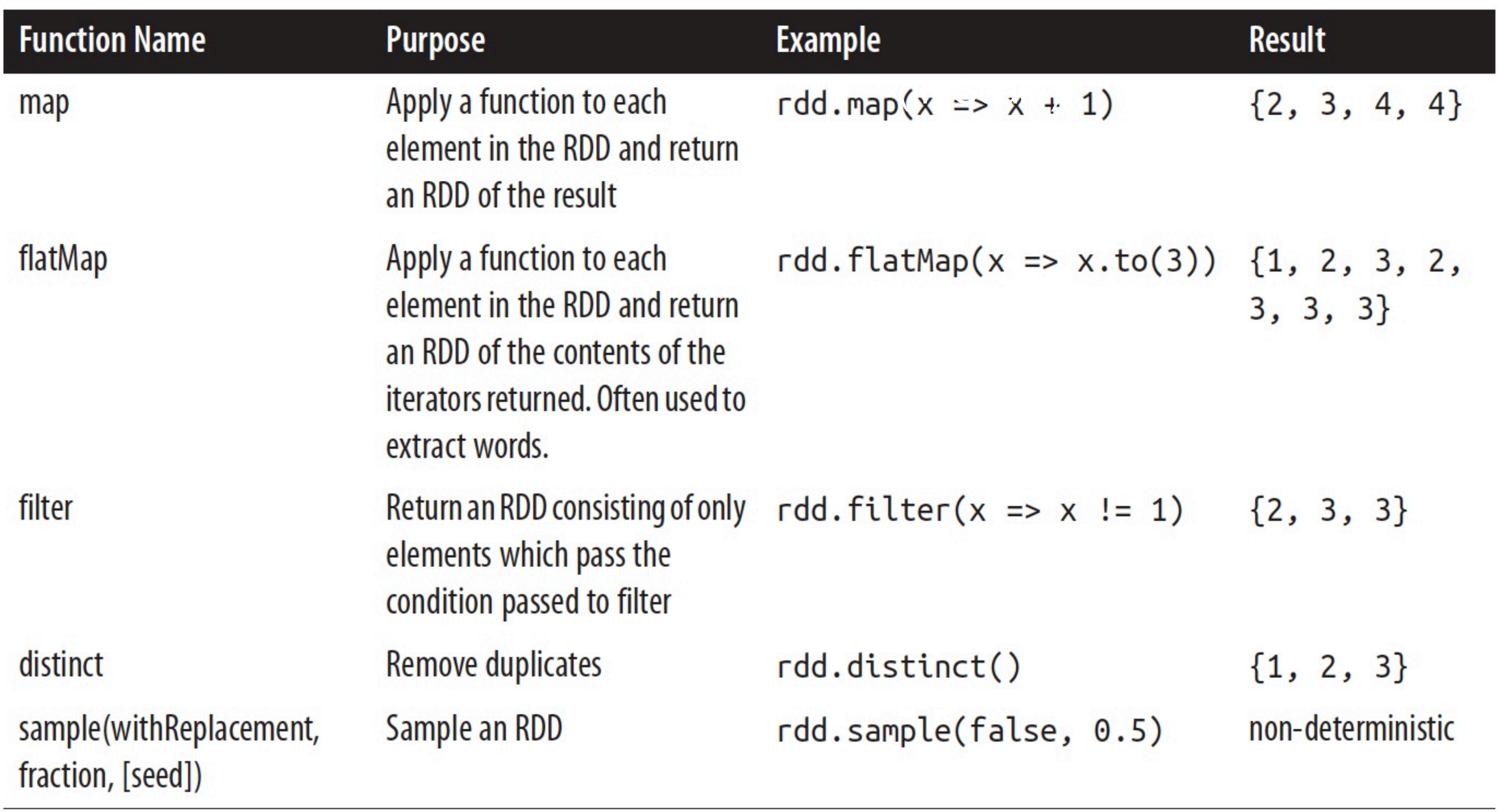
Output RDD:
{1, 2, 3, 2, 3, 3, 3}

Output RDD:
{1, 2, 3}

Transformations I (Cont.)

From Book in Chap 2

- Transformations (lazily evaluated—no immediate computation)



Function Name	Purpose	Example	Result
map	Apply a function to each element in the RDD and return an RDD of the result	`rdd.map(x => x + 1)`	{2, 3, 4, 4}
flatMap	Apply a function to each element in the RDD and return an RDD of the contents of the iterators returned. Often used to extract words.	`rdd.flatMap(x => x.to(3))`	{1, 2, 3, 2, 3, 3, 3}
filter	Return an RDD consisting of only elements which pass the condition passed to filter	`rdd.filter(x => x != 1)`	{2, 3, 3}
distinct	Remove duplicates	`rdd.distinct()`	{1, 2, 3}
sample(withReplacement, fraction, [seed])	Sample an RDD	`rdd.sample(false, 0.5)`	non-deterministic

Use *map* Operation on Numbers

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()

# create a collection
# elements form distributed dataset that can be operated on in parallel
#  Spark set number of partitions automatically based on cluster
# you can set partitions manually by passing  number
# second parameter in parallelize (e.g., sc.parallelize(data, 10))
numbers = sc.parallelize([1, 2, 3, 3])
squared = numbers.map(lambda x: x * x)
```

Use *map* and *first* Operations on Text

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()


lines = sc.parallelize(["hello world", "hi"])
words = lines.map(lambda line: line.split(" "))
words.first()
```

What is the output?

