Opaque: An Oblivious and Encrypted Distributed Analytics Platform

[NSDI'17]

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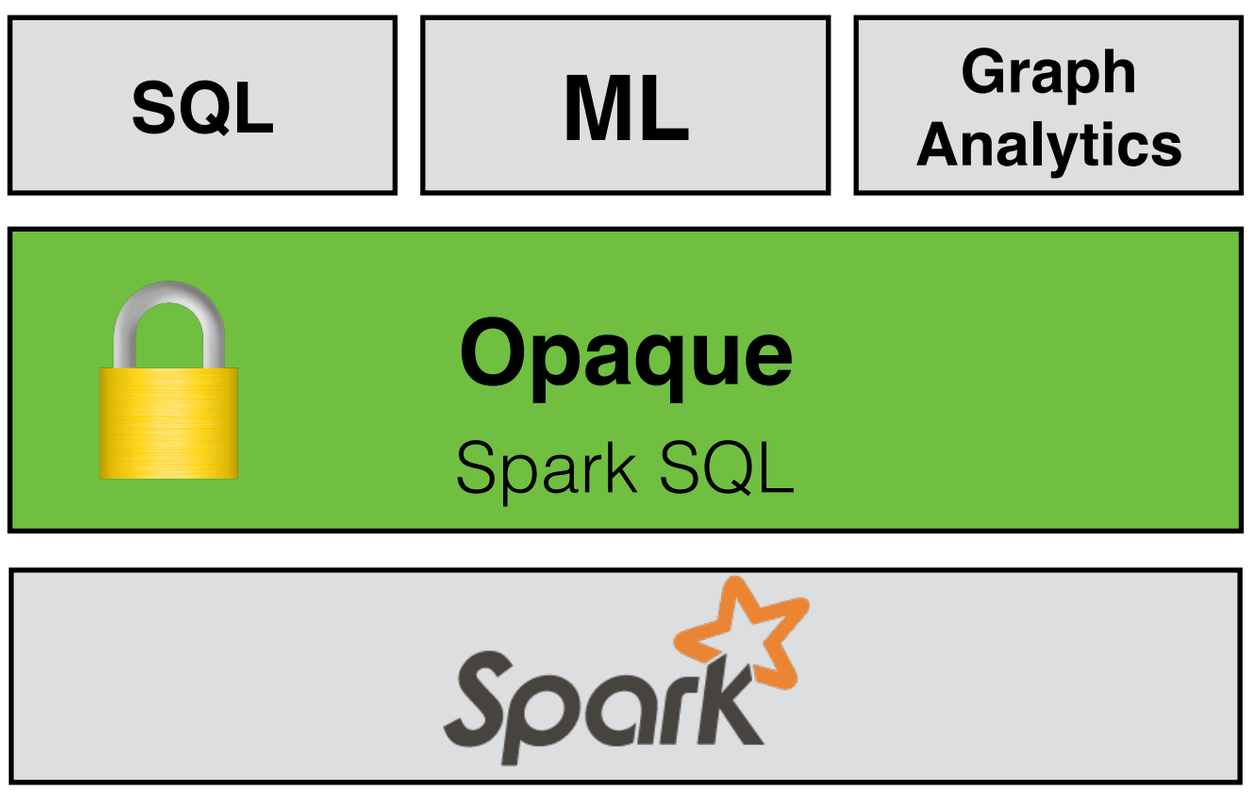
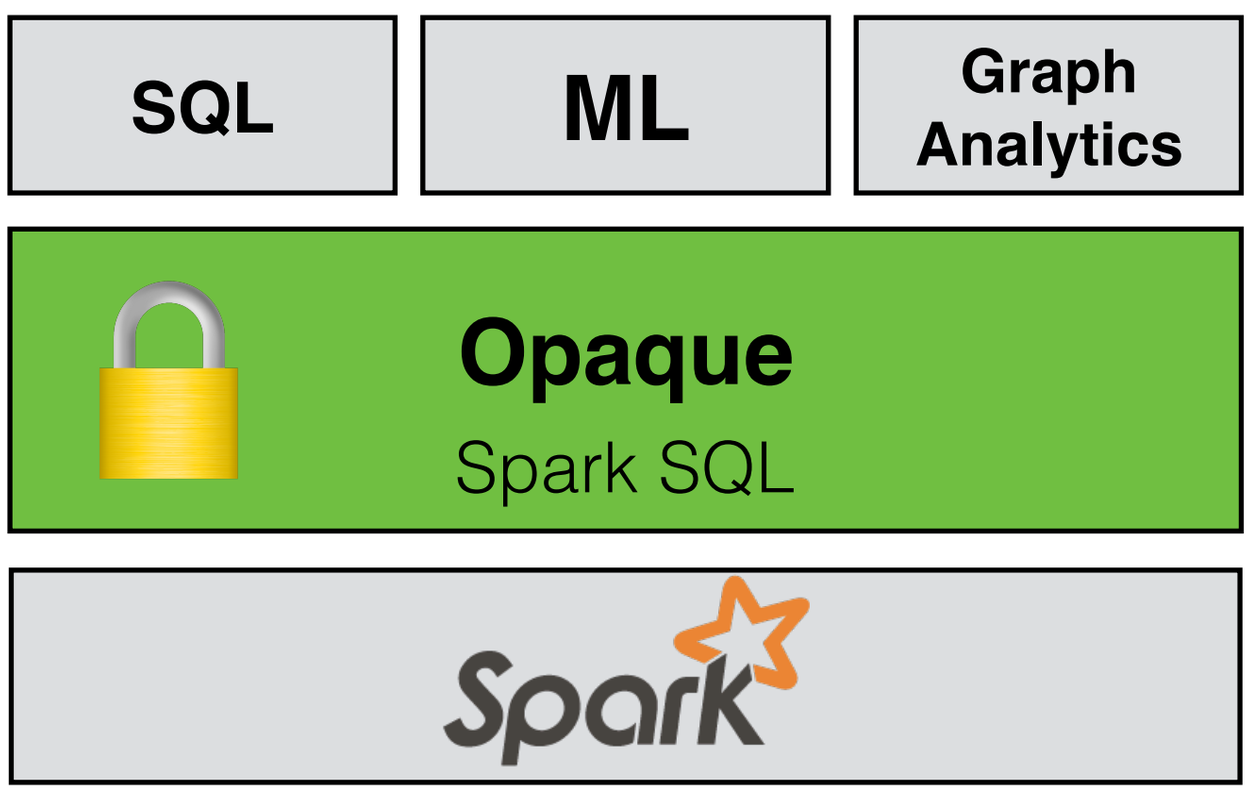
UC Berkeley

Opaque*: oblivious and encrypted distributed analytics platform



* Oblivious Platform for Analytic QUEries

Opaque*: oblivious and encrypted distributed analytics platform

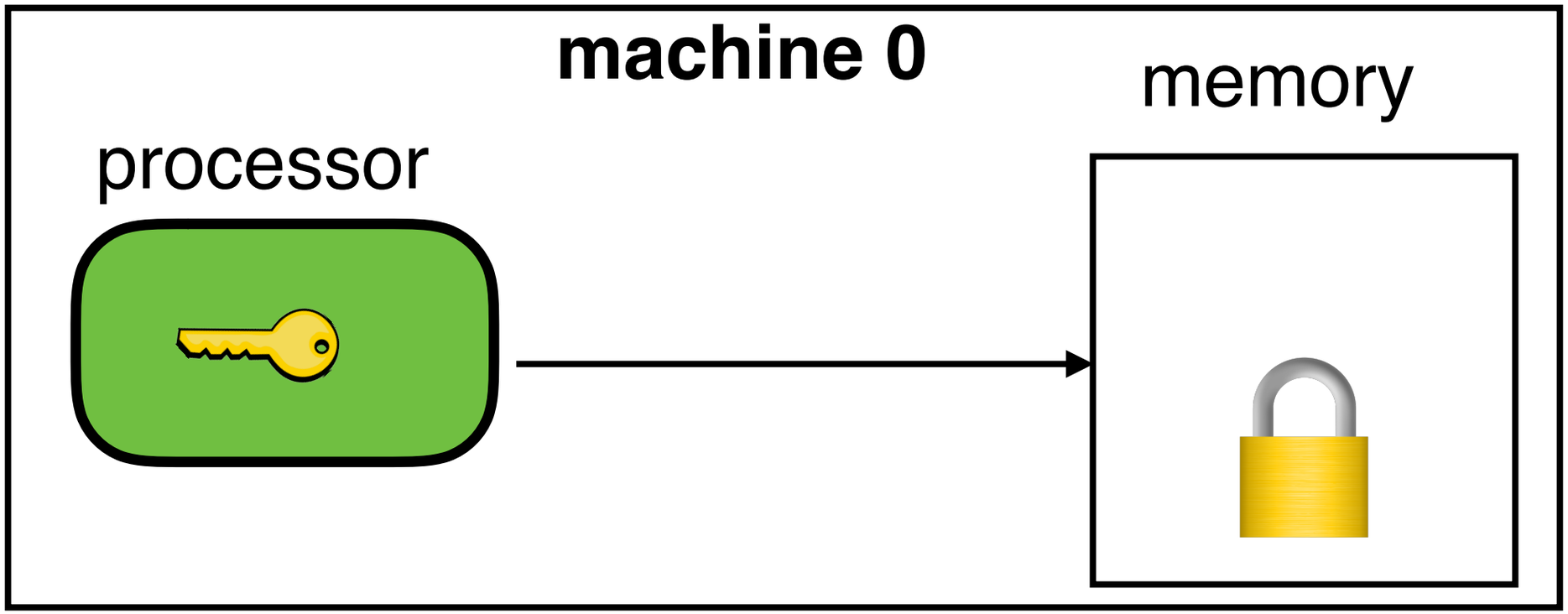


Leverages hardware enclaves (Intel SGX)

* Oblivious Platform for Analytic QUEries

Access patterns leakage

Access patterns



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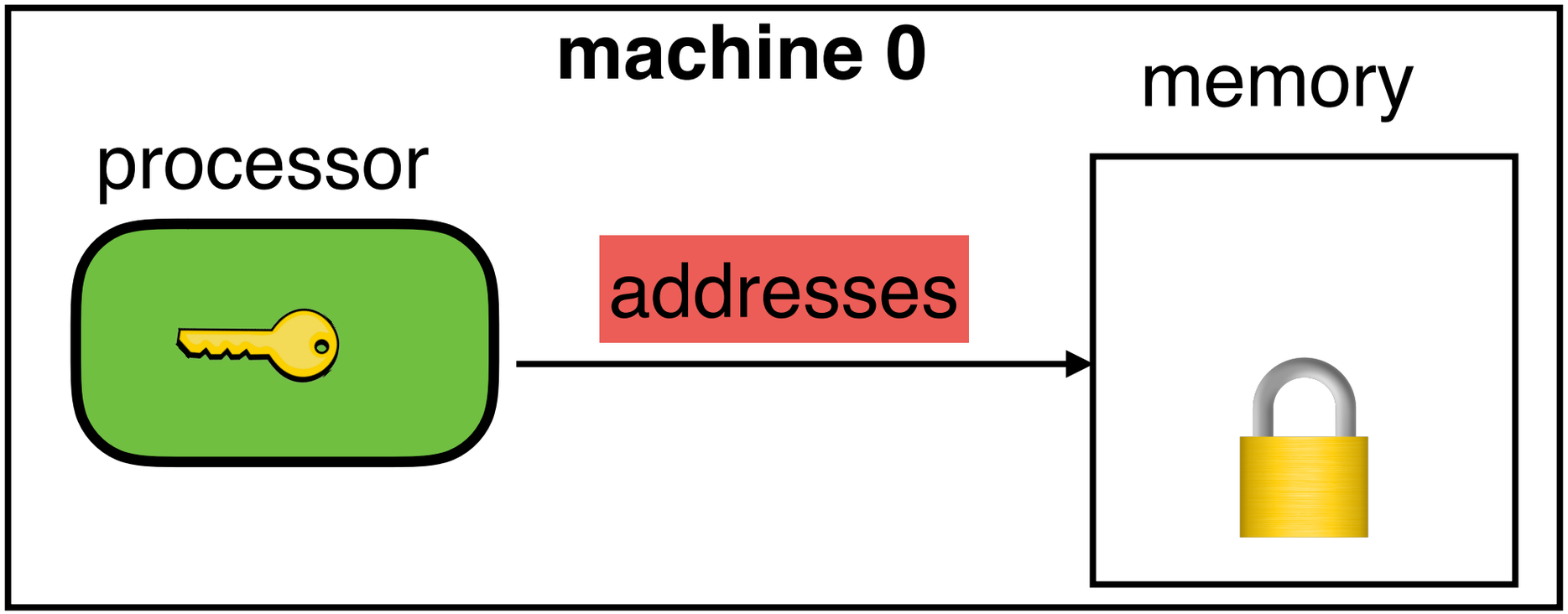

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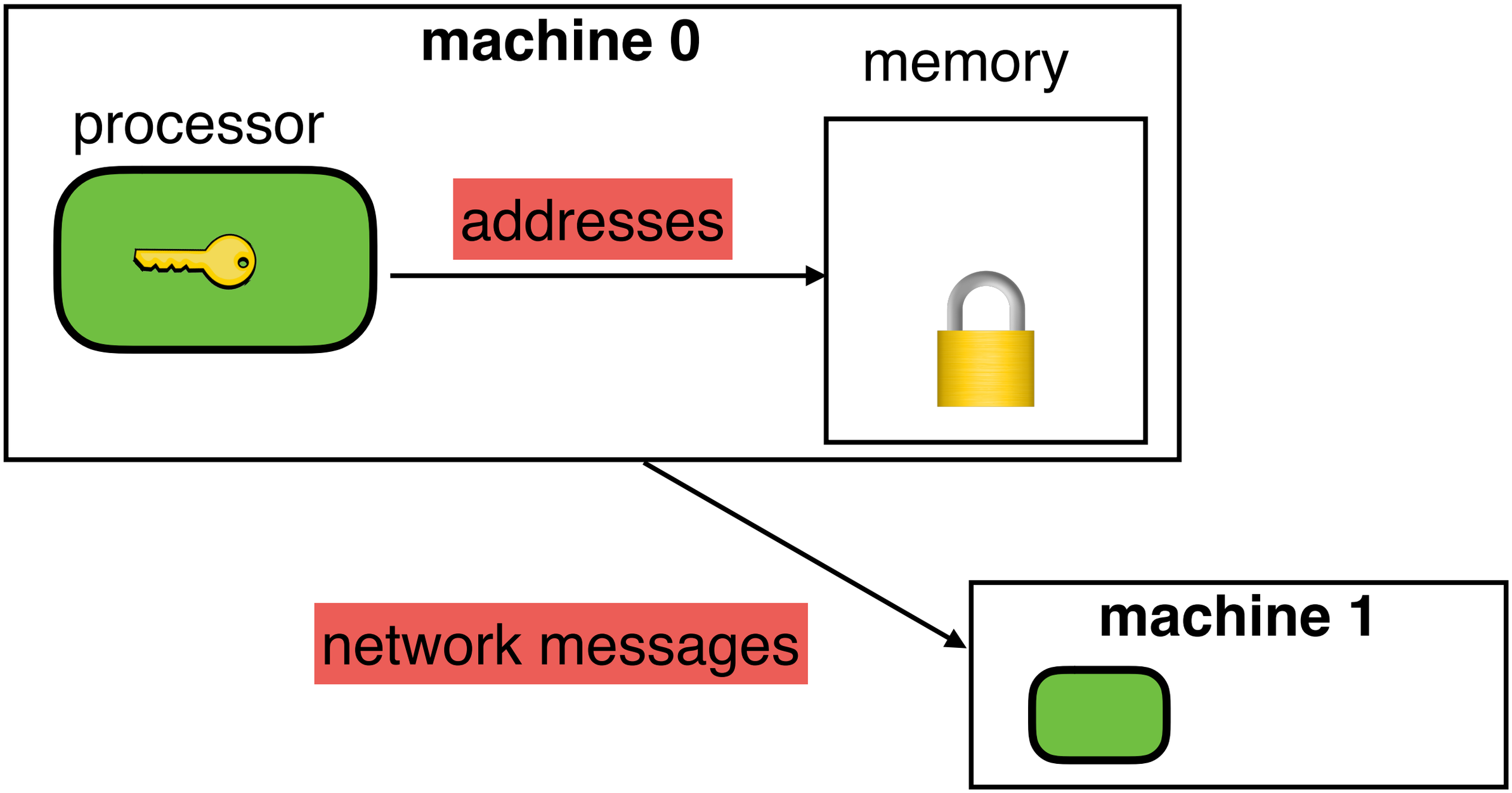

Example: network access pattern leakage

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ID	Name	Age	Disease
12809	Amanda D. Edwards	40	Diabetes
29489	Robert R. McGowan	56	Diabetes
13744	Kimberly R. Seay	51	Cancer
18740	Dennis G. Bates	32	Diabetes
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SELECT count(*) FROM medical
GROUP BY disease

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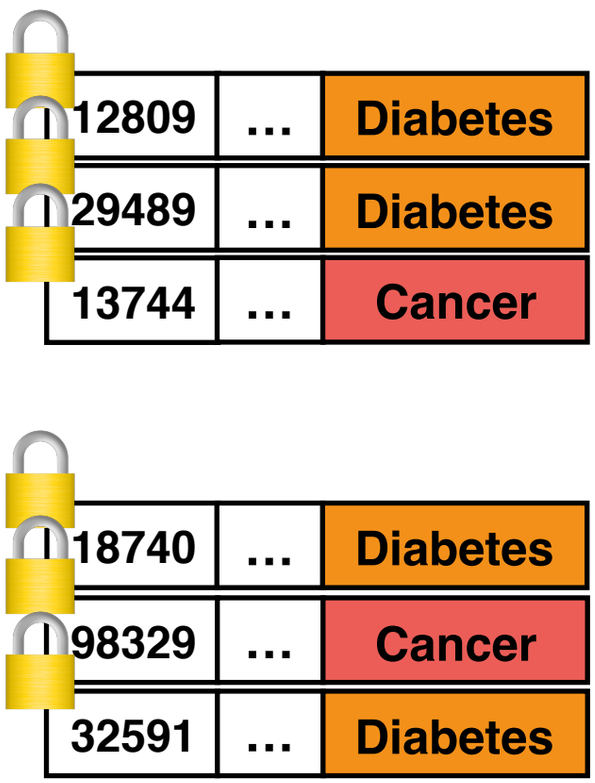

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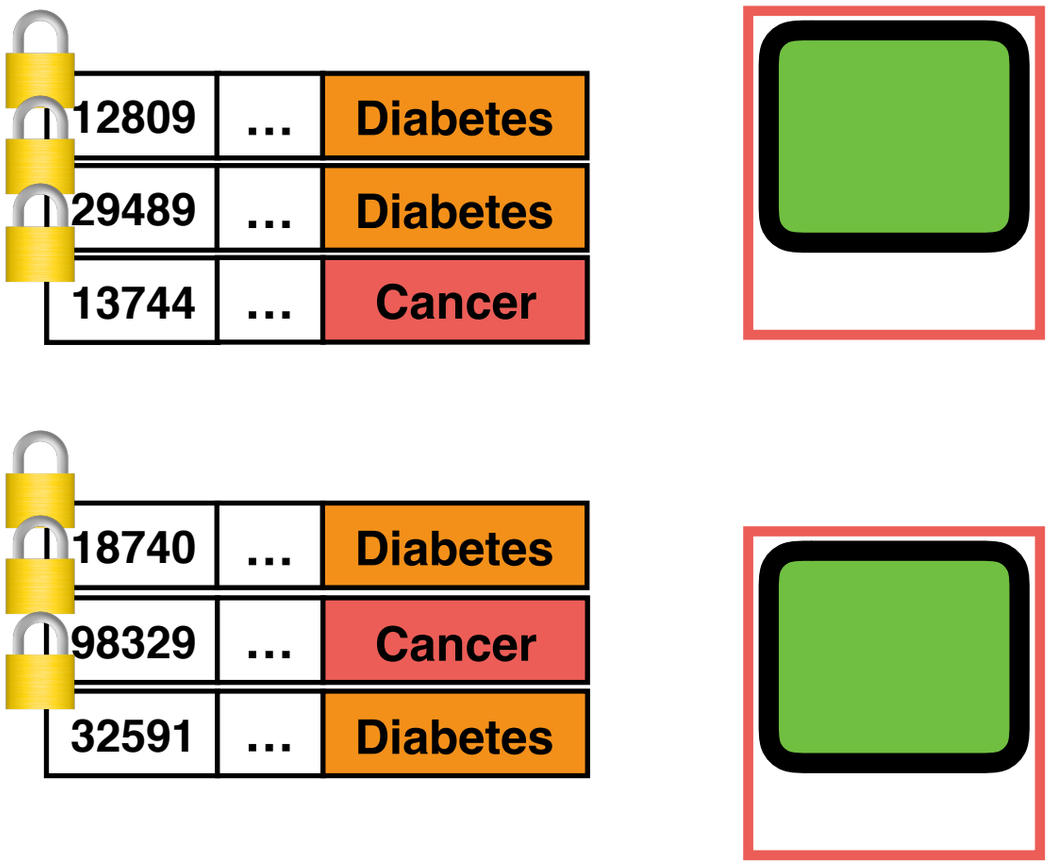