Use *map* and *first* Operations on Text

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()

lines = sc.parallelize(["hello world", "hi"])
words = lines.map(lambda line: line.split(" "))
words.first()
```

```
[['hello', 'world'], ['hi']]
```

Use *flatMap* and *first* Operations on Text

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()


lines = sc.parallelize(["hello world", "hi"])
words = lines.flatMap(lambda line: line.split(" "))
words.first()
```

What is the output?

Use *flatMap* and *first* Operations on Text

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()

lines = sc.parallelize(["hello world", "hi"])
words = lines.flatMap(lambda line: line.split(" "))
words.first()
```

```
['hello', 'world', 'hi']
```

Work on Text with *filter*

In [2]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(‘FoxInSocks.txt’)


def hasWhen(line):
        return ‘when’ in line


whenLines = lines.filter(hasWhen)
```

Work on Text with *filter* (Cont.)

In [3]

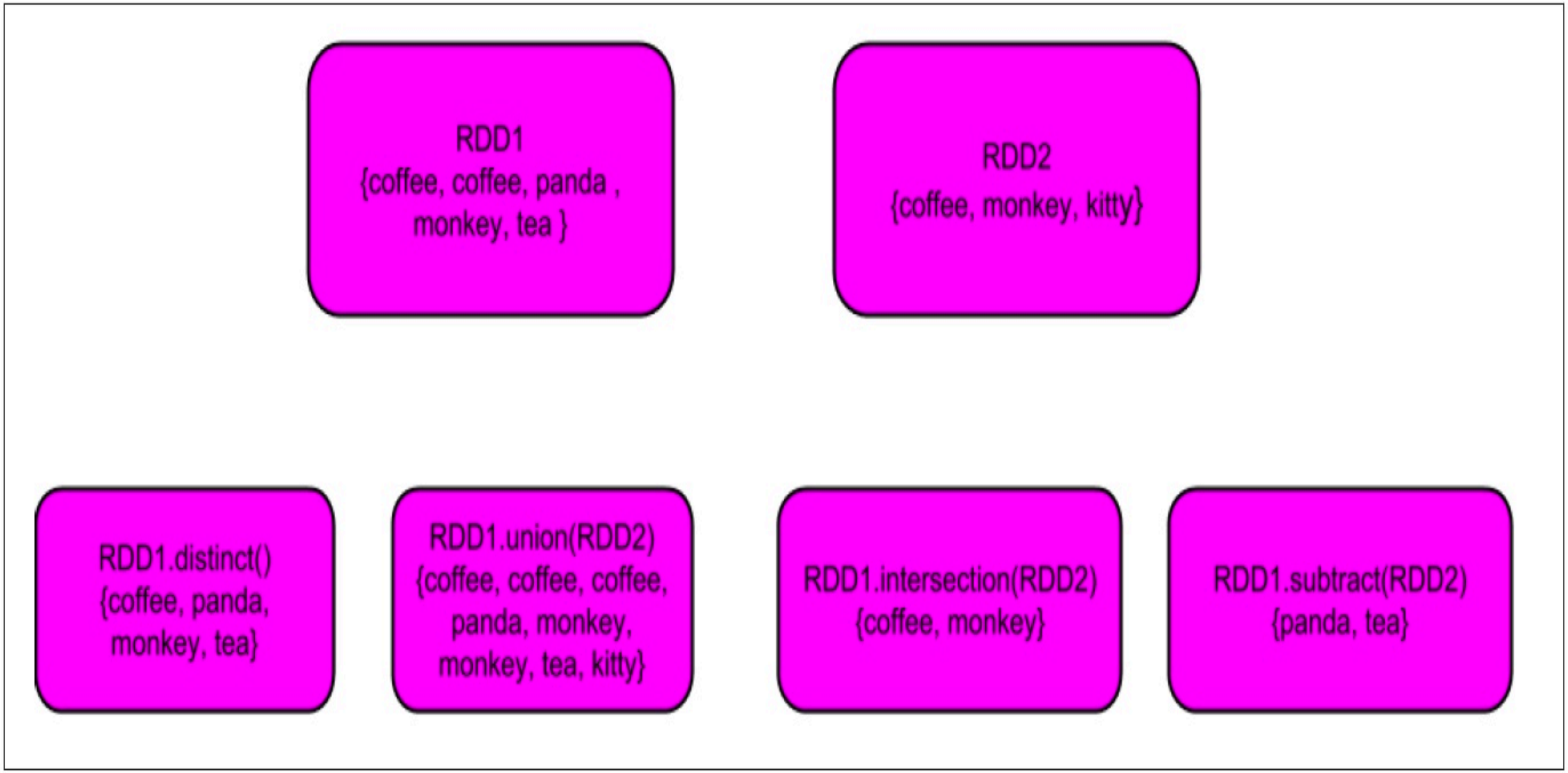
```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(‘FoxInSocks.txt’)

whenLines = lines.filter(lambda line: ‘when’ in line)
```

Transformations II (Cont.)

From Book in Chap 2

- Transformations (lazily evaluated—no immediate computation)



RDD1
{coffee, coffee, panda , monkey, tea }

RDD2
{coffee, monkey, kitty}

RDD1.distinct()
{coffee, panda, monkey, tea}

RDD1.union(RDD2)
{coffee, coffee, coffee, panda, monkey, monkey, tea, kitty}

RDD1.intersection(RDD2)
{coffee, monkey}

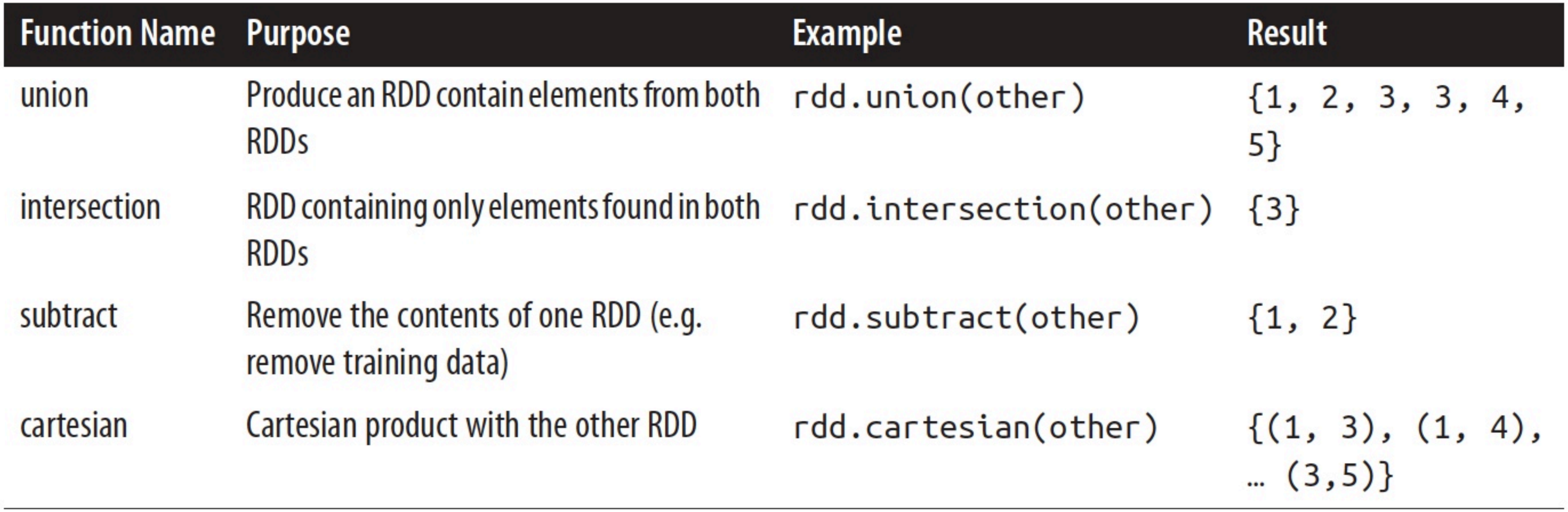
RDD1.subtract(RDD2)
{panda, tea}

Transformations II (Cont.)

From Book in Chap 2

- Transformations (lazily evaluated—no immediate computation)