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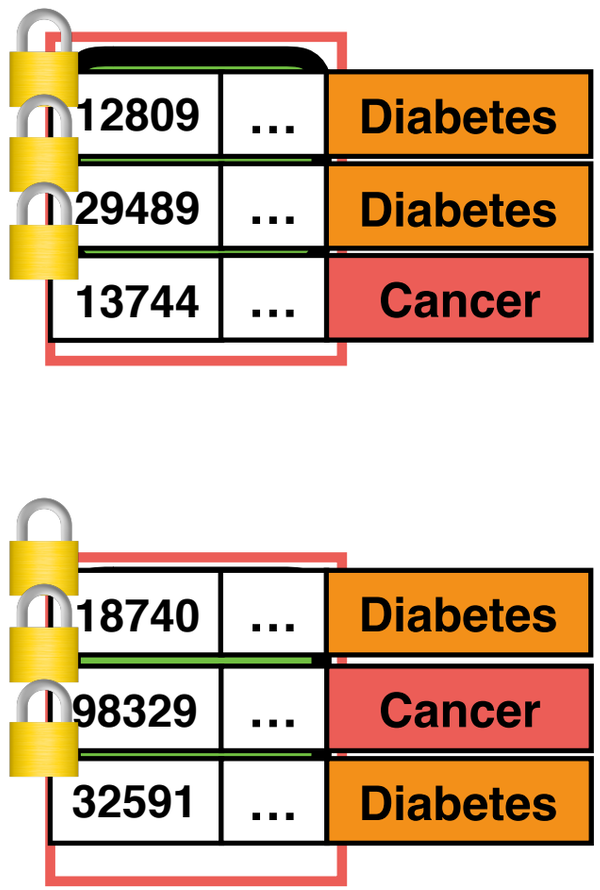

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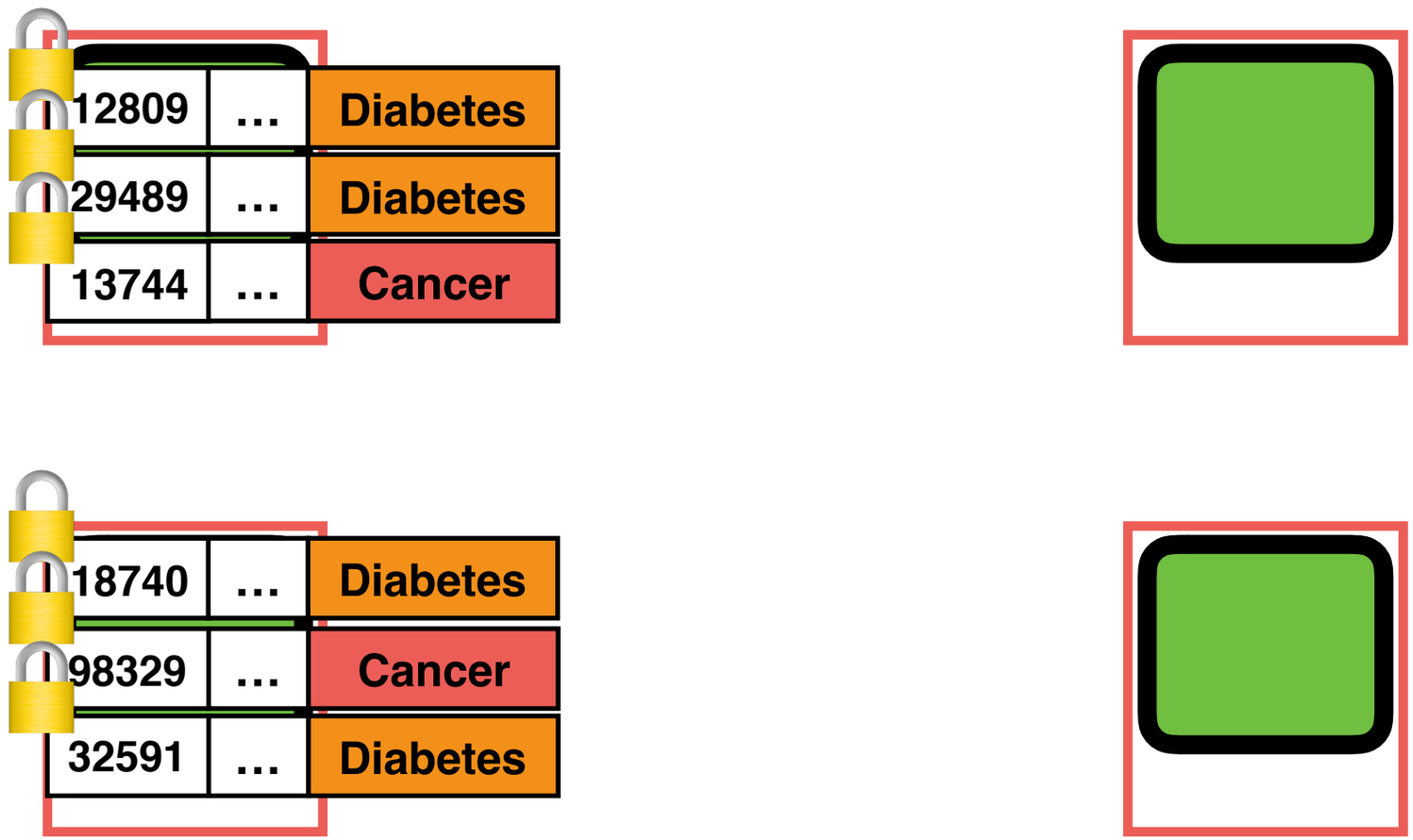

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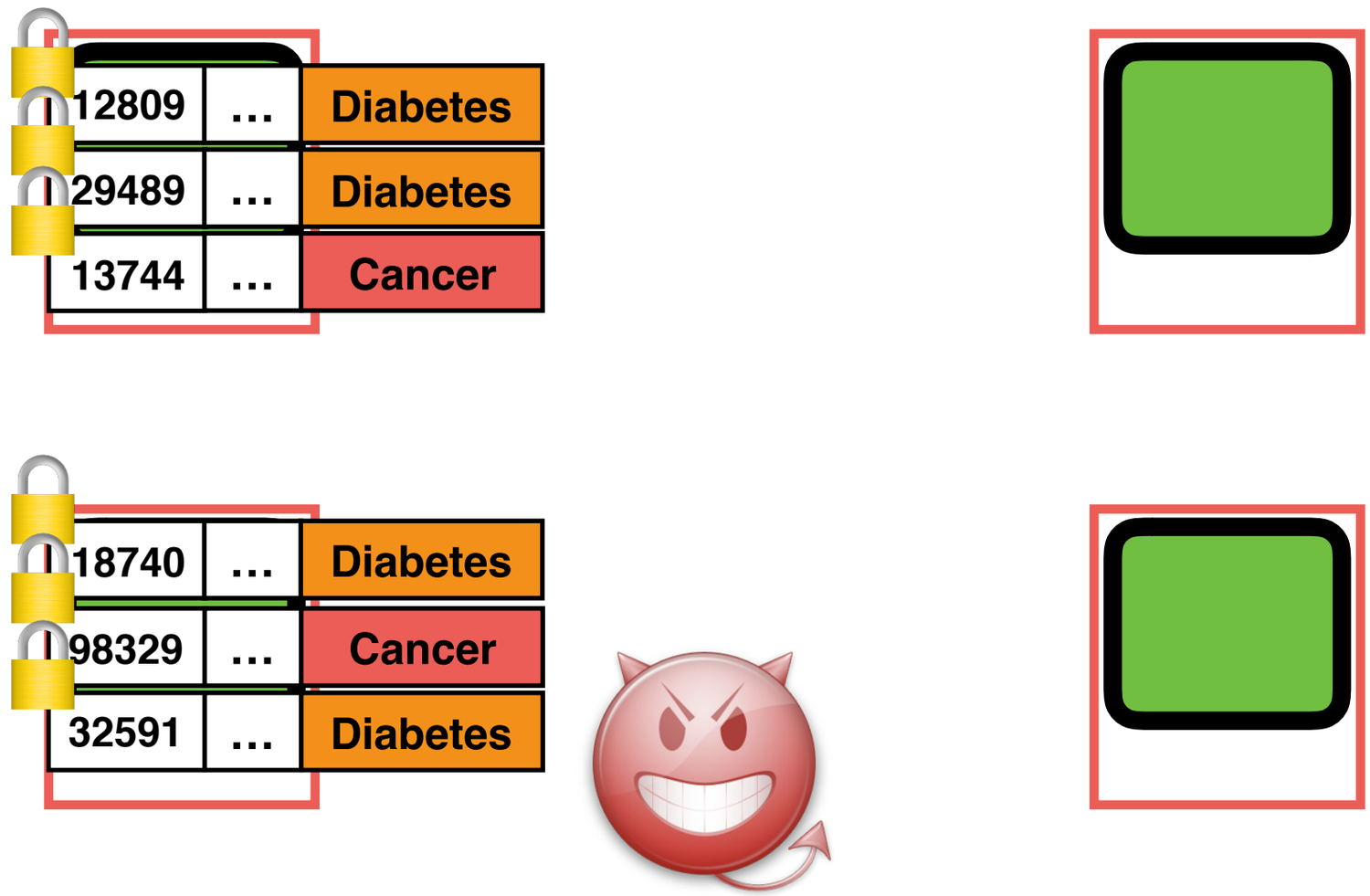

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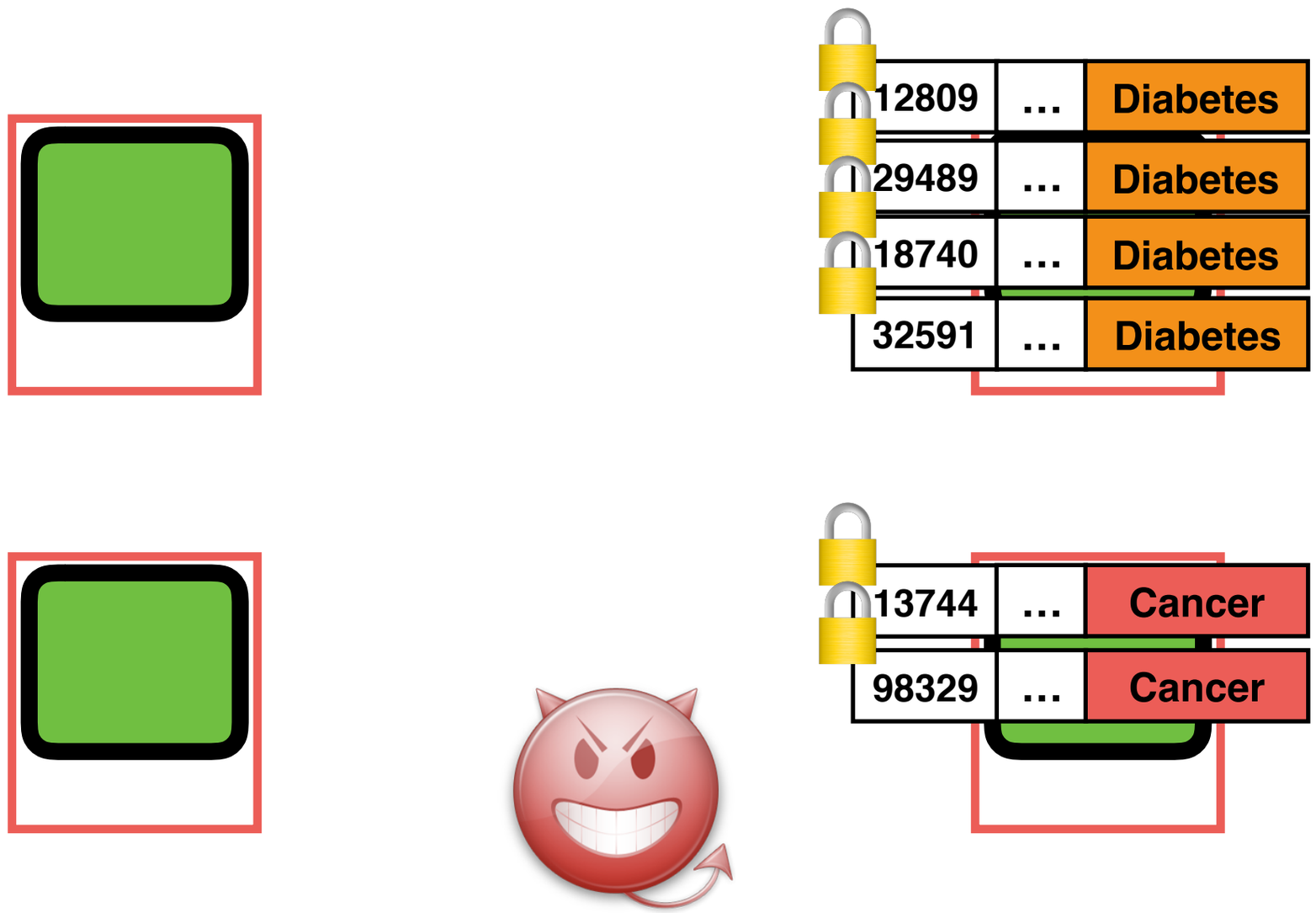

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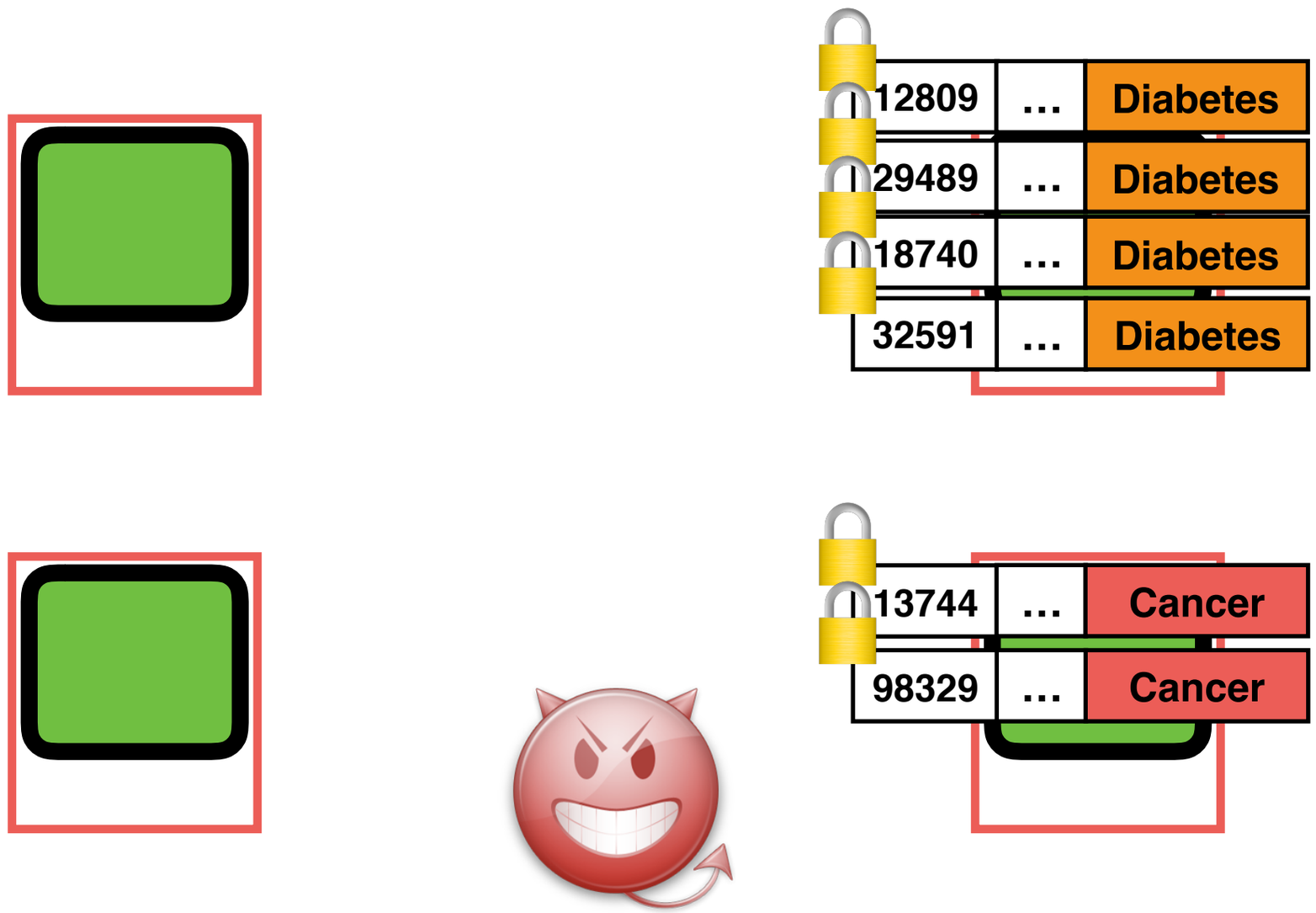

Public information:
Diabetes twice as common as cancer

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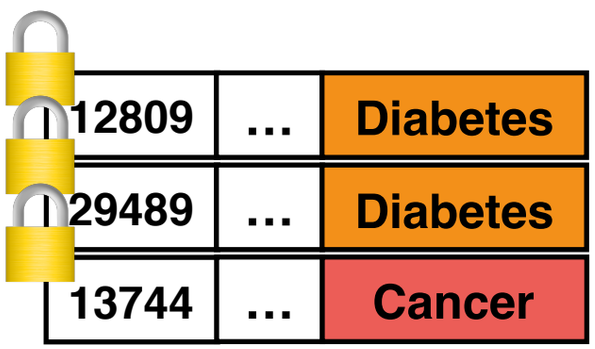