RDDs for the examples in the table:
rdd = {1, 2, 3}
other = {3, 4, 5}

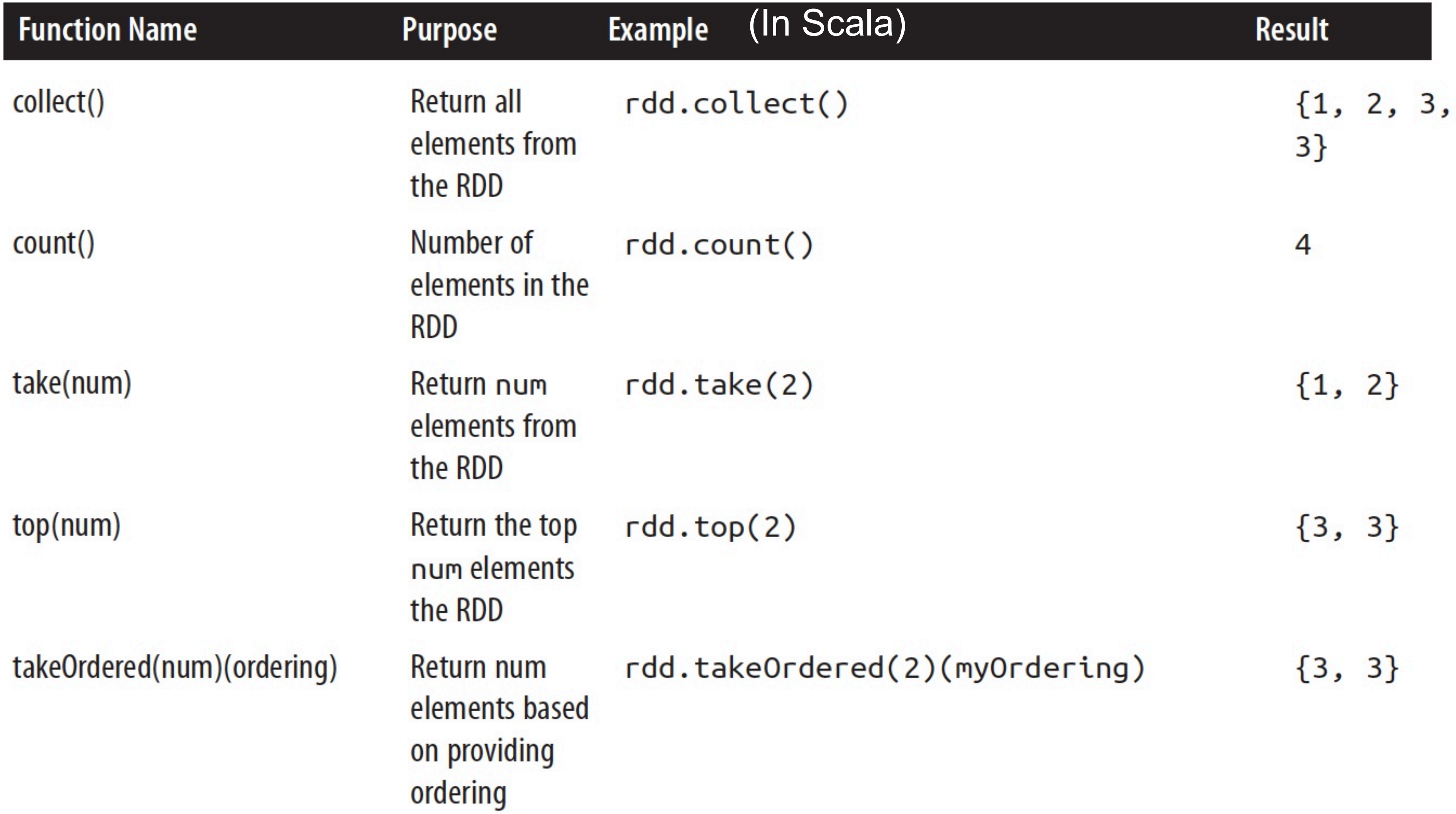


Function Name	Purpose	Example	Result
union	Produce an RDD contain elements from both RDDs	`rdd.union(other)`	{1, 2, 3, 3, 4, 5}
intersection	RDD containing only elements found in both RDDs	`rdd.intersection(other)`	{3}
subtract	Remove the contents of one RDD (e.g. remove training data)	`rdd.subtract(other)`	{1, 2}
cartesian	Cartesian product with the other RDD	`rdd.cartesian(other)`	{(1, 3), (1, 4), … (3,5)}