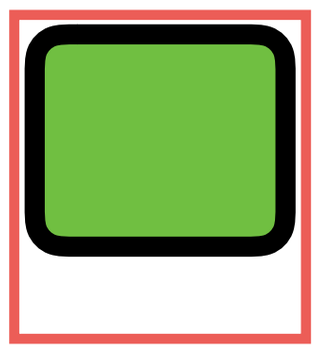

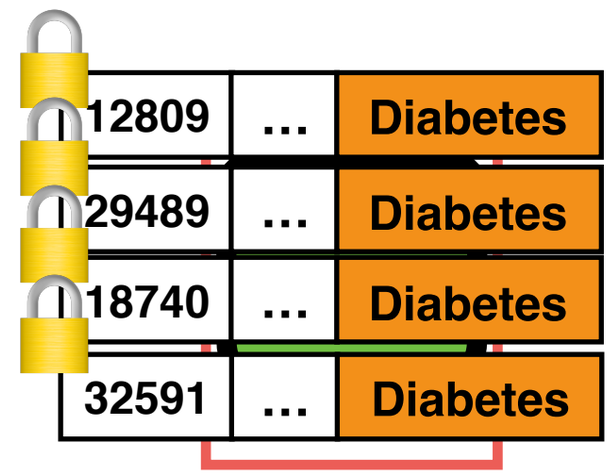

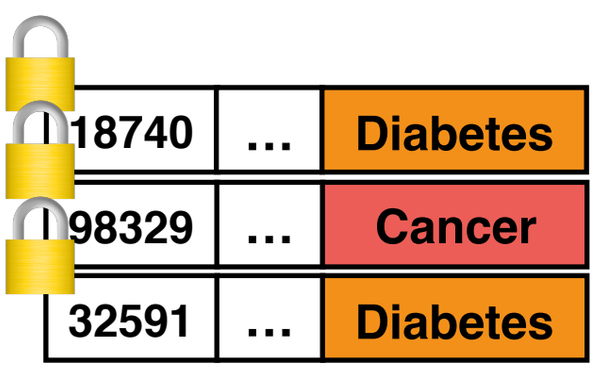

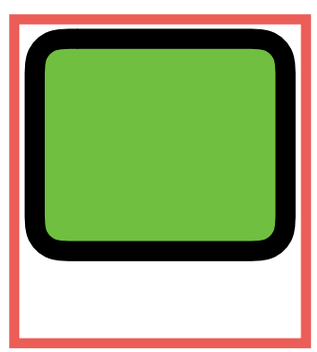

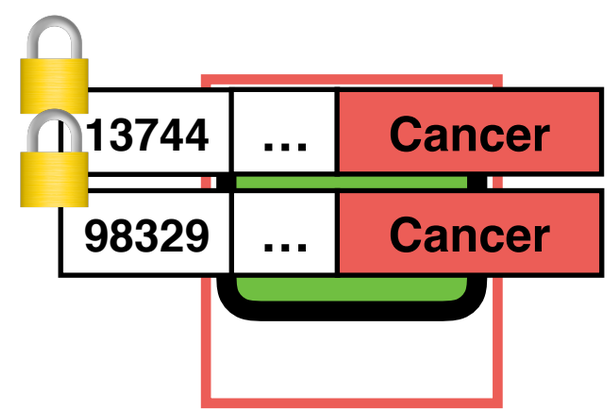

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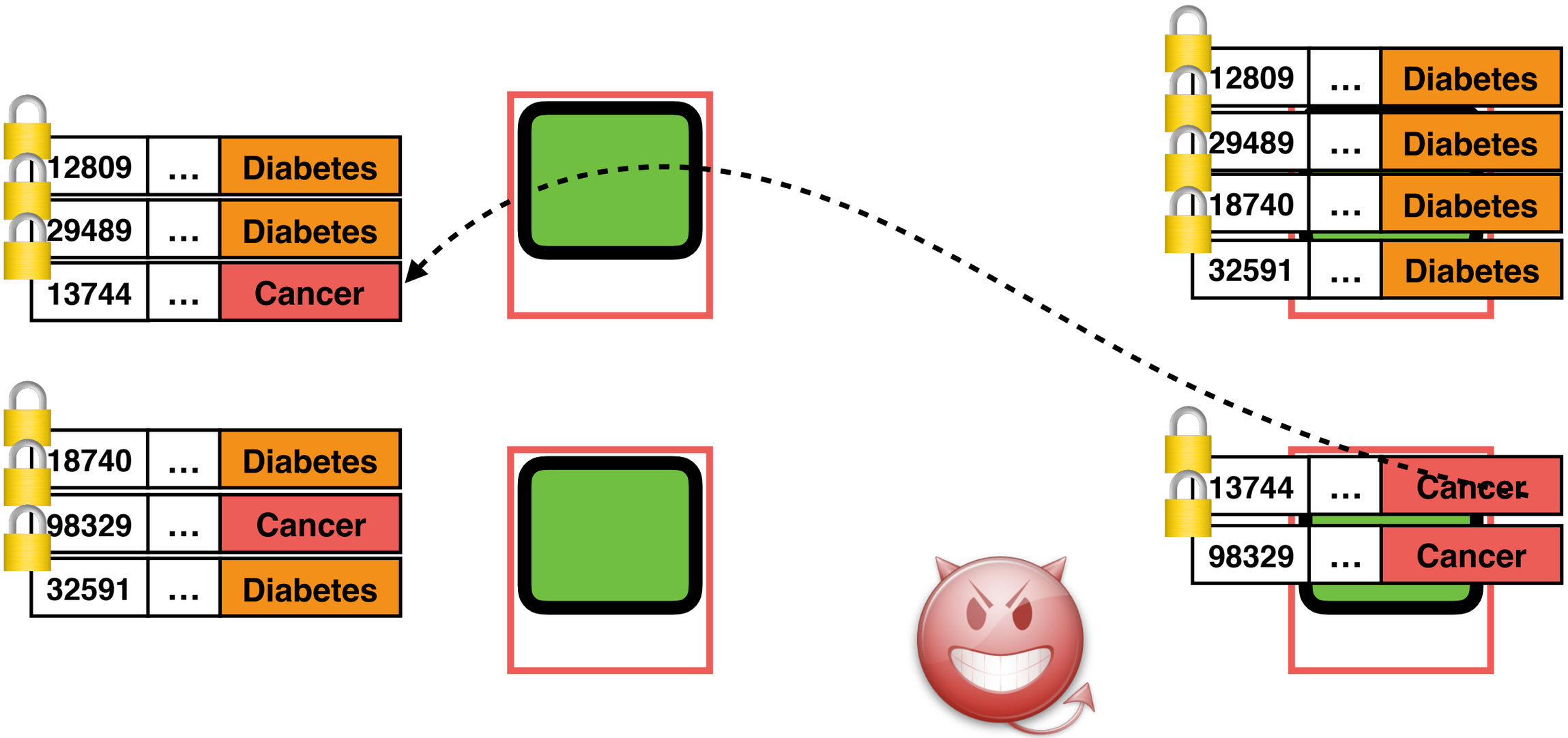

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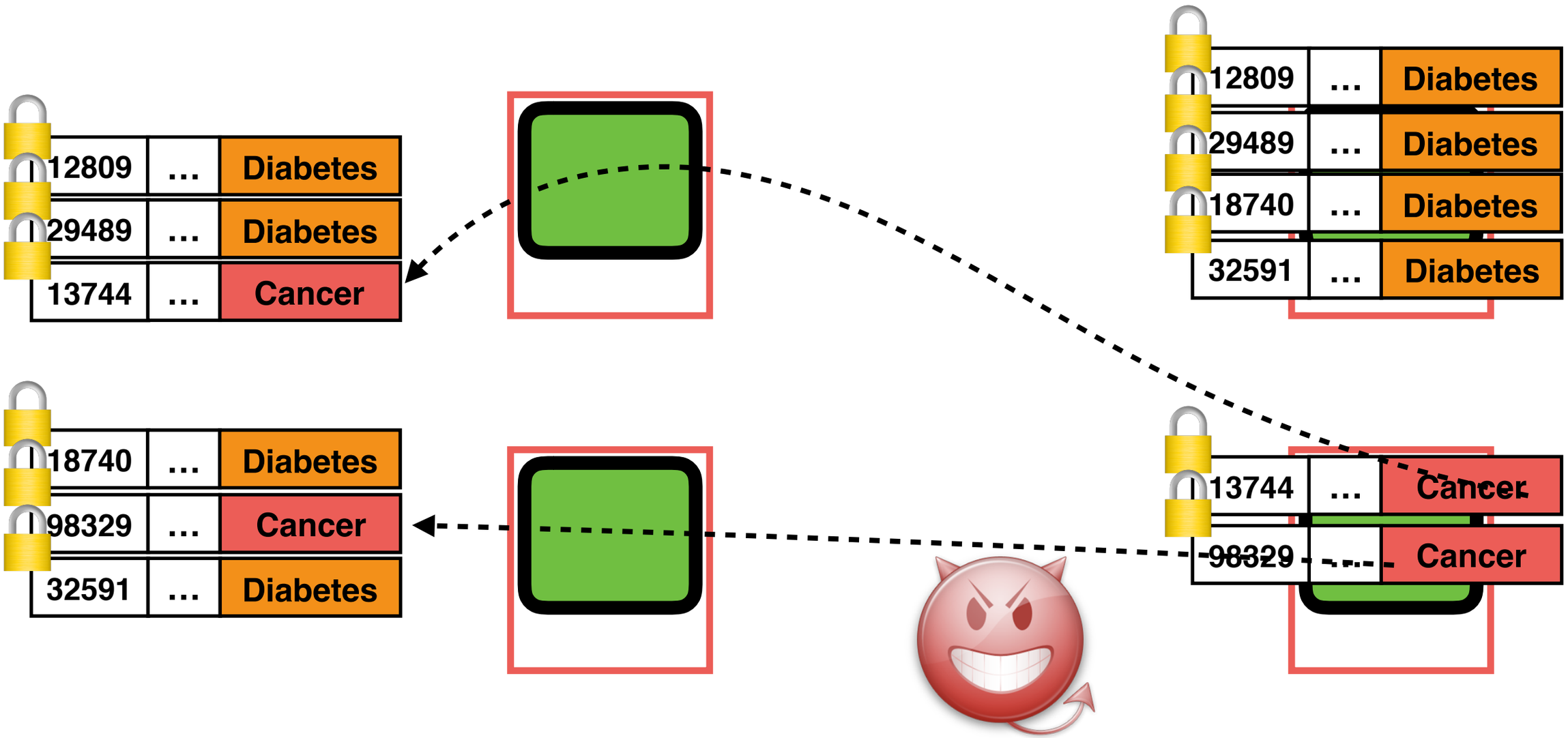

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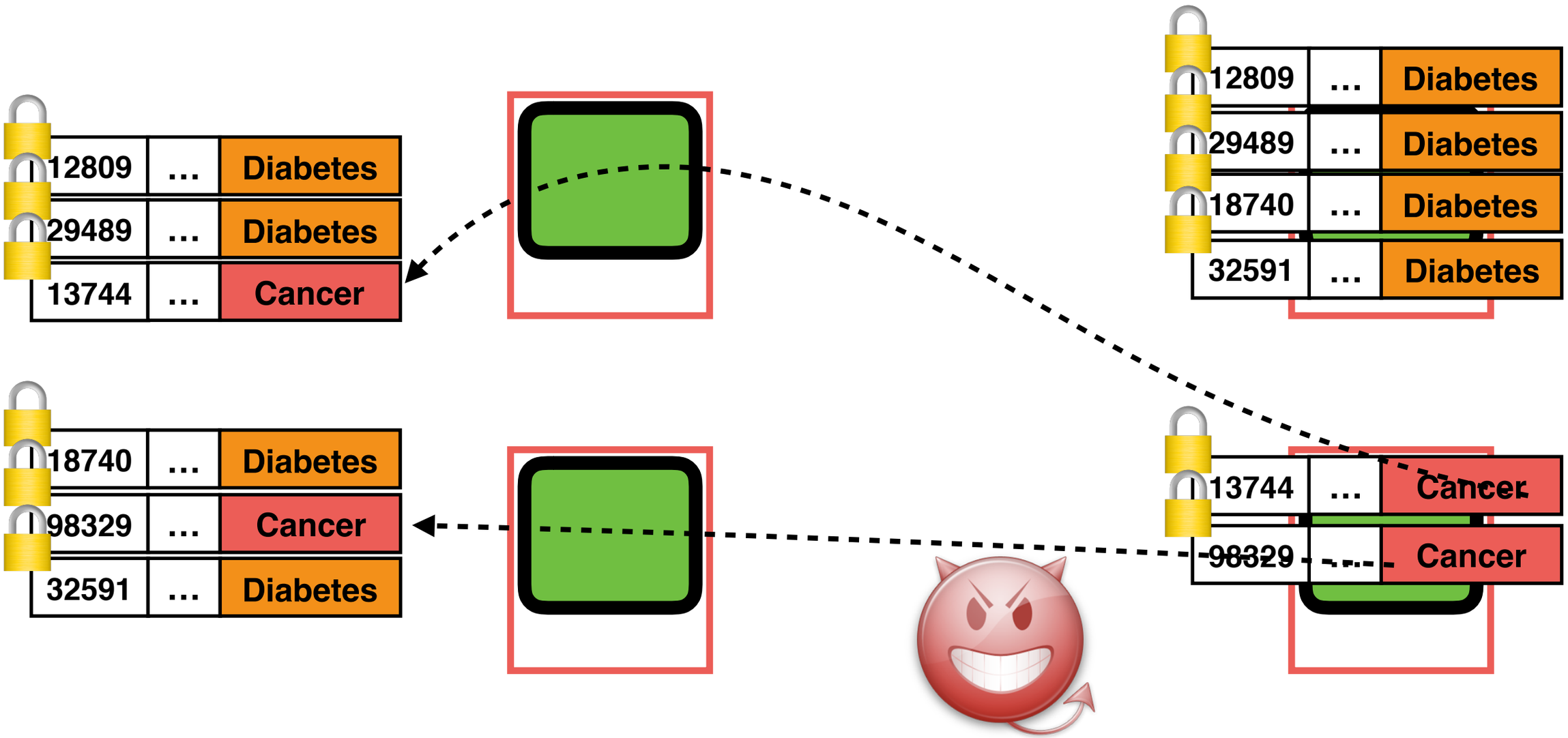

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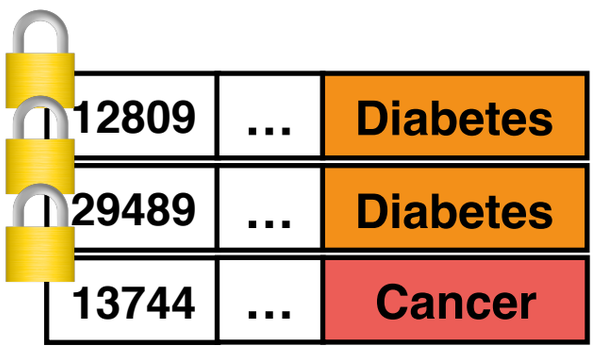

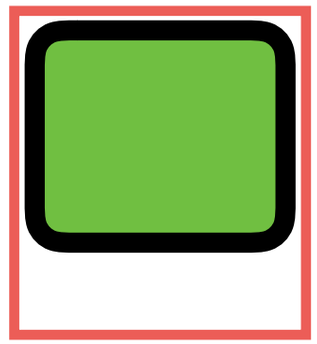

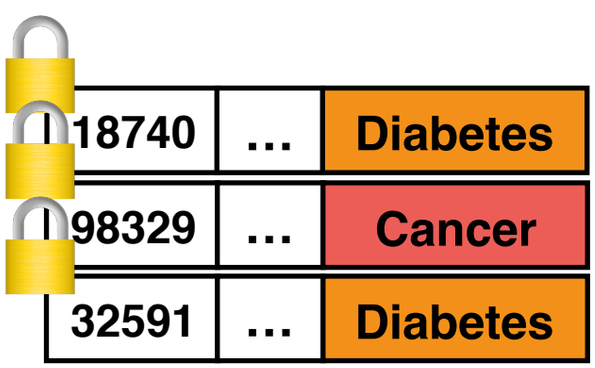

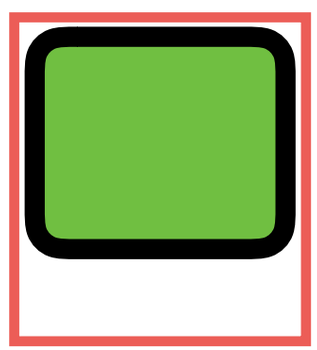

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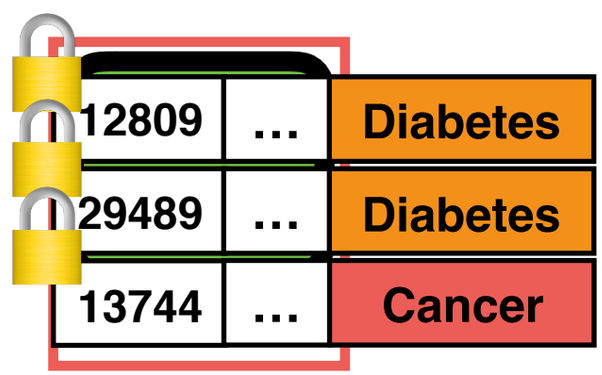

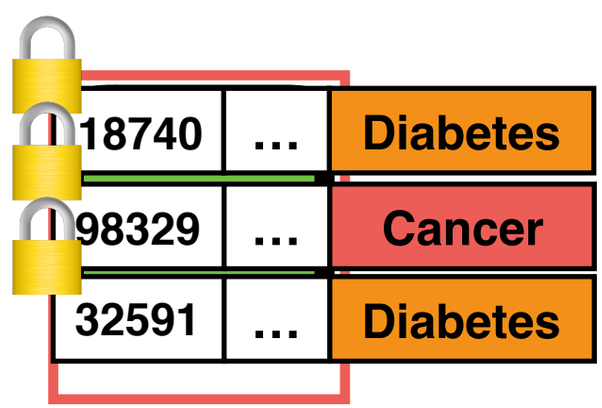

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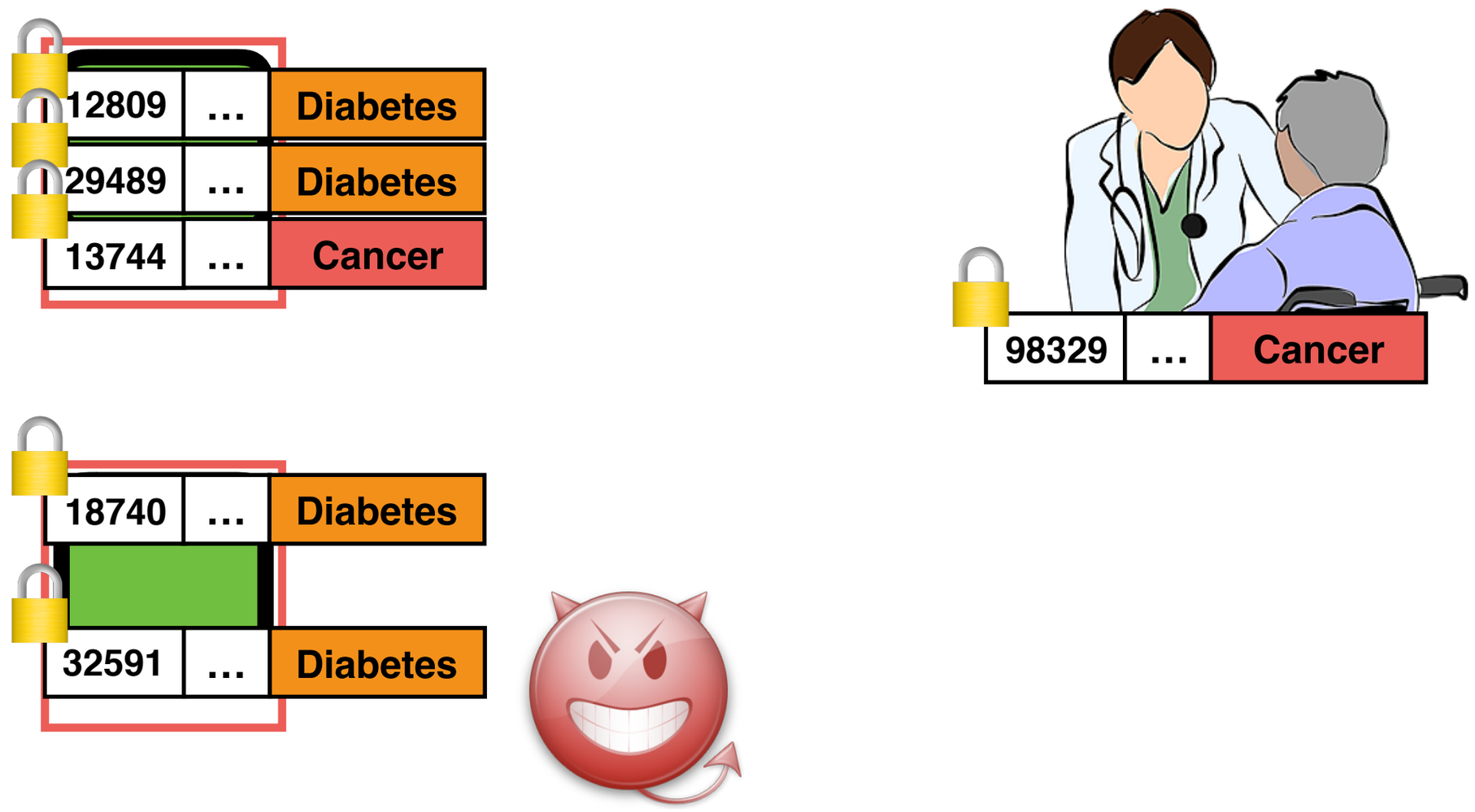

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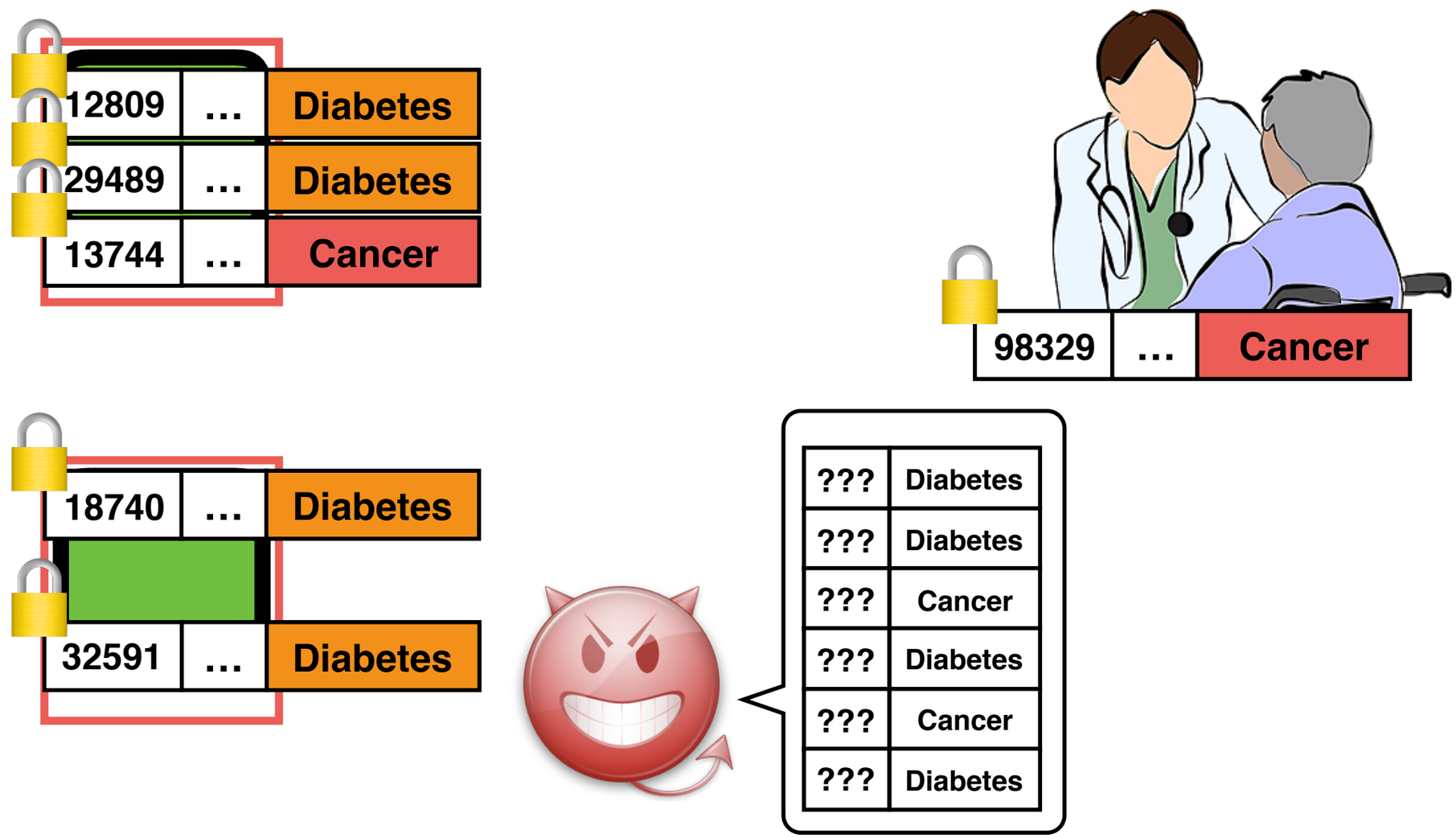

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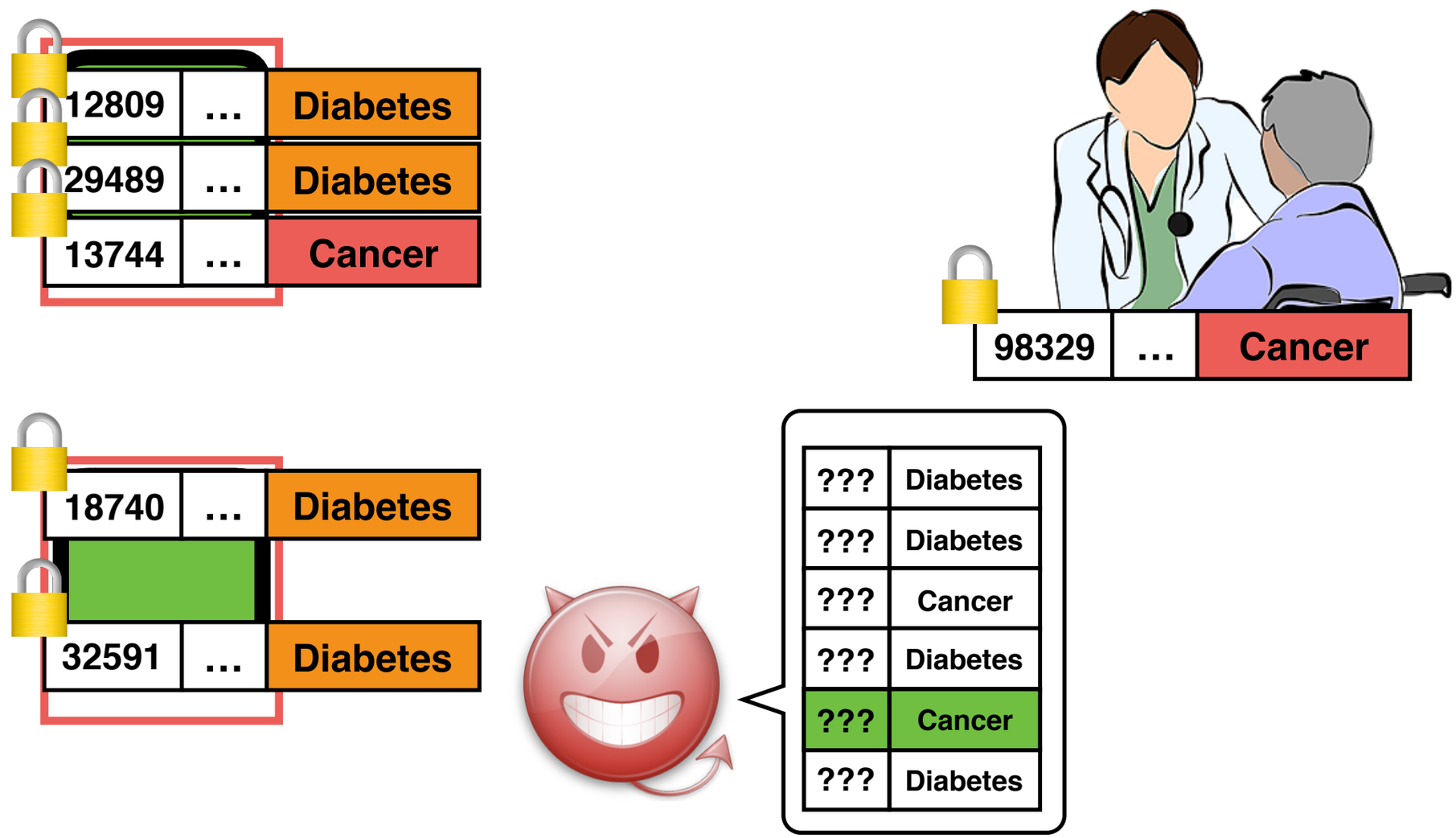

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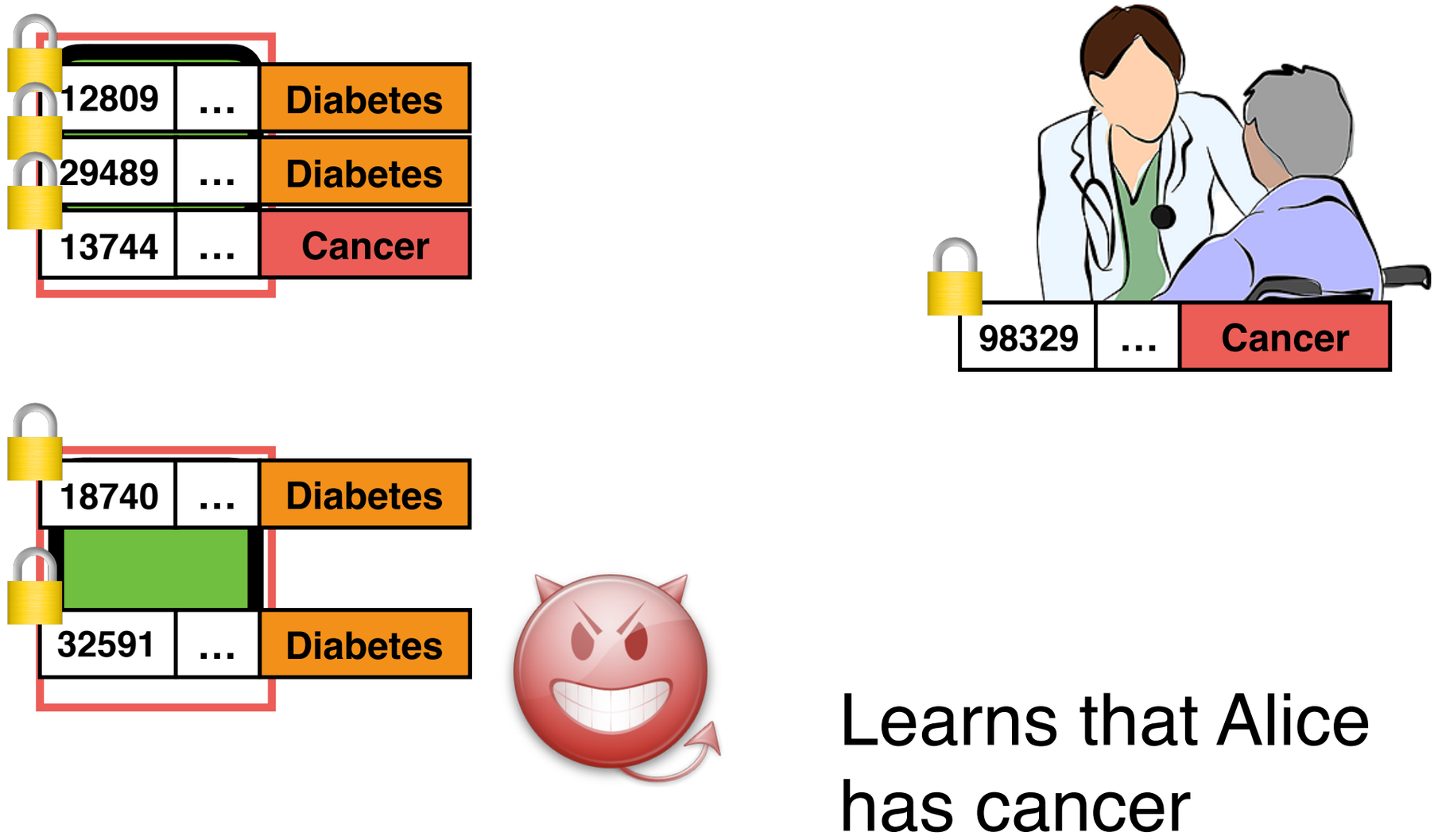
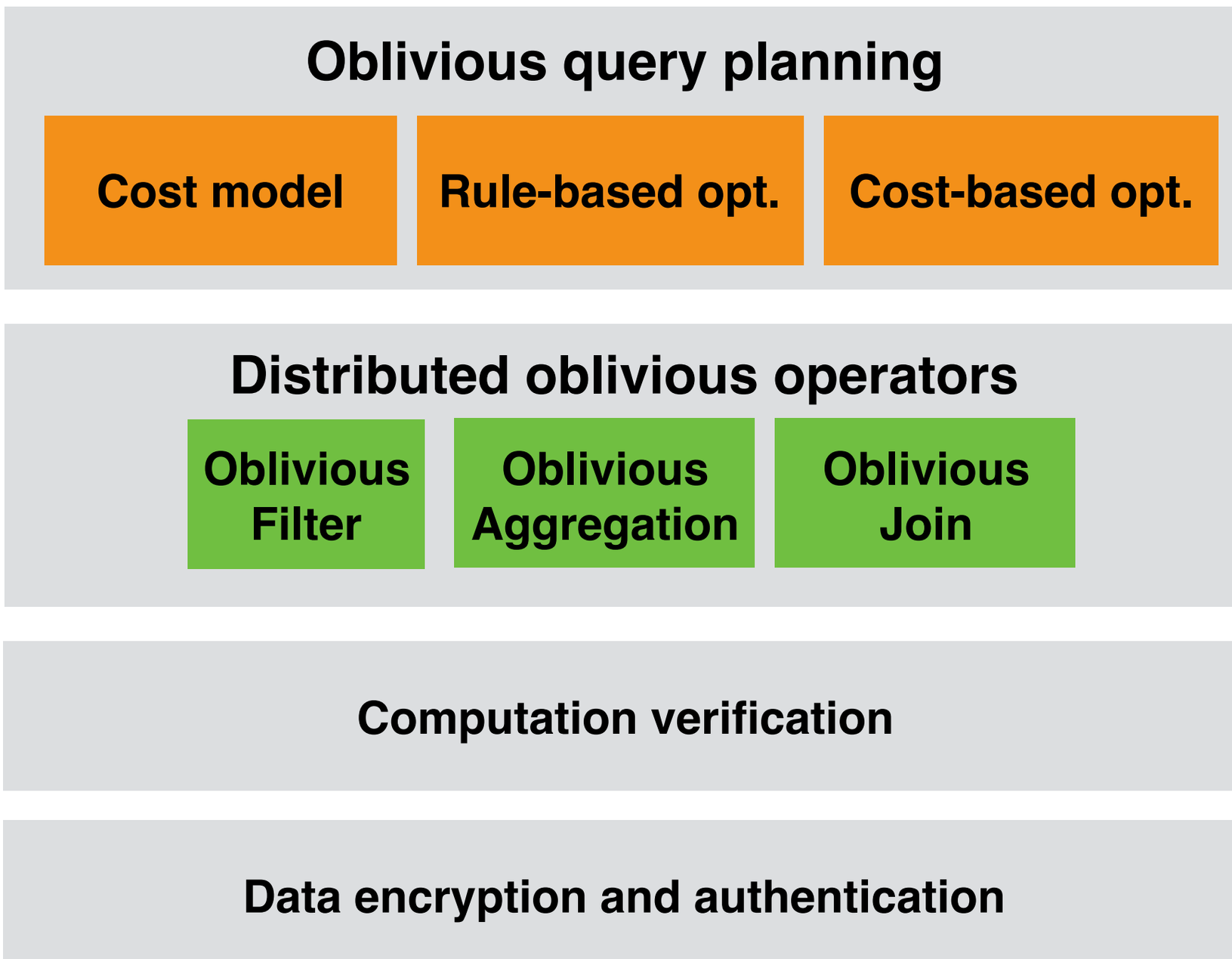


Goal: oblivious distributed analytics

access patterns are independent of data content

Goal: oblivious distributed analytics

Opaque components



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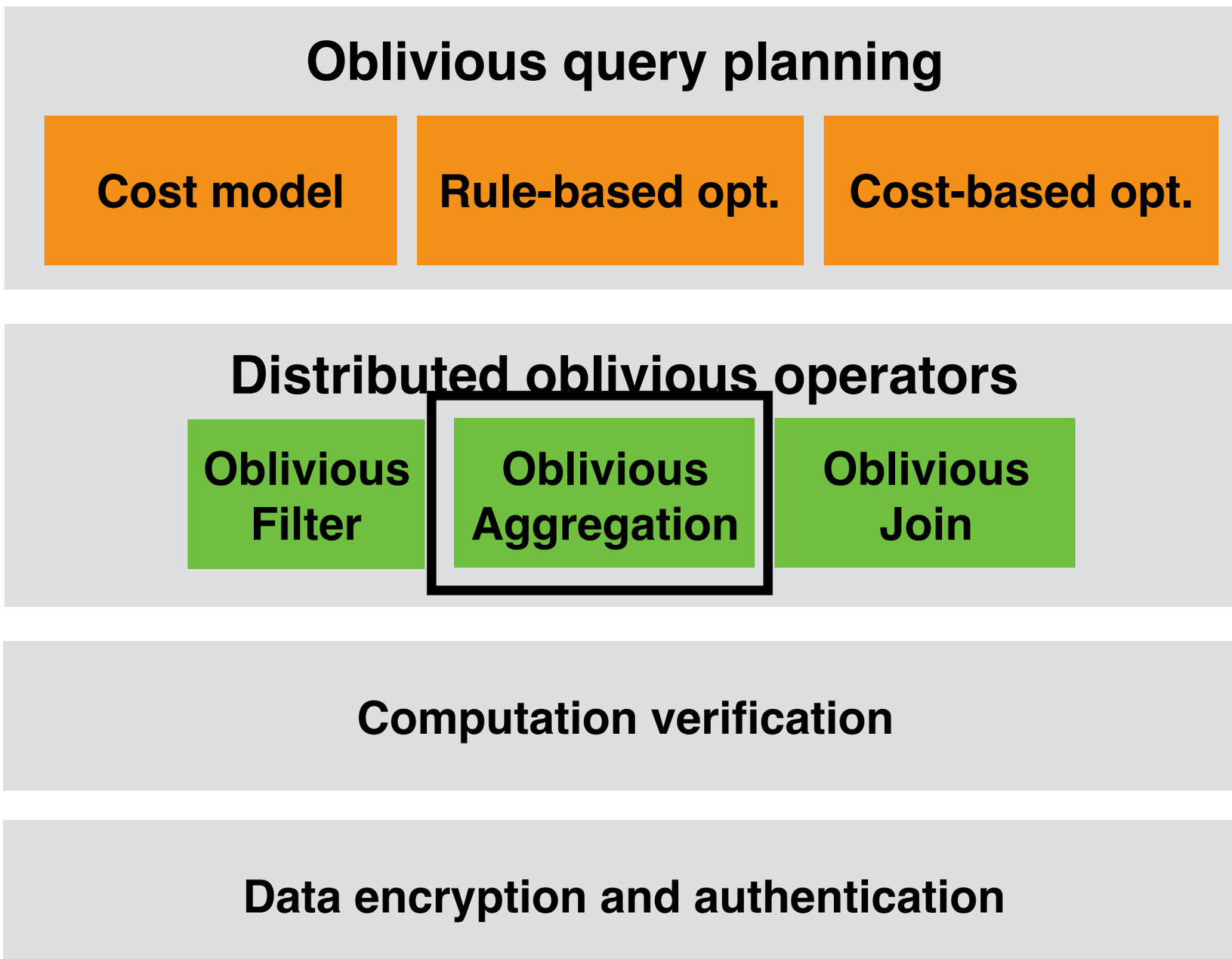
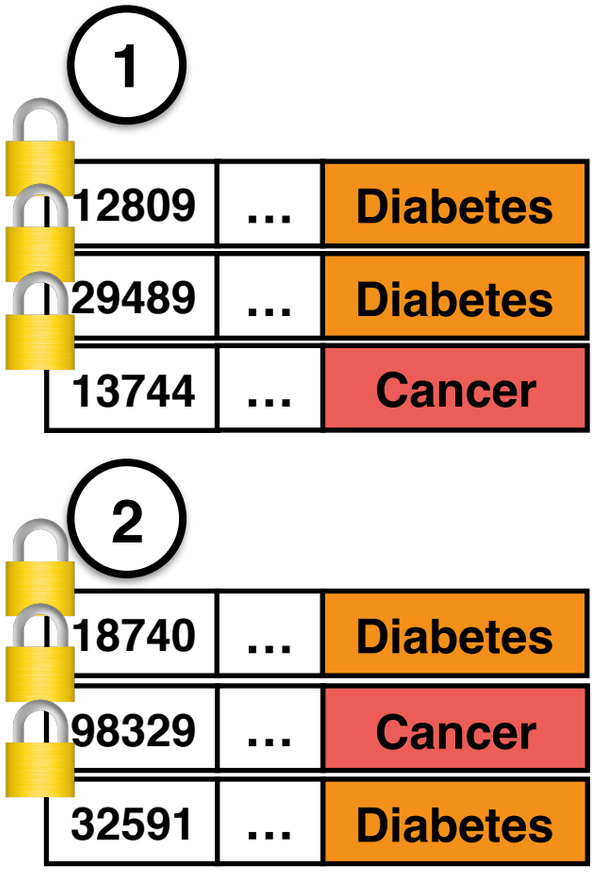