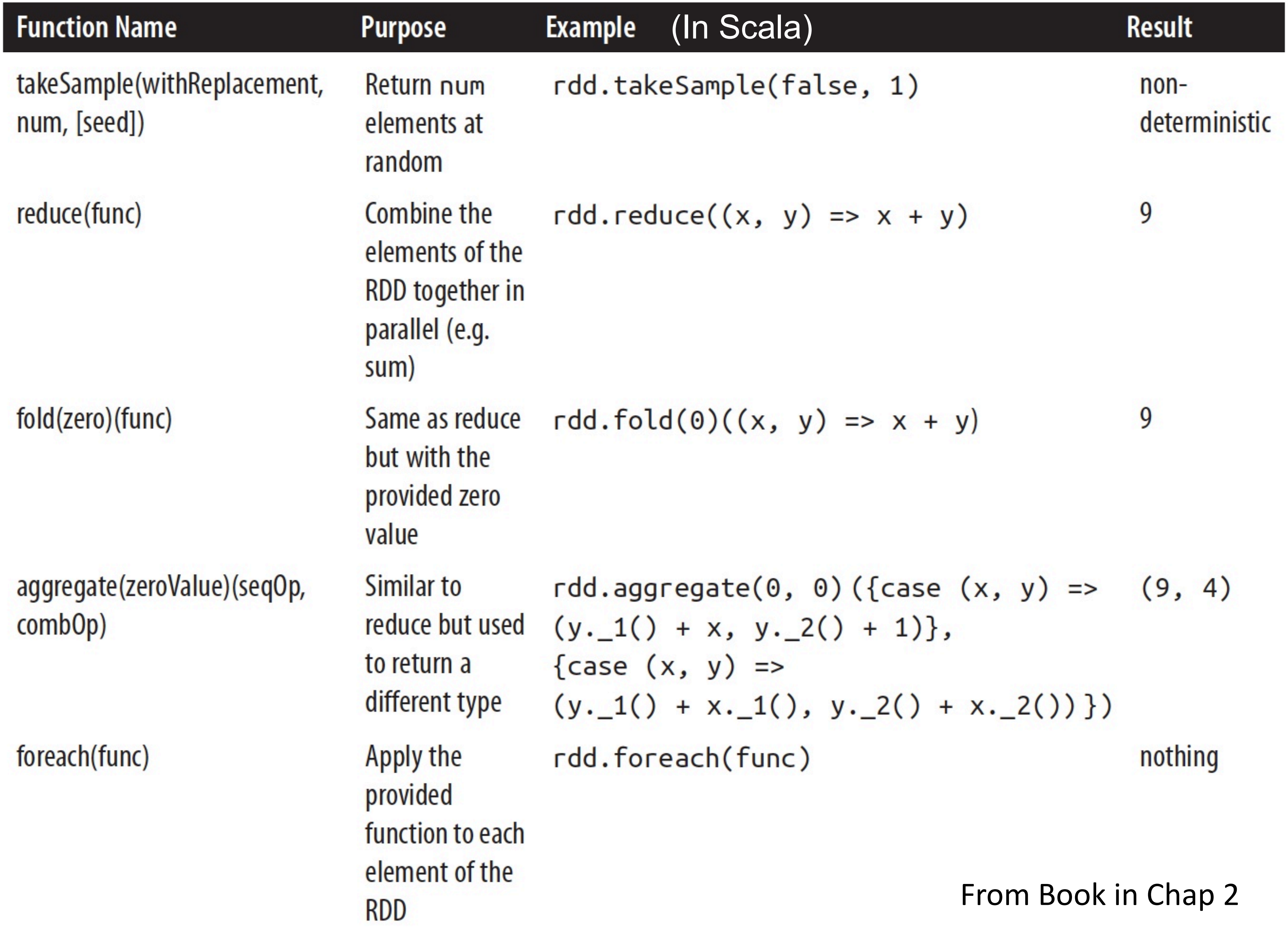
Actions

From Book in Chap 2

RDD for the examples in the table:
rdd = {1, 2, 3, 3}



Function Name	Purpose	Example (In Scala)	Result
collect()	Return all elements from the RDD	`rdd.collect()`	`{1, 2, 3, 3}`
count()	Number of elements in the RDD	`rdd.count()`	4
take(num)	Return `num` elements from the RDD	`rdd.take(2)`	`{1, 2}`
top(num)	Return the top `num` elements the RDD	`rdd.top(2)`	`{3, 3}`
takeOrdered(num)(ordering)	Return num elements based on providing ordering	`rdd.takeOrdered(2)(myOrdering)`	`{3, 3}`



Function Name	Purpose	Example (In Scala)	Result
takeSample(withReplacement, num, [seed])	Return `num` elements at random	`rdd.takeSample(false, 1)`	non-deterministic
reduce(func)	Combine the elements of the RDD together in parallel (e.g. sum)	`rdd.reduce((x, y) => x + y)`	9
fold(zero)(func)	Same as reduce but with the provided zero value	`rdd.fold(0)((x, y) => x + y)`	9
aggregate(zeroValue)(seqOp, combOp)	Similar to reduce but used to return a different type	`rdd.aggregate(0, 0)({case (x, y) => (y._1() + x, y._2() + 1)}, {case (x, y) => (y._1() + x._1(), y._2() + x._2())})`	(9, 4)
foreach(func)	Apply the provided function to each element of the RDD	`rdd.foreach(func)`	nothing

From Book in Chap 2

REVIEW:
Use *map* Operation on Numbers

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()

# create a collection
# elements form distributed dataset that can be operated on in parallel
#  Spark set number of partitions automatically based on cluster
# you can set partitions manually by passing  number
# second parameter in parallelize (e.g., sc.parallelize(data, 10))
numbers = sc.parallelize([1, 2, 3, 3])
squared = numbers.map(lambda x: x * x)
squared.collect()
```