Oblivious aggregation

SELECT count(*) FROM medical GROUP BY disease



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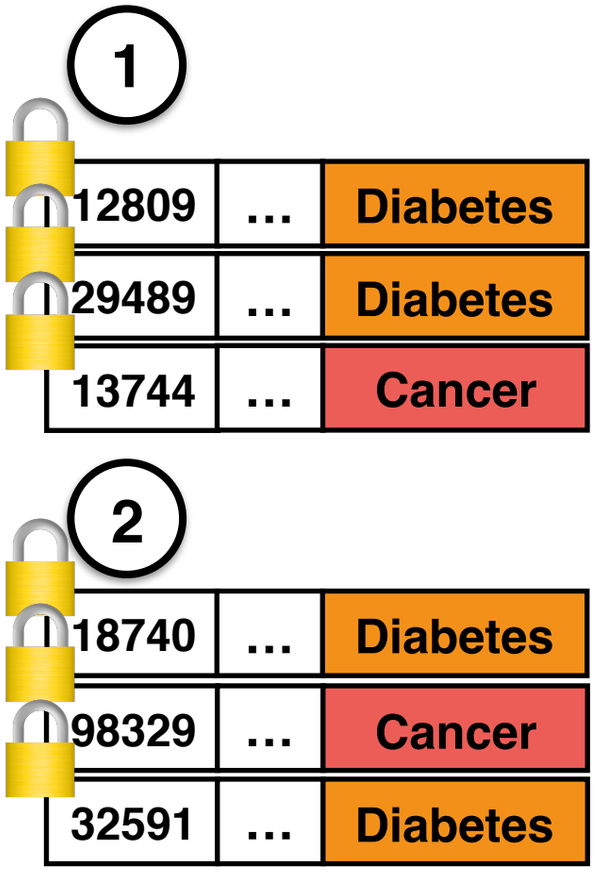

There can be many partitions

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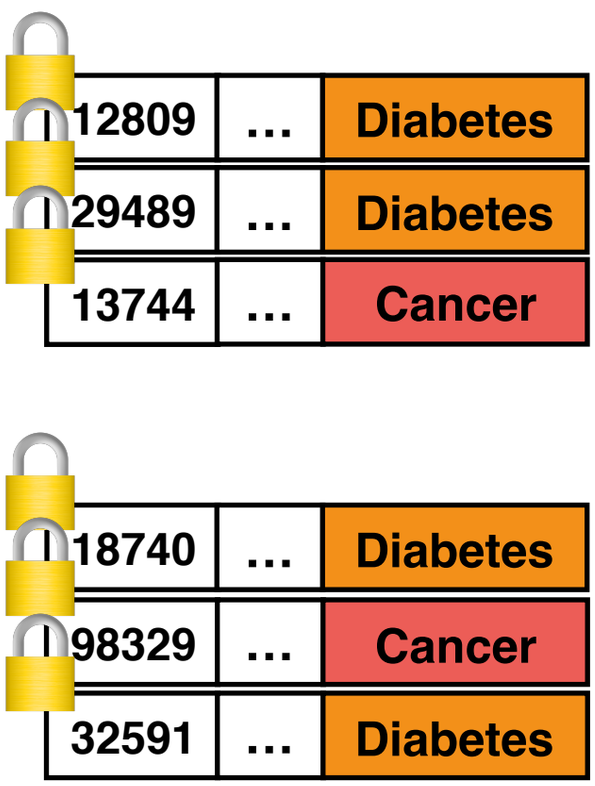
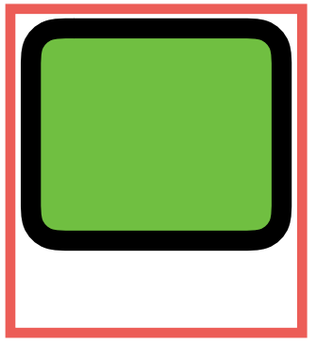
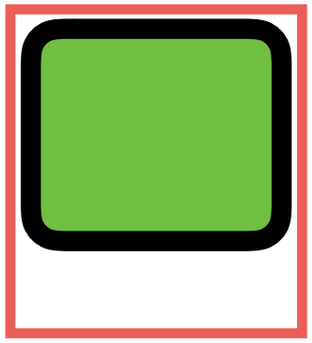


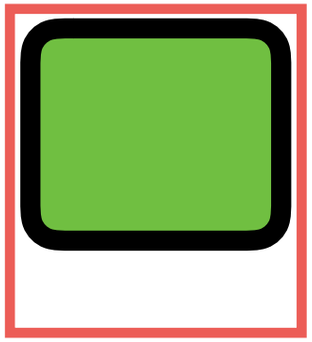


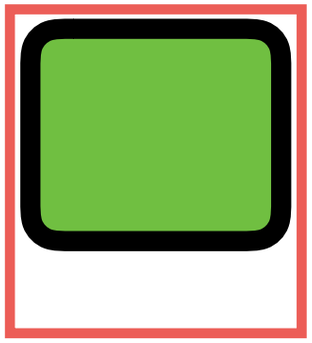


Map

Oblivious sort
[CLRS, Leighton '85]

Sort





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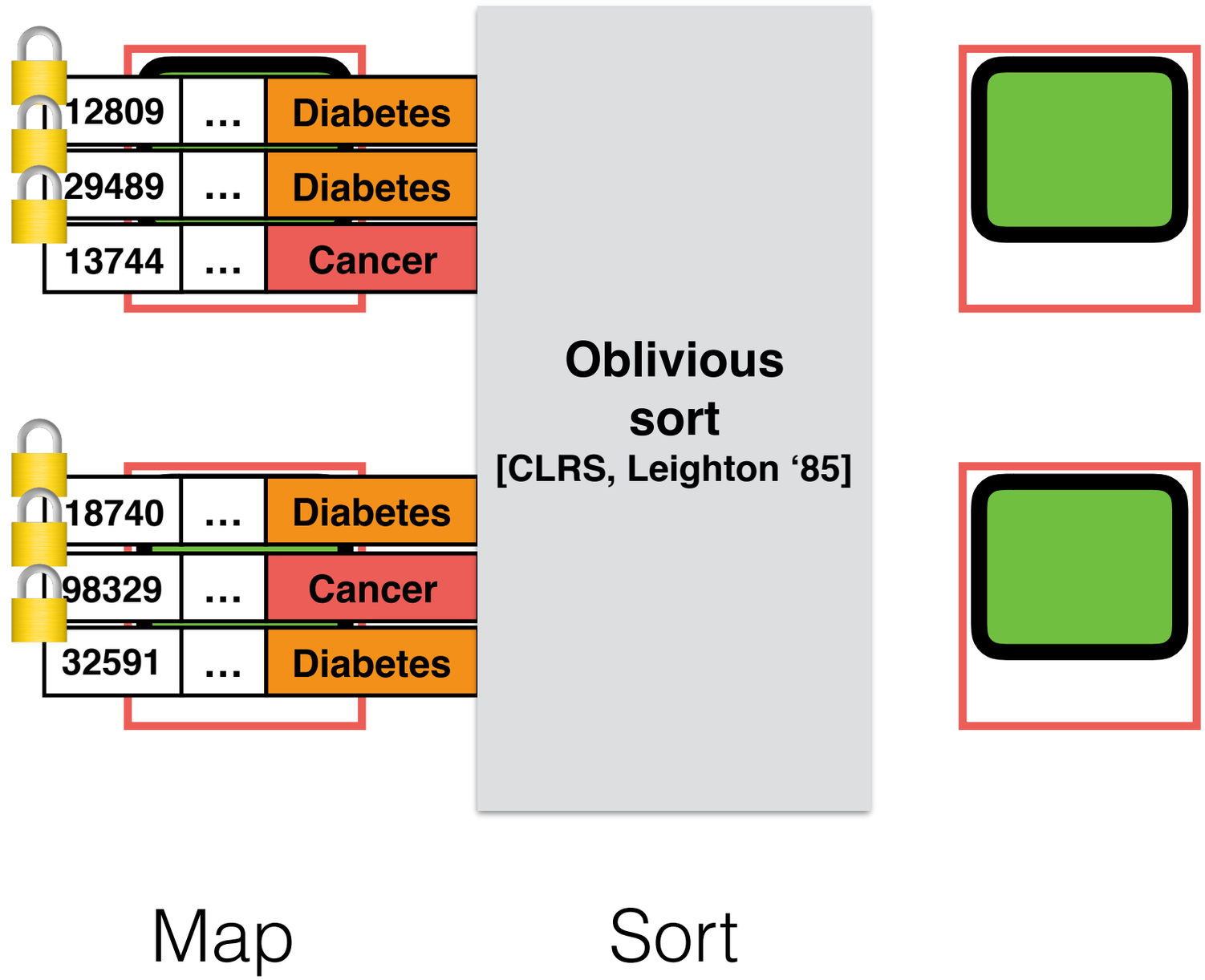

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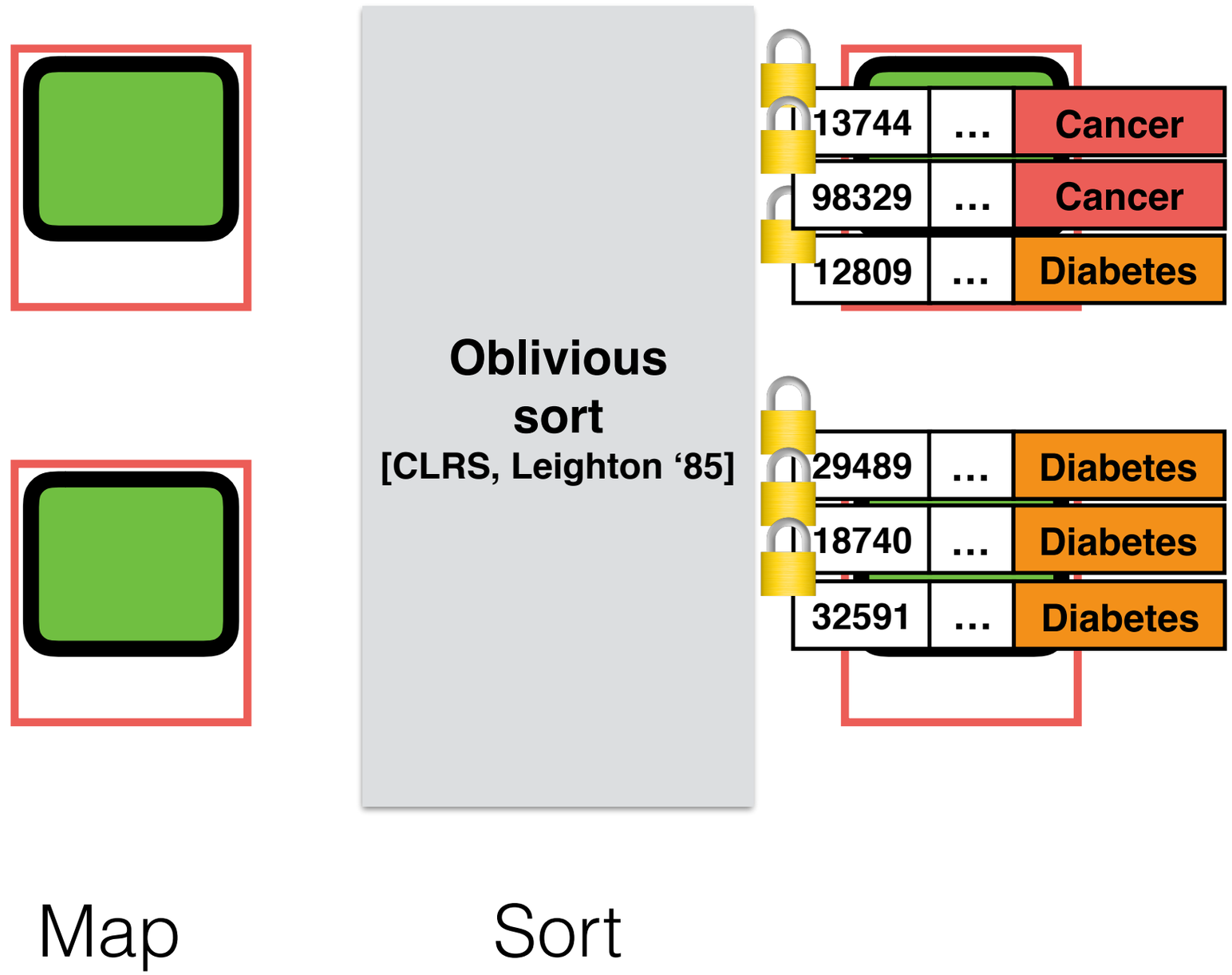

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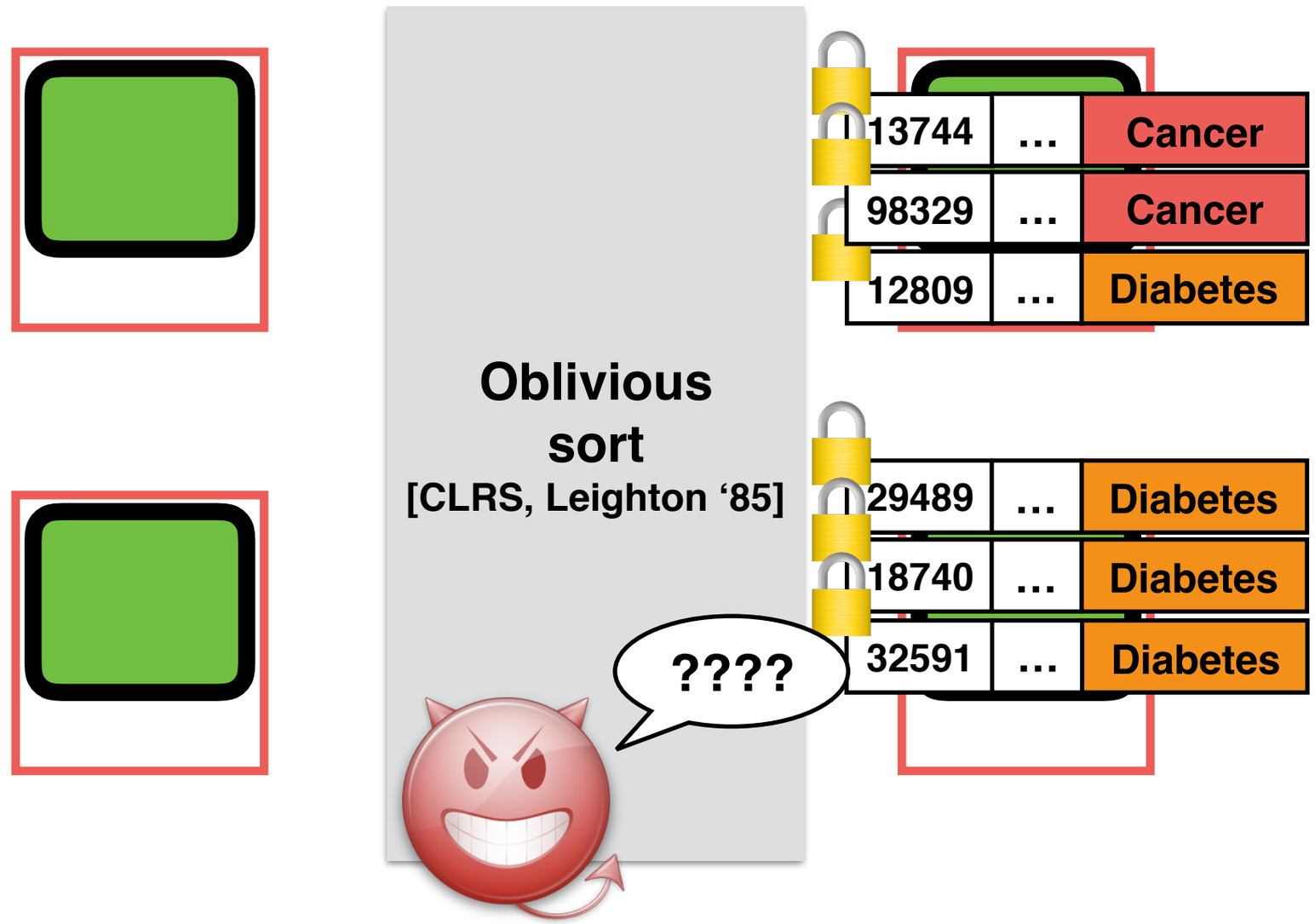

Map Sort

Oblivious aggregation

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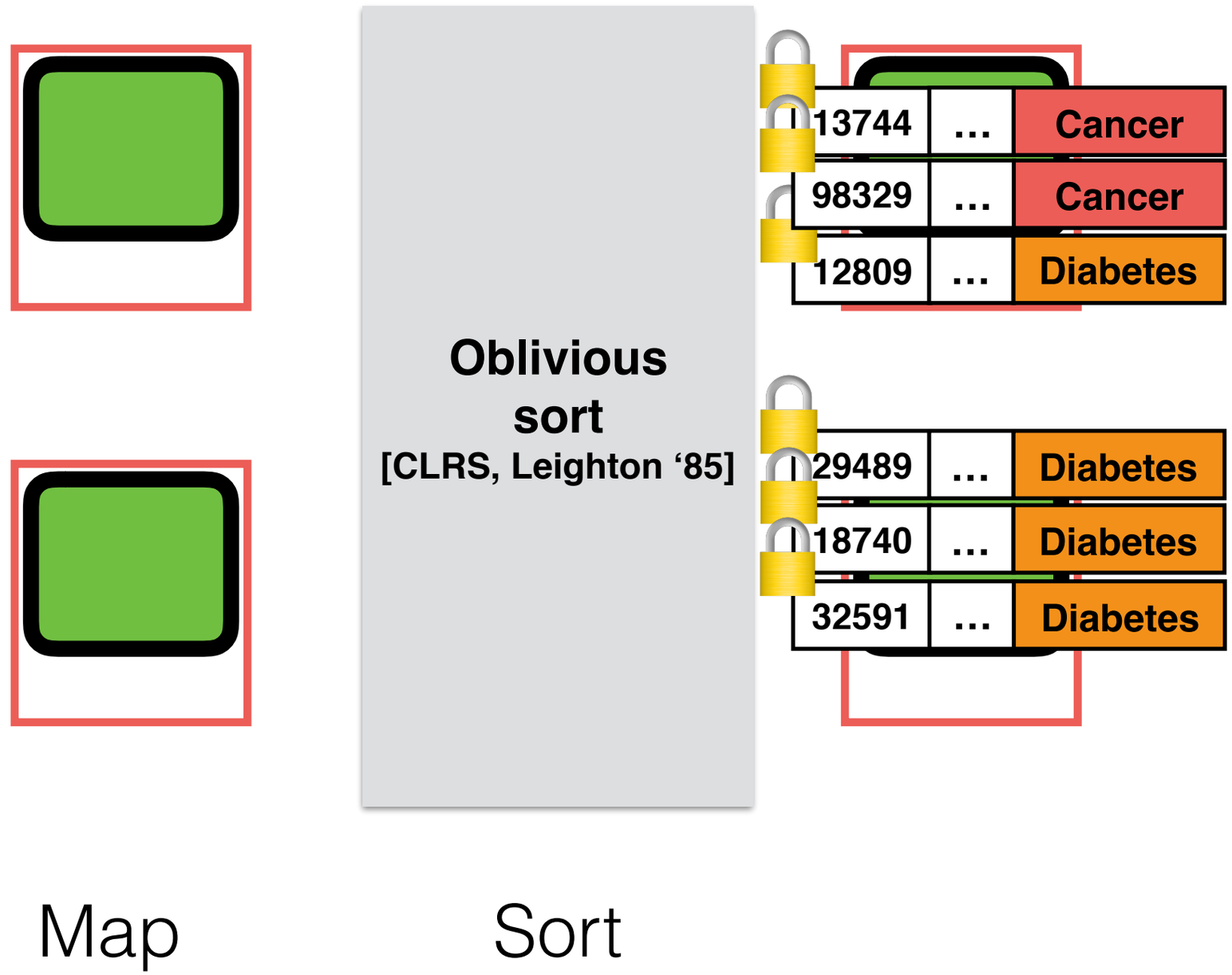

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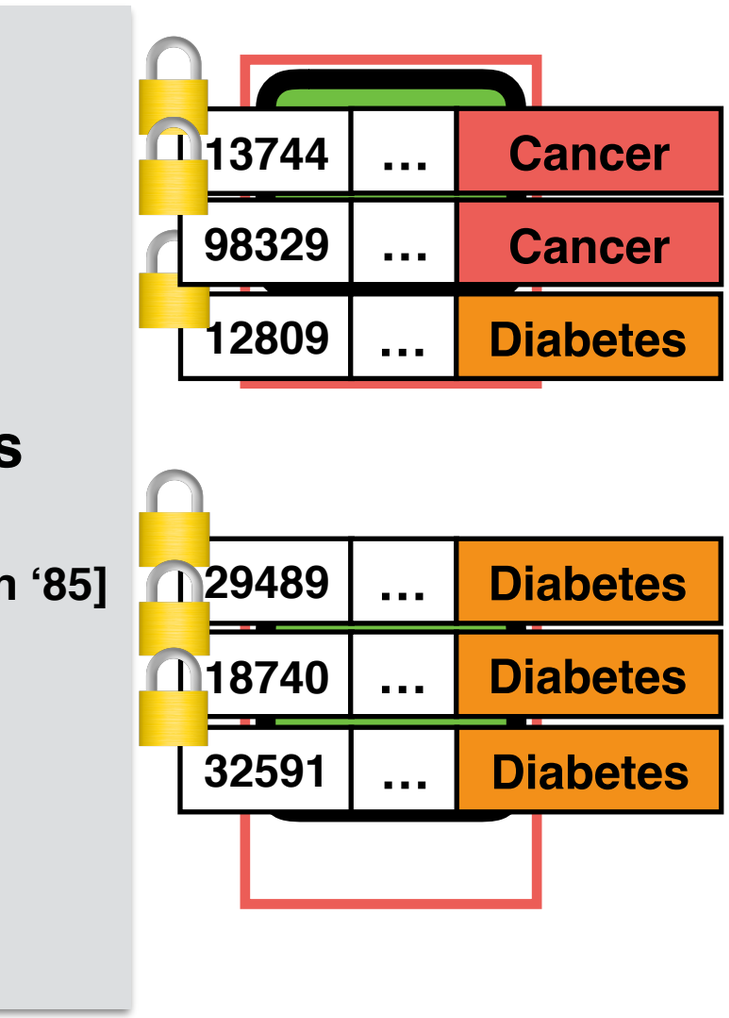

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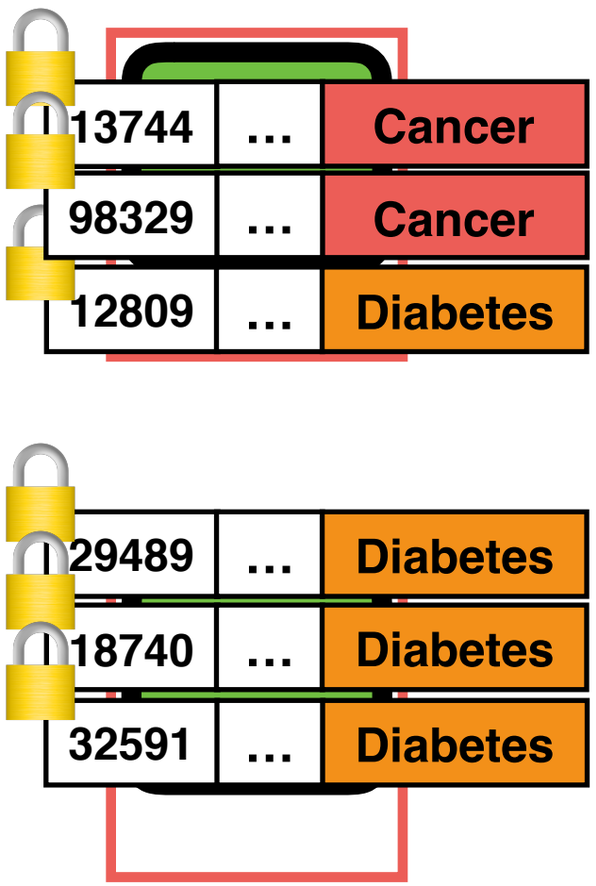

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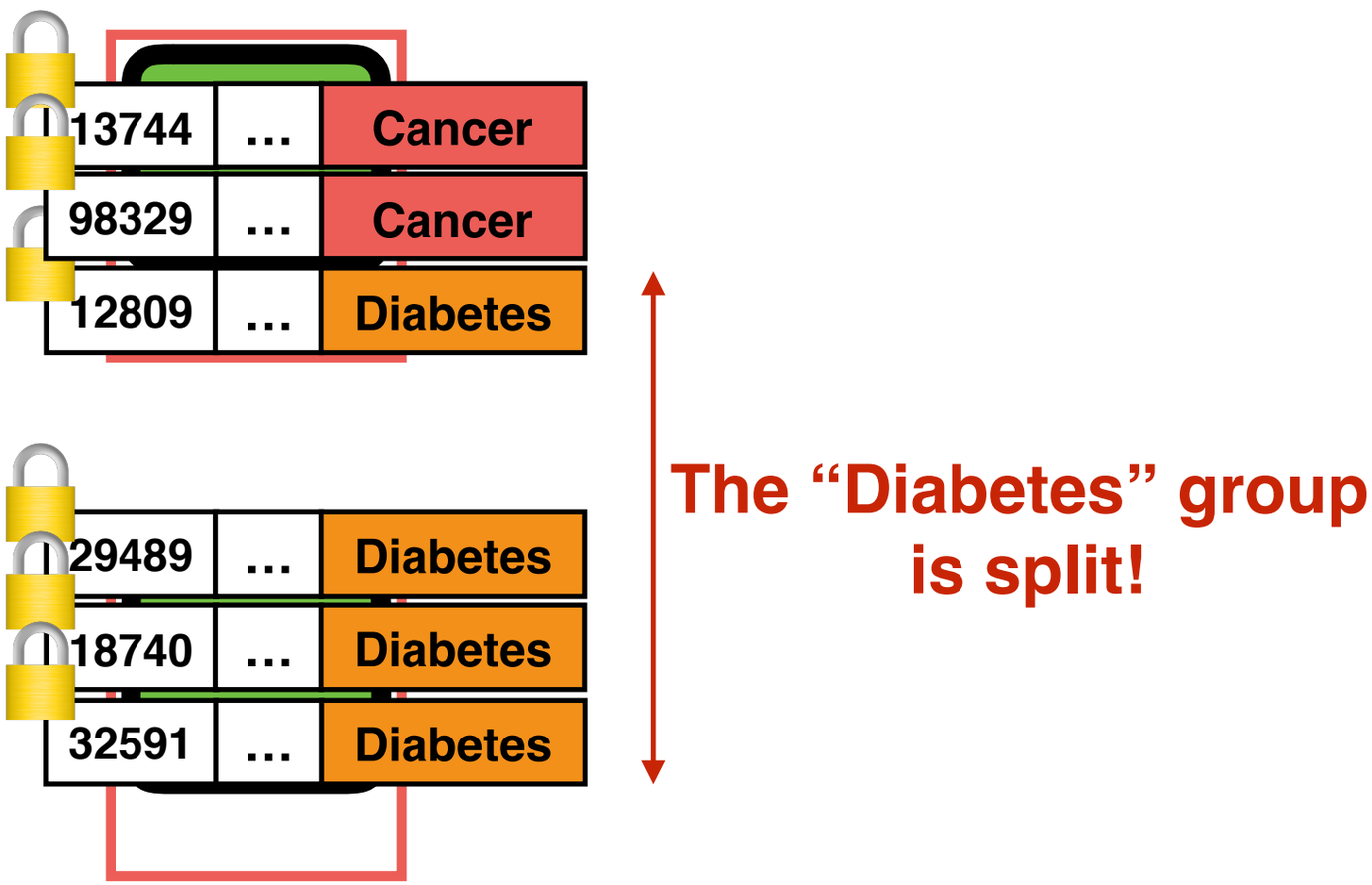

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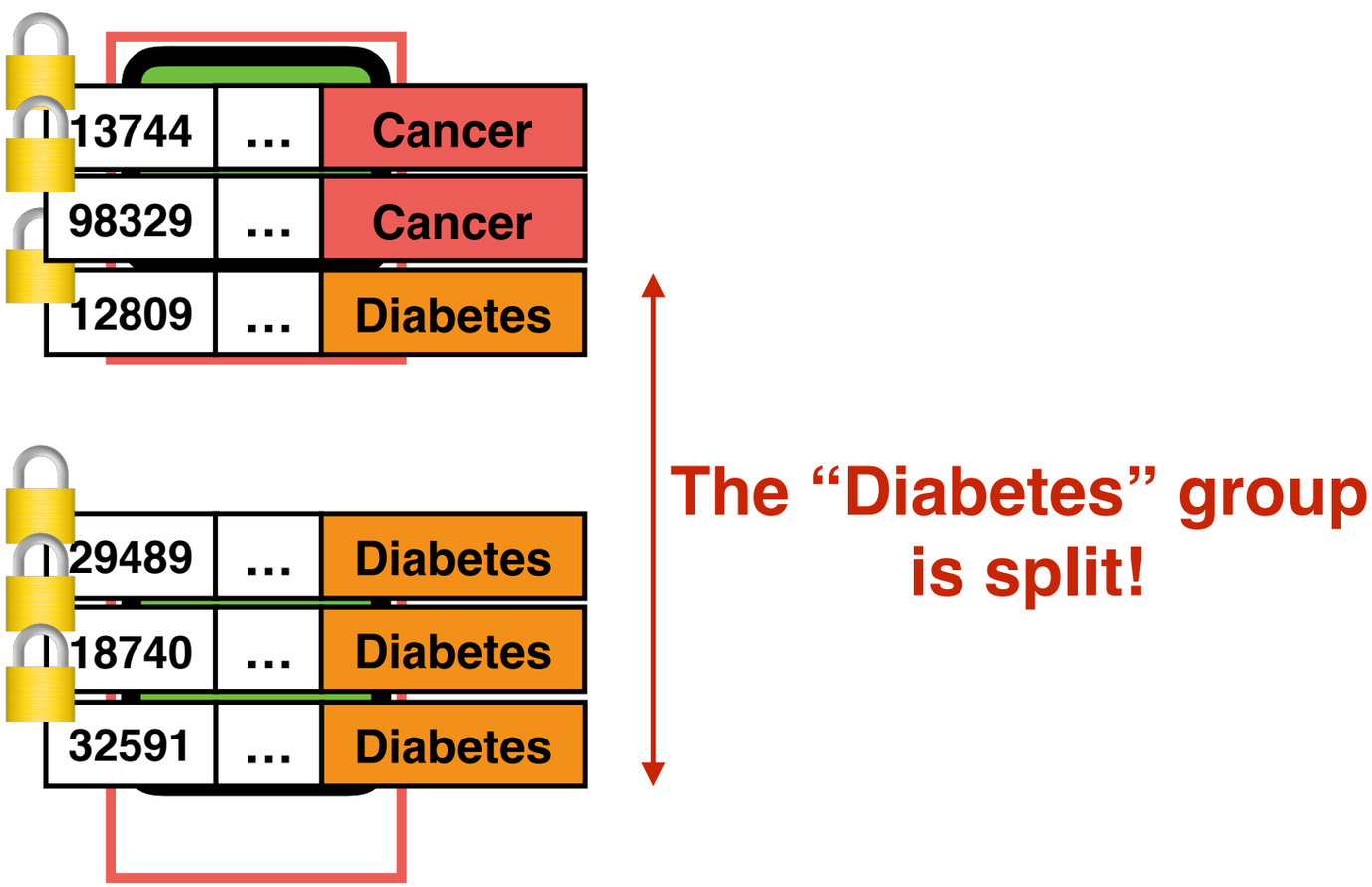

How to aggregate *obliviously* and in *parallel*?

Oblivious aggregation

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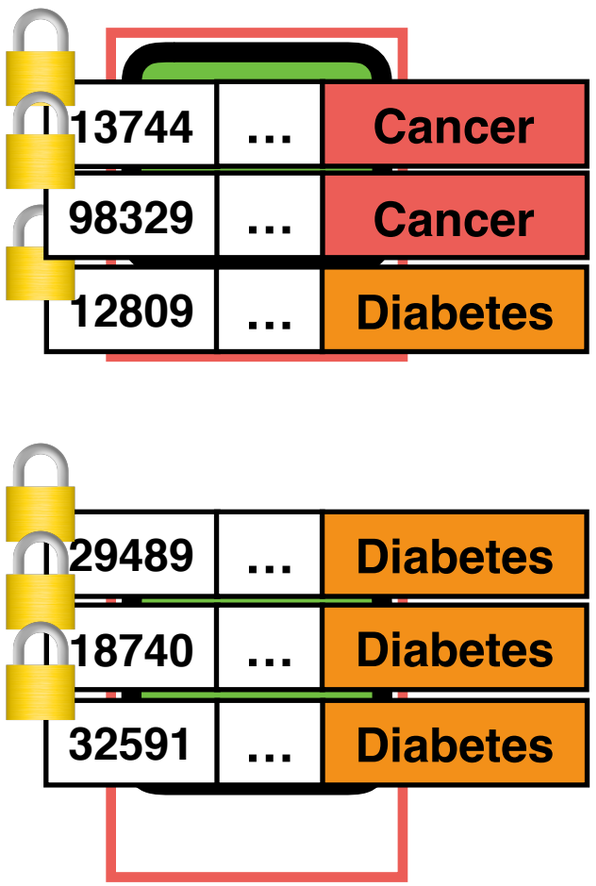

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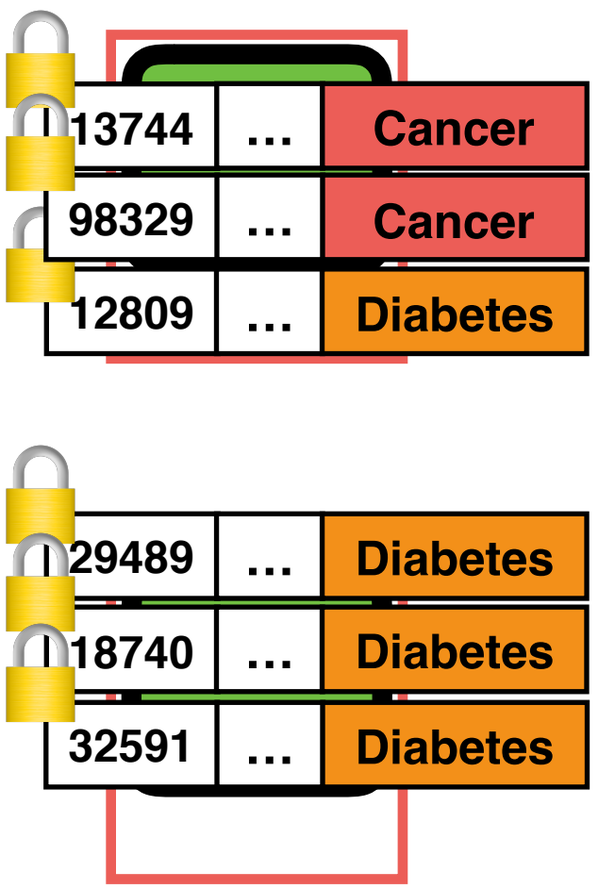

Scan

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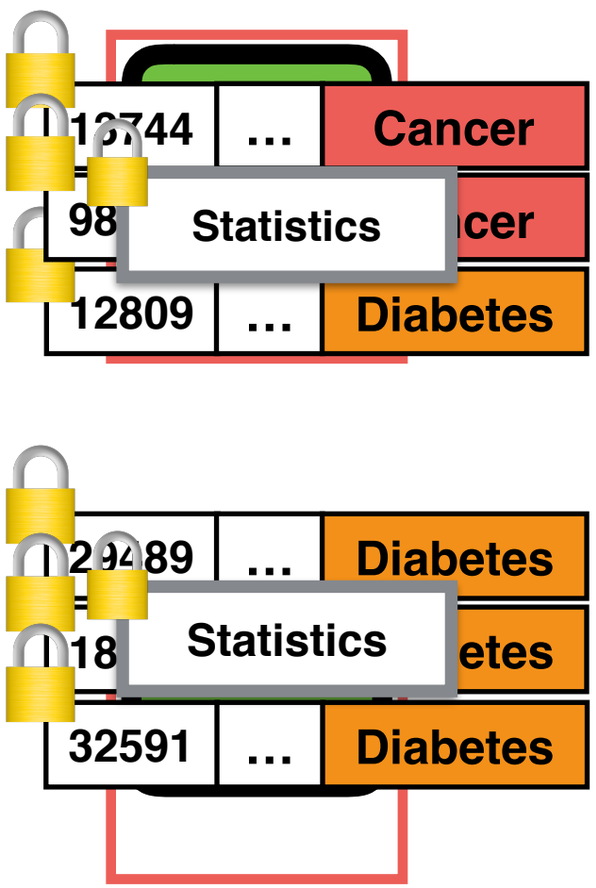

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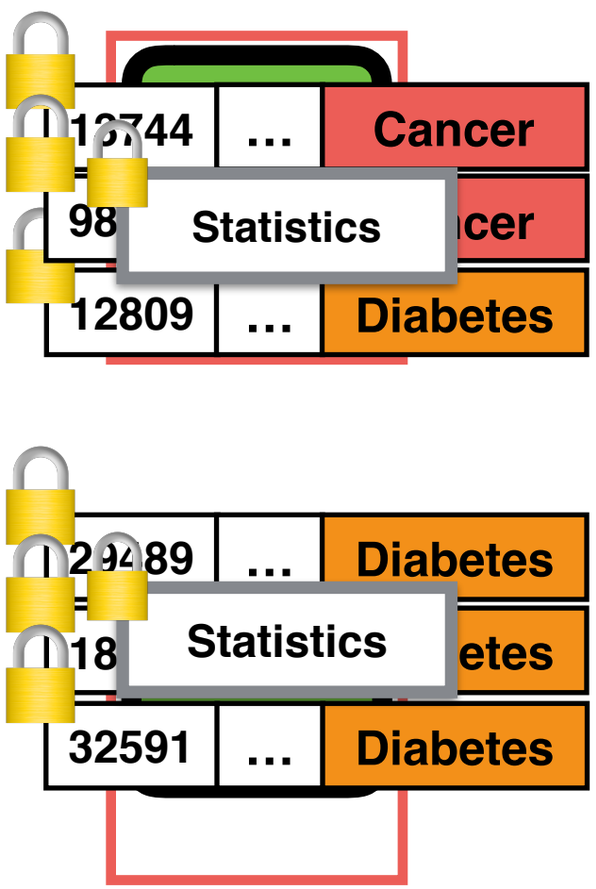