```
[1, 4, 9, 9]
```

REVIEW:
Use *flatmap* Operation on Numbers

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()


lines = sc.parallelize(["hello world", "hi"])
words = lines.flatMap(lambda line: line.split(" "))
words.collect()
```

```
['hello', 'world', 'hi']
```

REVIEW:
Work on Text with *filter*

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(‘FoxInSocks.txt’)

whenLines = lines.filter(lambda line: ‘when’ in line)
whenLines.collect()
```

```
['And when they battle in a puddle, ', 'AND when tweetle beetles
battle with paddles in a puddle, ']
```

Use *map* and *collect* Operations on Numbers

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()


numbers = sc.parallelize([1, 2, 3, 4])
squared = numbers.map(lambda x: x * x).collect()
for num in squared:
    print (num)
```

What is the output?

Create Key-Values in RDDs (I)

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(‘FoxInSocks.txt’)


pairs= lines.map(lambda x: (x.split(" ")[0], x))
```

Create Key-Values in RDDs (I)

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(‘FoxInSocks.txt’)


pairs= lines.map(lambda x: (x.split(" ")[0], x))
```

```
<When, When tweetle beetles fight,>
<it’s, it’s called a tweetle beetle battle.>
<And, And when they battle in a puddle,>
….
```

Create Key-Values in RDDs (II)

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(”FoxInSocks.txt")

pairs= lines.map(lambda x: (x.split(" ")[0], x))
results = pairs.filter(lambda x: len(x[1]) < 28)
```

Create Key-Values in RDDs

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(”FoxInSocks.txt")


pairs= lines.map(lambda x: (x.split(" ")[0], x))
results = pairs.filter(lambda x: len(x[1]) < 28)


                <When, When tweetle beetles fight,>
                …
```

Create Key-Values in RDDs

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(’FoxInSocks.txt’)


words = lines.flatMap(lambda x: x.split(" "))
```

Create Key-Values in RDDs

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(’FoxInSocks.txt’)

words = lines.flatMap(lambda x: x.split(" "))
pairs= words.map(lambda x: (x, 1))
```

Create Key-Values in RDDs

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(‘FoxInSocks.txt’)


words = lines.flatMap(lambda x: x.split(" "))
pairs= words.map(lambda x: (x, 1))
```

```
<“When”, 1> <“tweetle”, 1> <“beetles”,1> <“fight,”, 1>
…
```

Create Key-Values in RDDs

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(”FoxInSocks.txt")

words = lines.flatMap(lambda x: x.split(" "))
pairs= words.map(lambda x: (x, 1))
results = pairs.reduceByKey(lambda x, y: x + y)
```

Create Key-Values in RDDs

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(”FoxInSocks.txt")

words = lines.flatMap(lambda x: x.split(" "))
pairs= words.map(lambda x: (x, 1))
results = pairs.reduceByKey(lambda x, y: x + y)

## TRY to print the results
print(results)
```

Create Key-Values in RDDs

In [3]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()
lines = sc.textFile(”FoxInSocks.txt")

words = lines.flatMap(lambda x: x.split(" "))
pairs= words.map(lambda x: (x, 1))
results = pairs.reduceByKey(lambda x, y: x + y)

## TRY to print the results
print(results)
ERRORS!!!
```

The Special Case of *ReduceByKey*

- Reduce takes a function and use it to combine values
- ReduceByKey takes a function and use it to combine values
- BUT ReduceByKey **DO NOT** implemented as an action
  - Return a new RDD consisting of each key and the reduced value for that key

WHY?