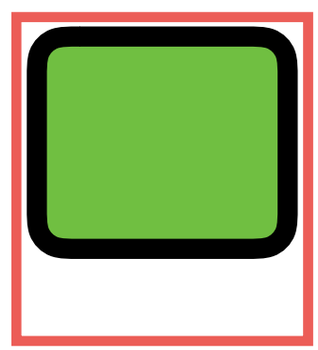

Scan

Boundary processing

Oblivious aggregation

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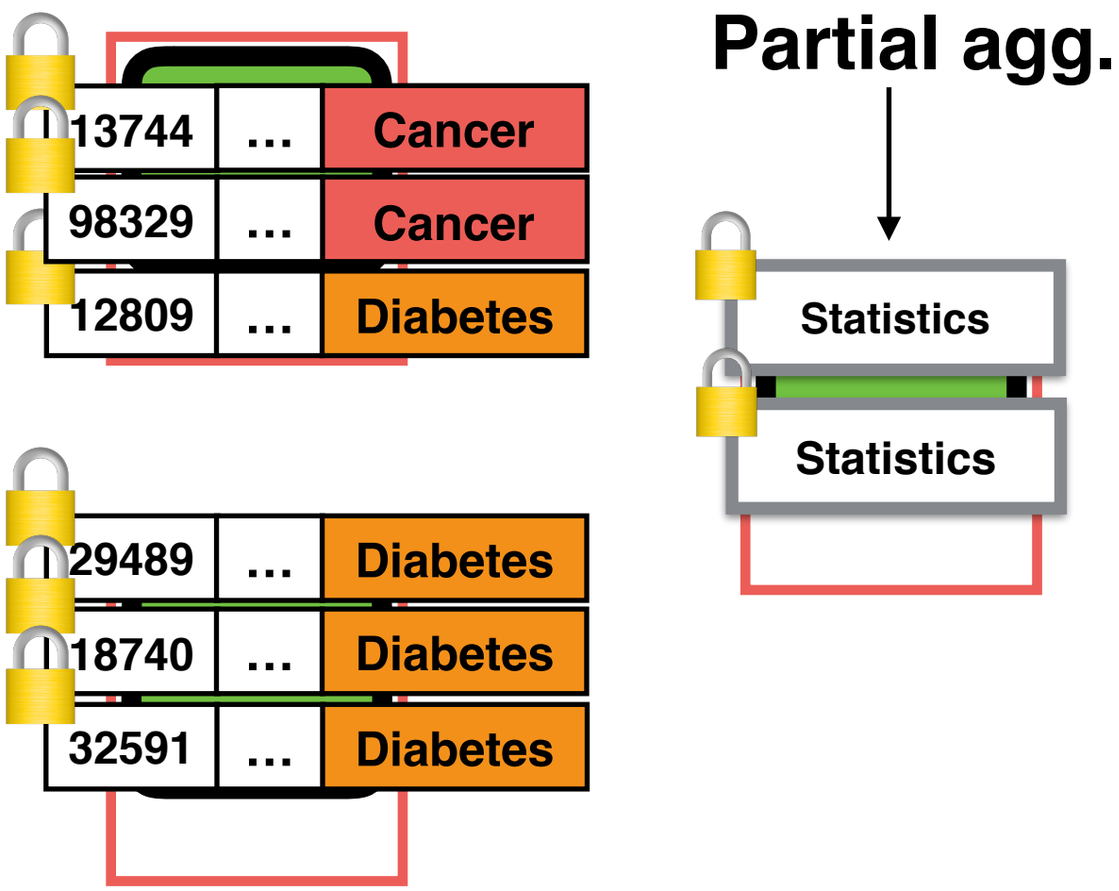

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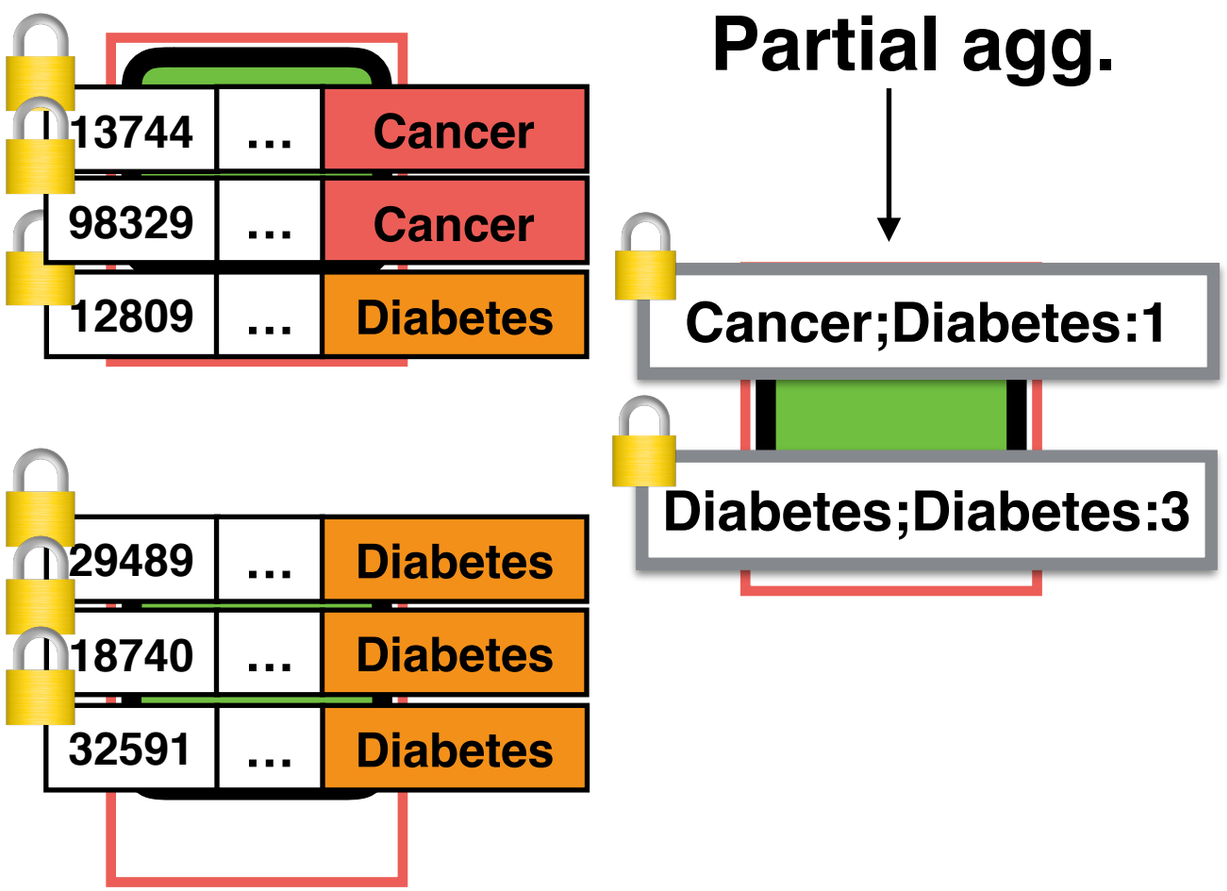

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Oblivious aggregation

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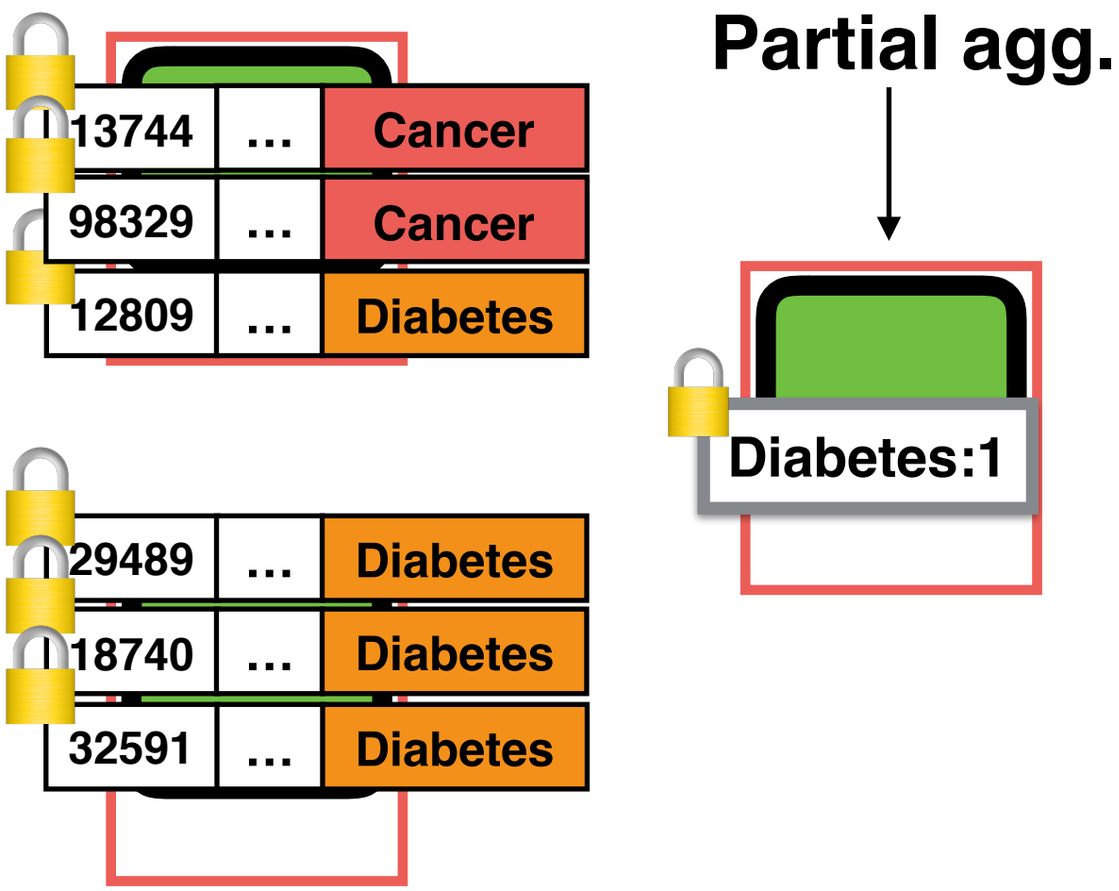

Scan

Boundary processing

Oblivious aggregation

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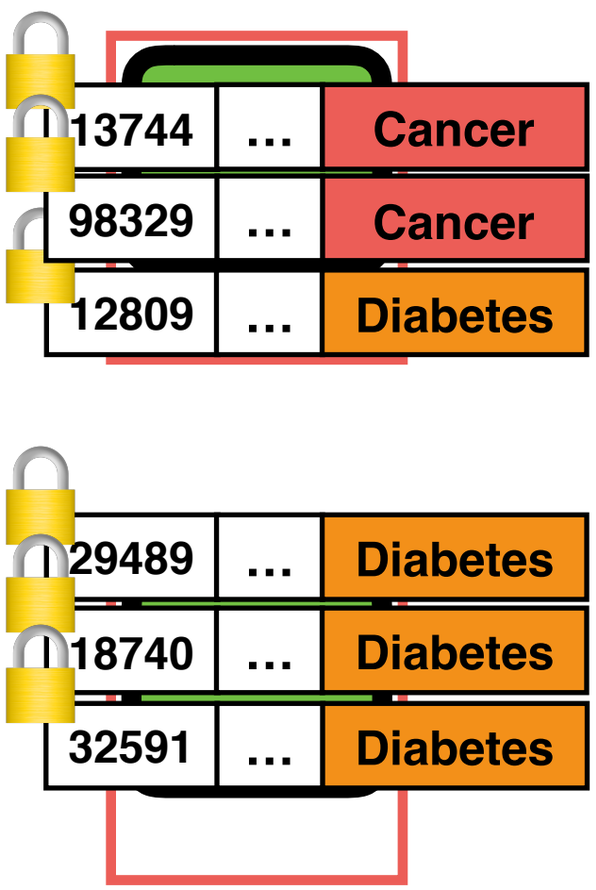

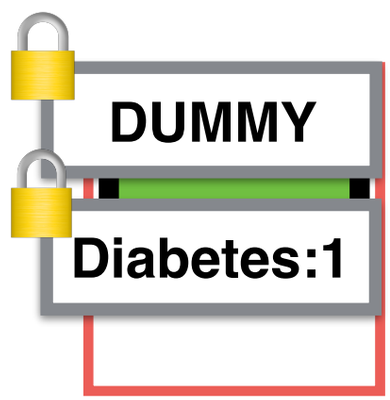

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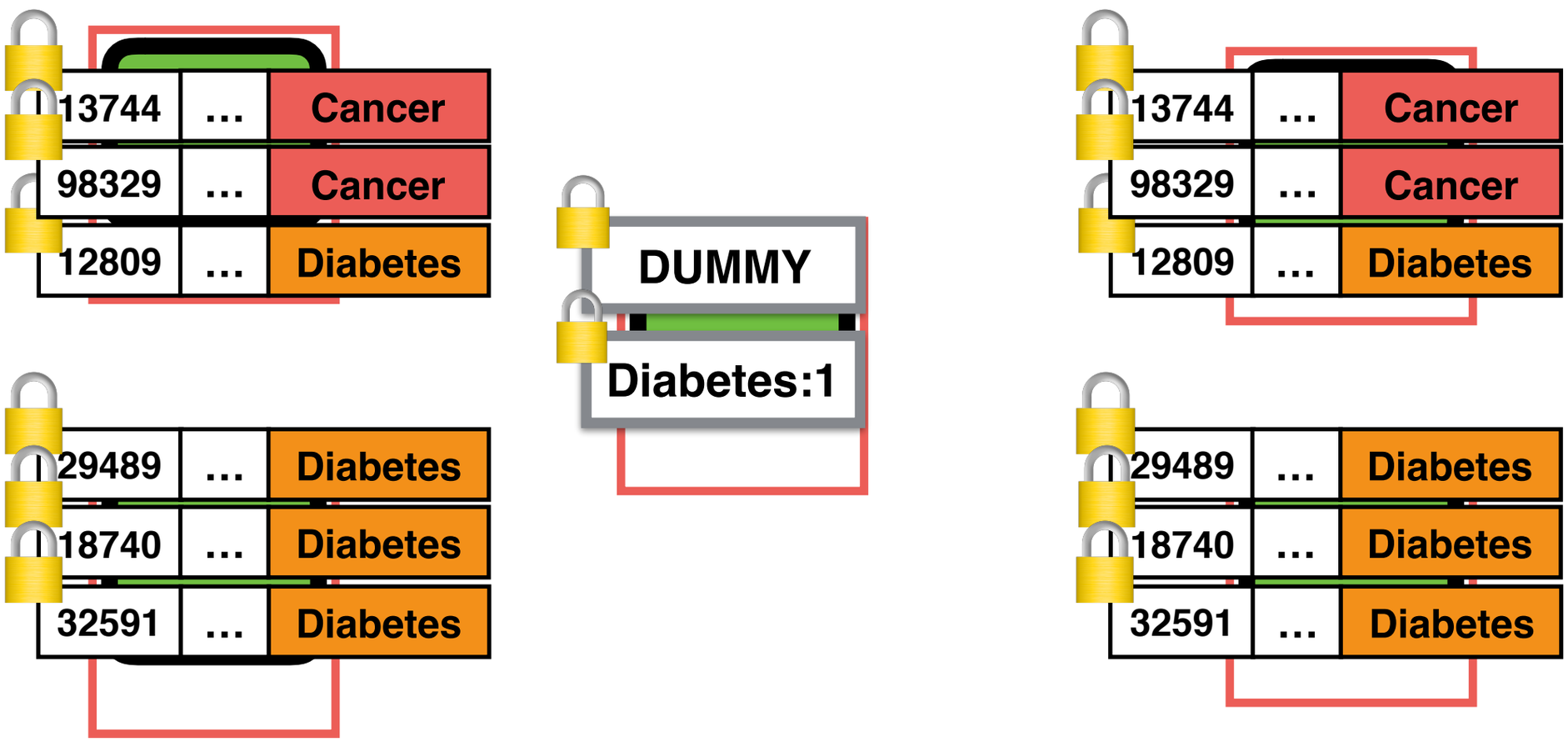

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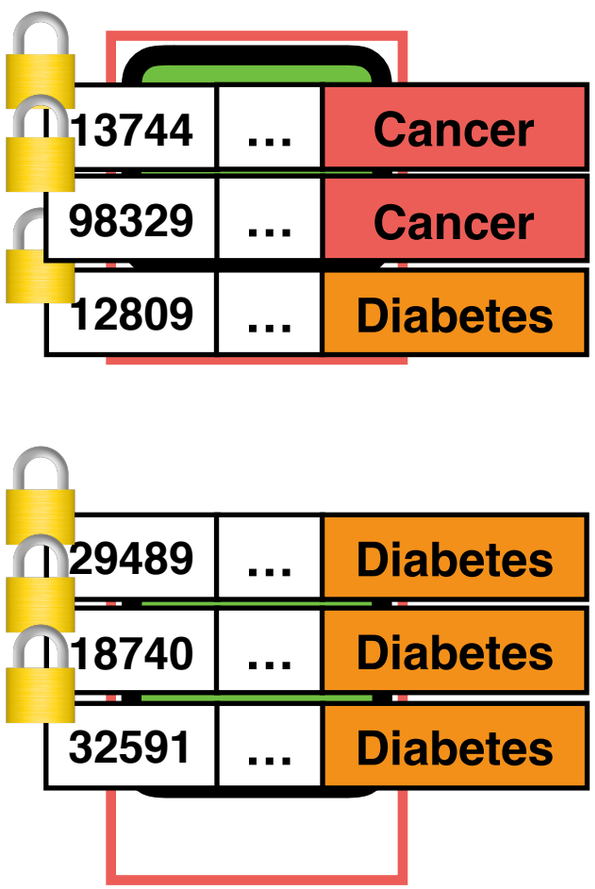

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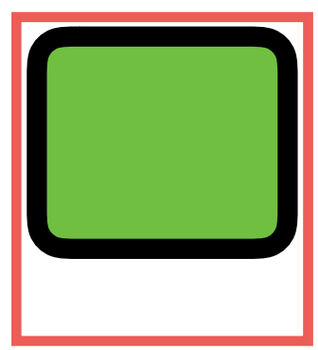

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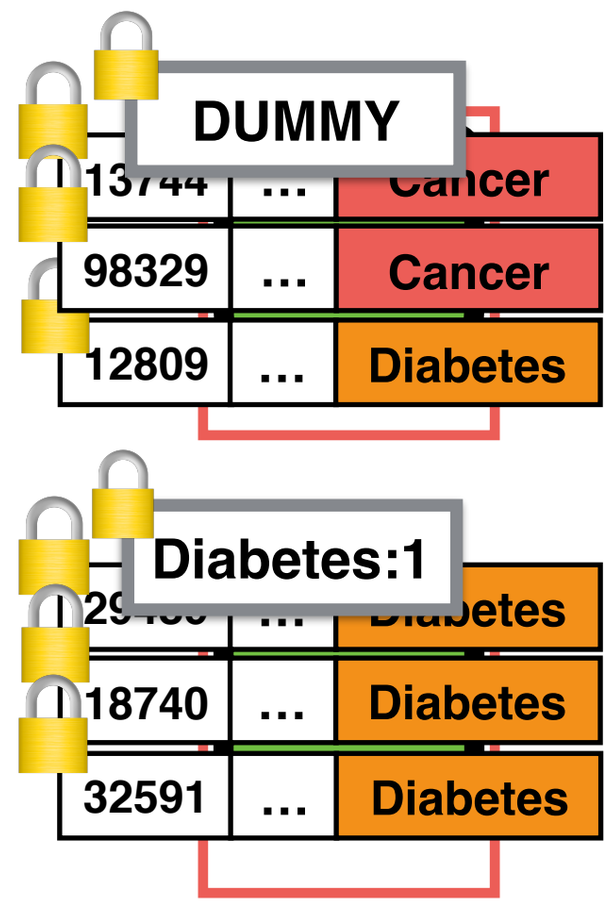