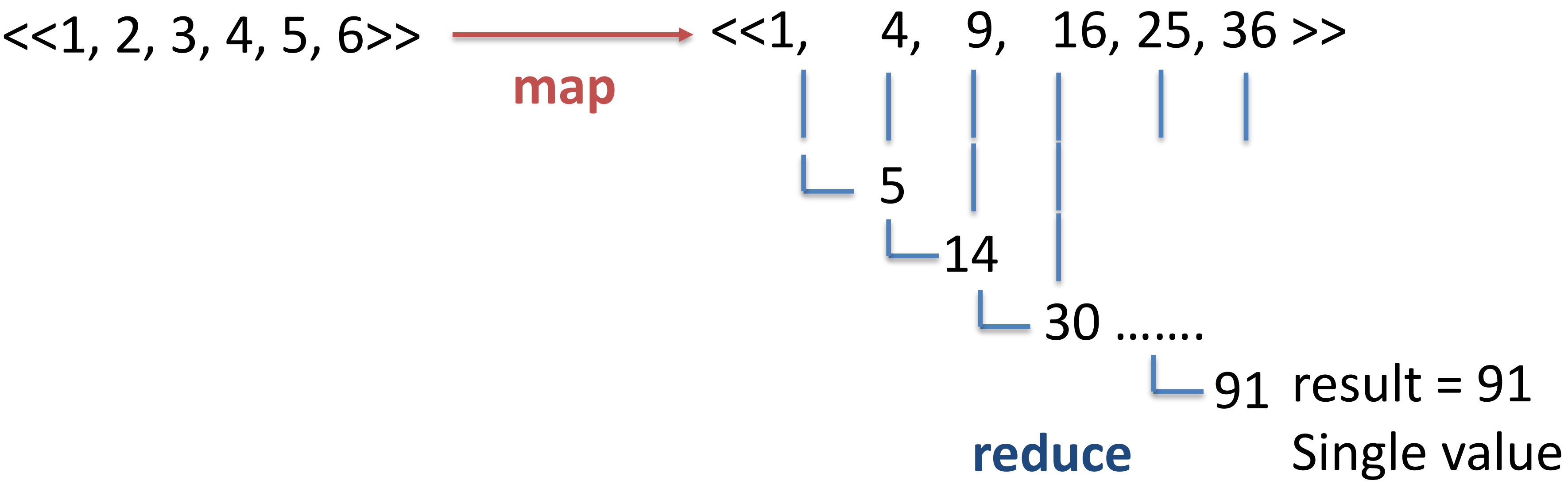
The Special Case of *ReduceByKey*

- Reduce takes a function and use it to combine values
- ReduceByKey takes a function and use it to combine values
- BUT ReduceByKey **DO NOT** implemented as an action
  - Return a new RDD consisting of each key and the reduced value for that key

WHY?

- *reduceByKey* runs several parallel reduce operations:
  - one for each key in the dataset
  - each operation combines values together which have the same key.
- Datasets can have very large numbers of keys!!!!

Use *reduce* Operation on Numbers (I)



<<1, 2, 3, 4, 5, 6>>

map

<<1, 4, 9, 16, 25, 36 >>

5

14

30 …….

91 result = 91

reduce

Single value

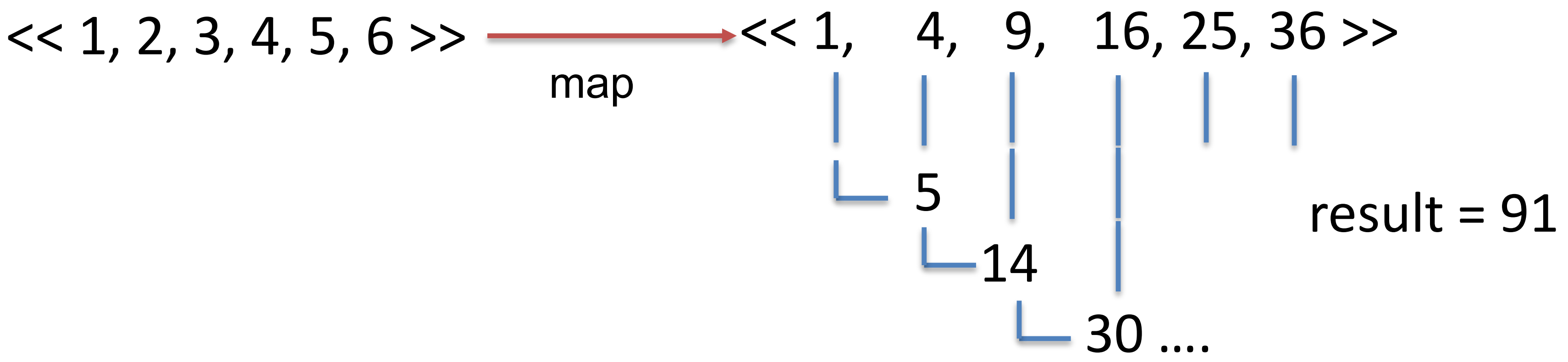
Note: Spark does NOT guarantee the order of operands

Use *reduce* Operation on Numbers I

In [1]

```
from pyspark import SparkContext
sc = SparkContext.getOrCreate()


numbers = sc.parallelize([1, 2, 3, 4, 5, 6])
squared = numbers.map(lambda x: x * x)
result = squared.reduce(lambda x, y: x+y) # single value
```



<< 1, 2, 3, 4, 5, 6 >>

map

<< 1, 4, 9, 16, 25, 36 >>

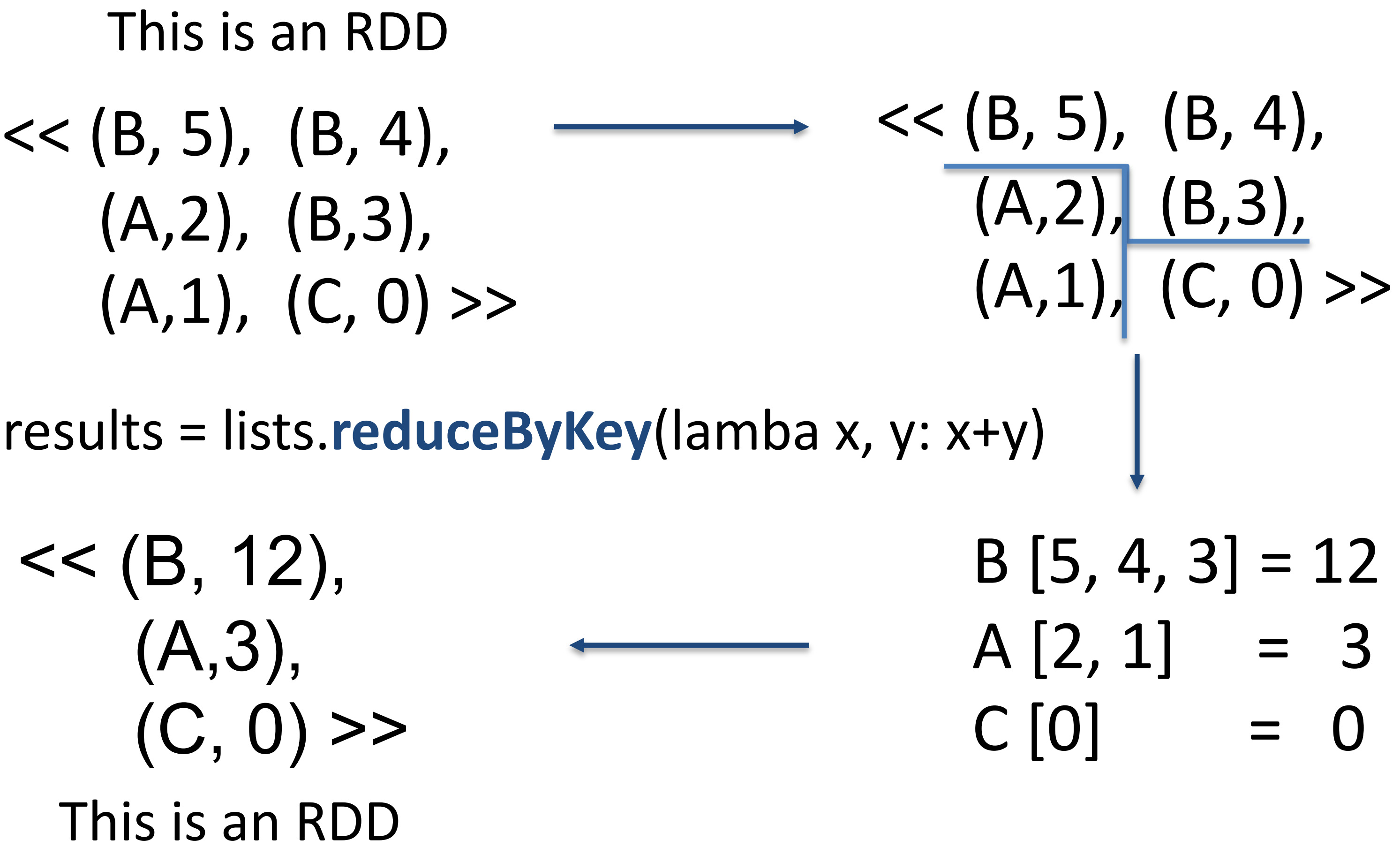
5

14

30 ….

result = 91

Use *reduce* Operation on Numbers I



This is an RDD

<< (B, 5), (B, 4),
(A,2), (B,3),
(A,1), (C, 0) >>

<< (B, 5), (B, 4),
(A,2), (B,3),
(A,1), (C, 0) >>

```
results = lists.reduceByKey(lamba x, y: x+y)
```

B [5, 4, 3] = 12
A [2, 1] = 3
C [0] = 0

<< (B, 12),
(A,3),
(C, 0) >>

This is an RDD

Assignment 4

Assignment 4 - CS 594 / CS 690

- Python has map and reduce functions:
  - Do NOT take advantage of parallel processing (i.e., they are sequential)
  - Define three methods mapSequential
  - reduceSequential
  - reduceByKeySequential
- Extend Python's map and reduce functions to act like those in *Apache Spark*

Deadline: ***October 1 - 8AM ET***

Assignment 4 - CS 690

- Read paper *“Spark: Cluster Computing with Working Sets”* Matei Zaharia, Mosharaf Chowdhury, Michael J. Franklin, Scott Shenker, Ion Stoica University of California, Berkeley
- Submit summary:
  - Add summary to your private GitHub repository
  - Use the template provided
  - Follow mandatory requirements for your summary

Deadline: ***October 8 - 8AM ET***

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