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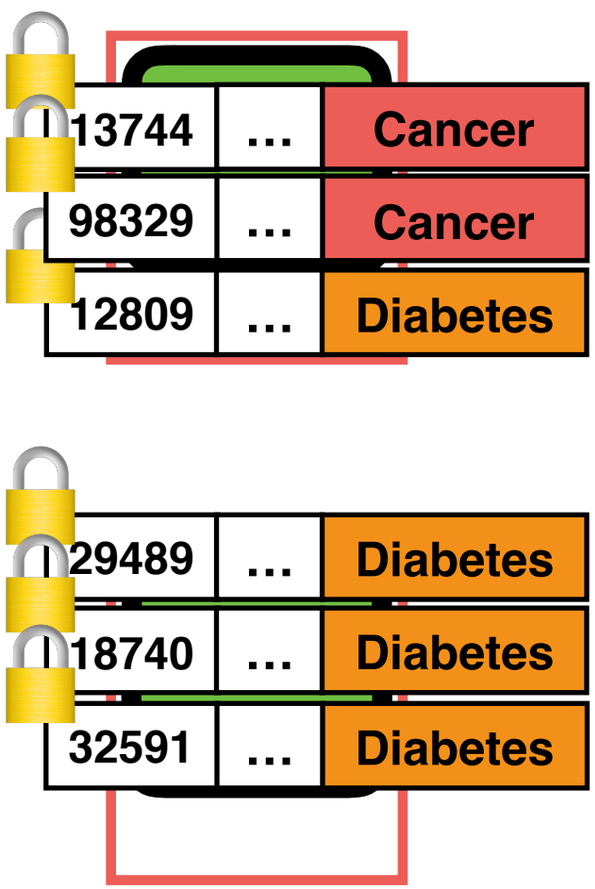

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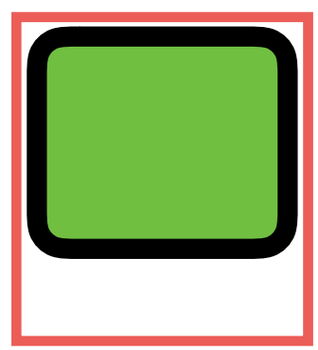

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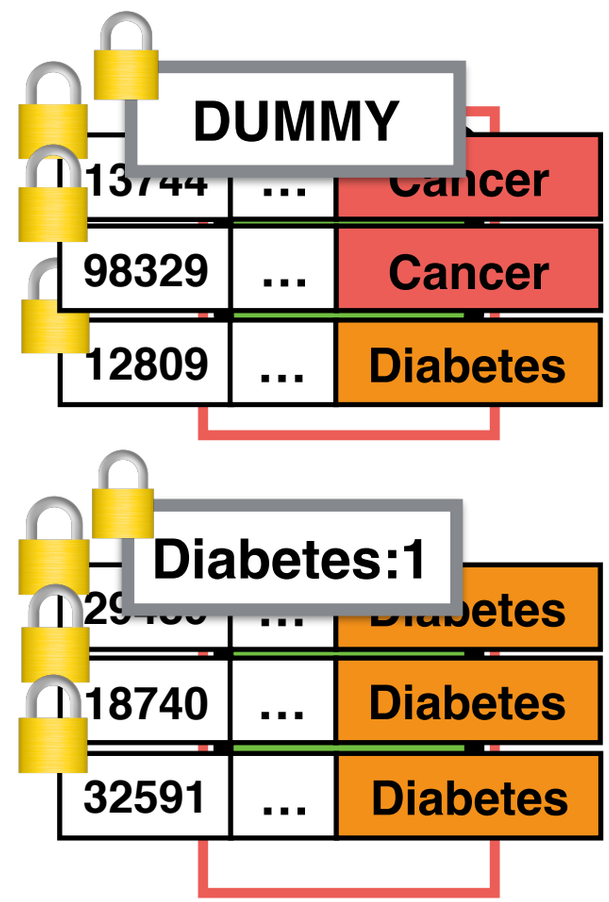

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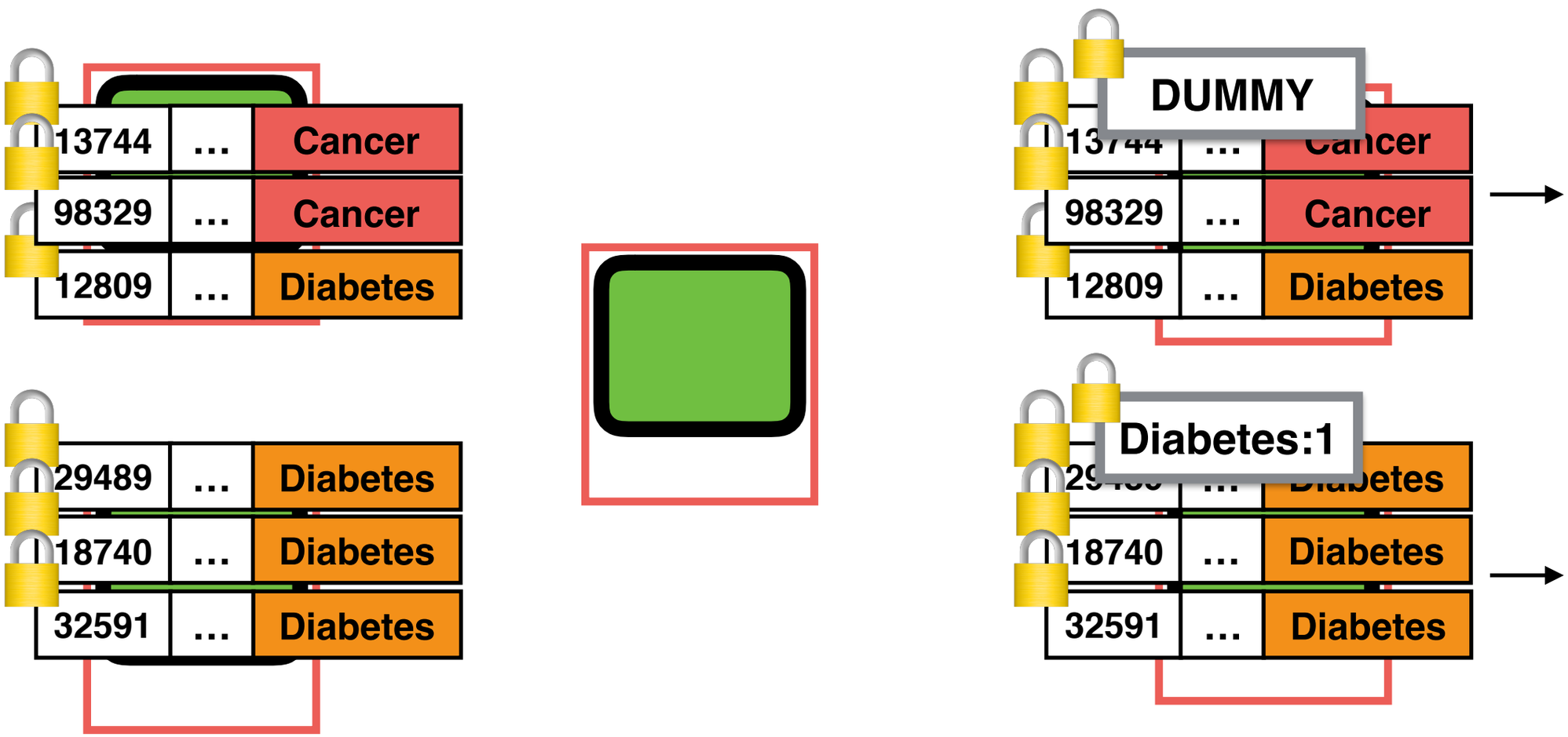

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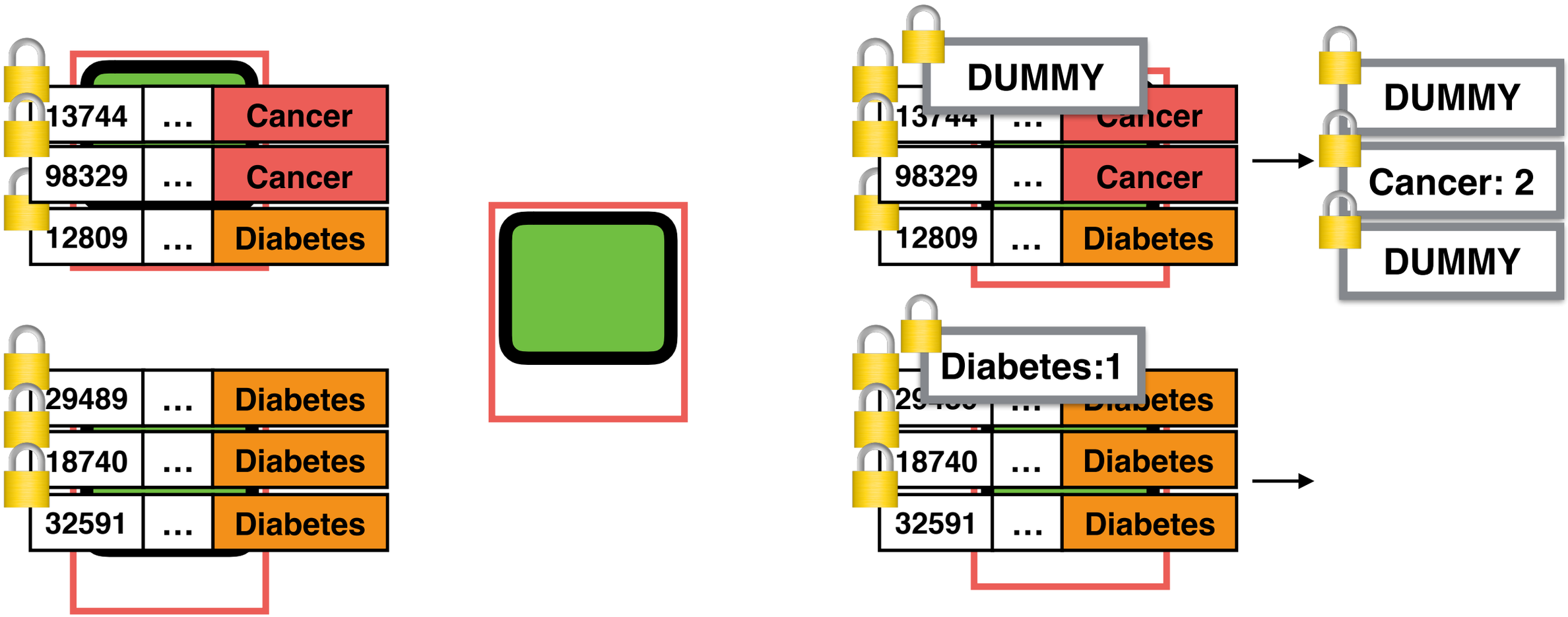

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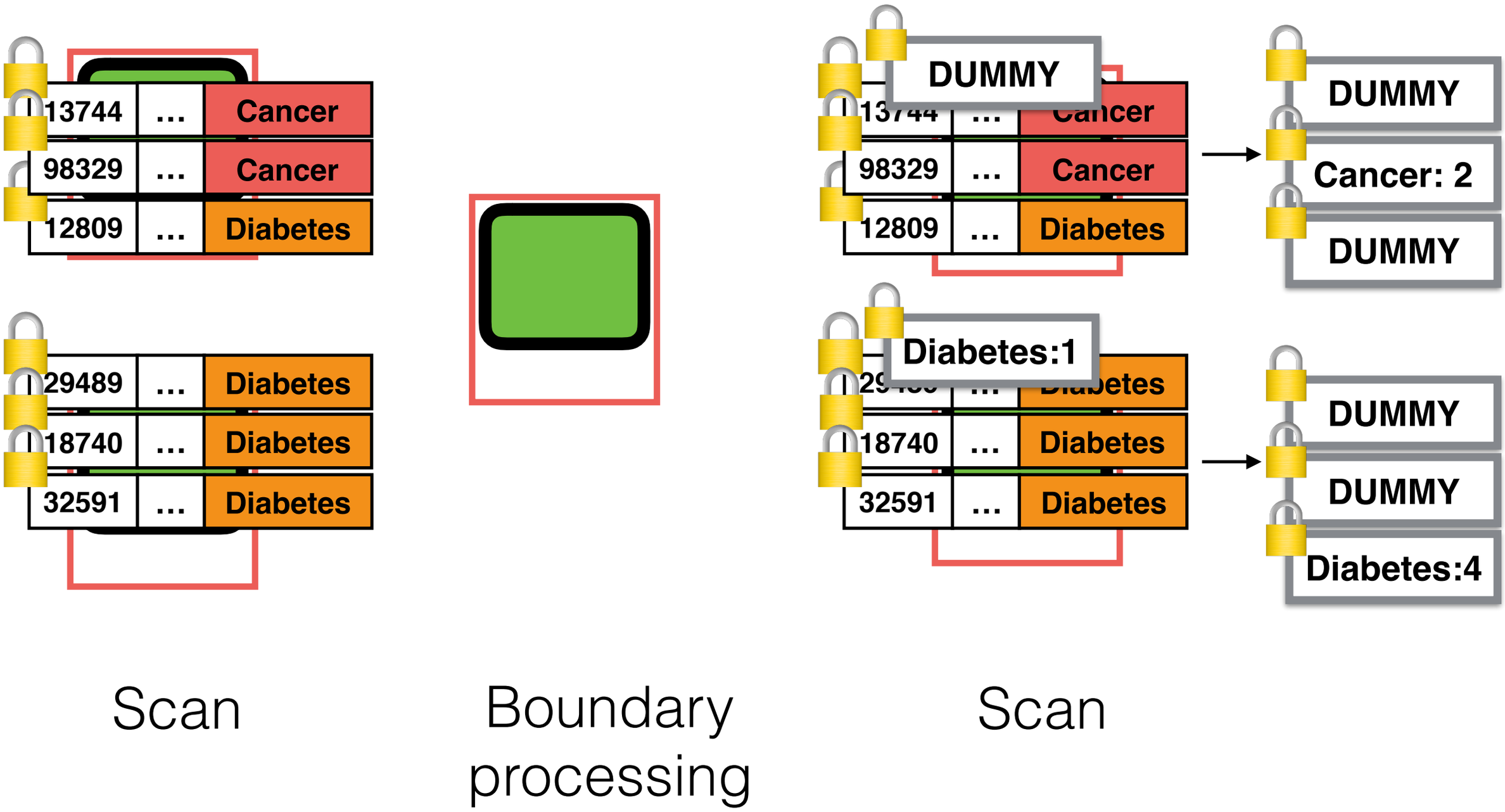

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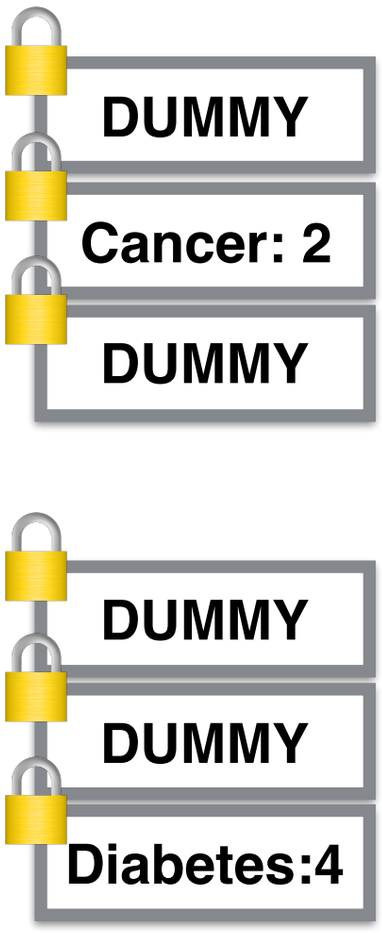

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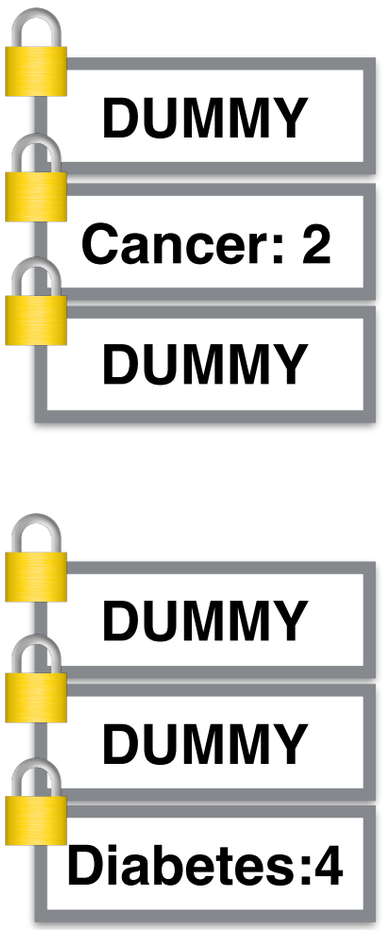

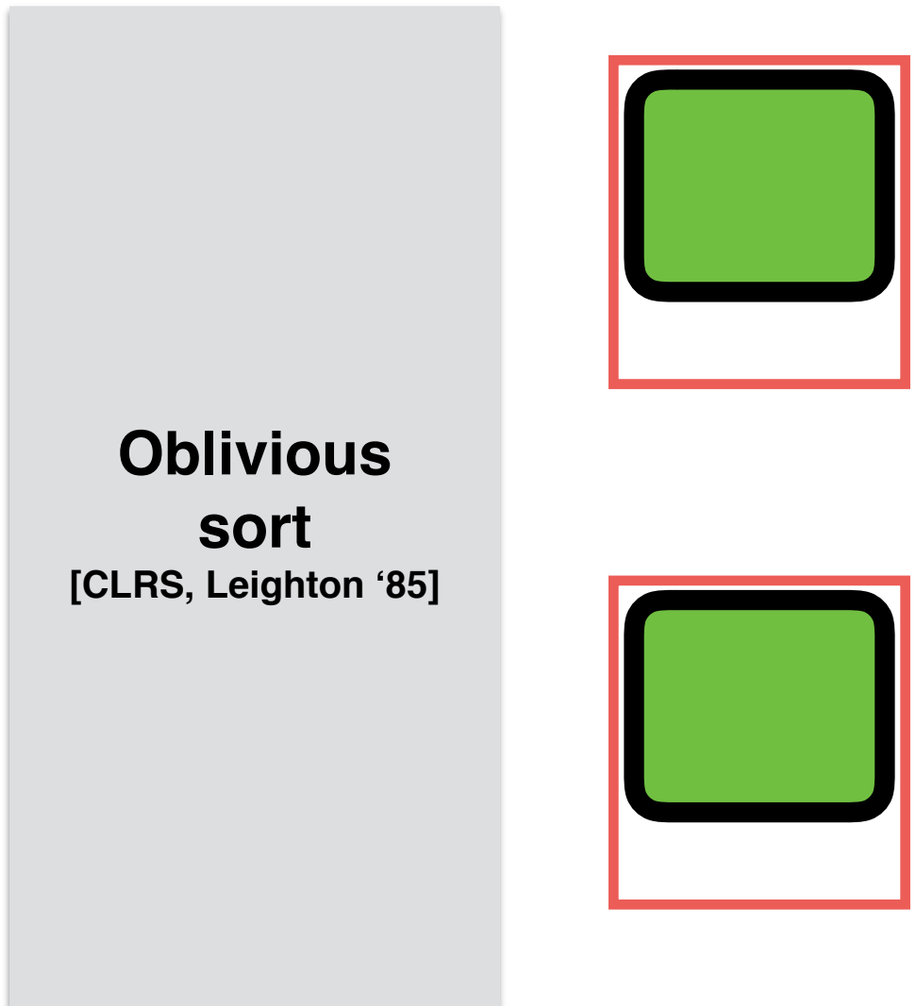

Sort

Oblivious aggregation

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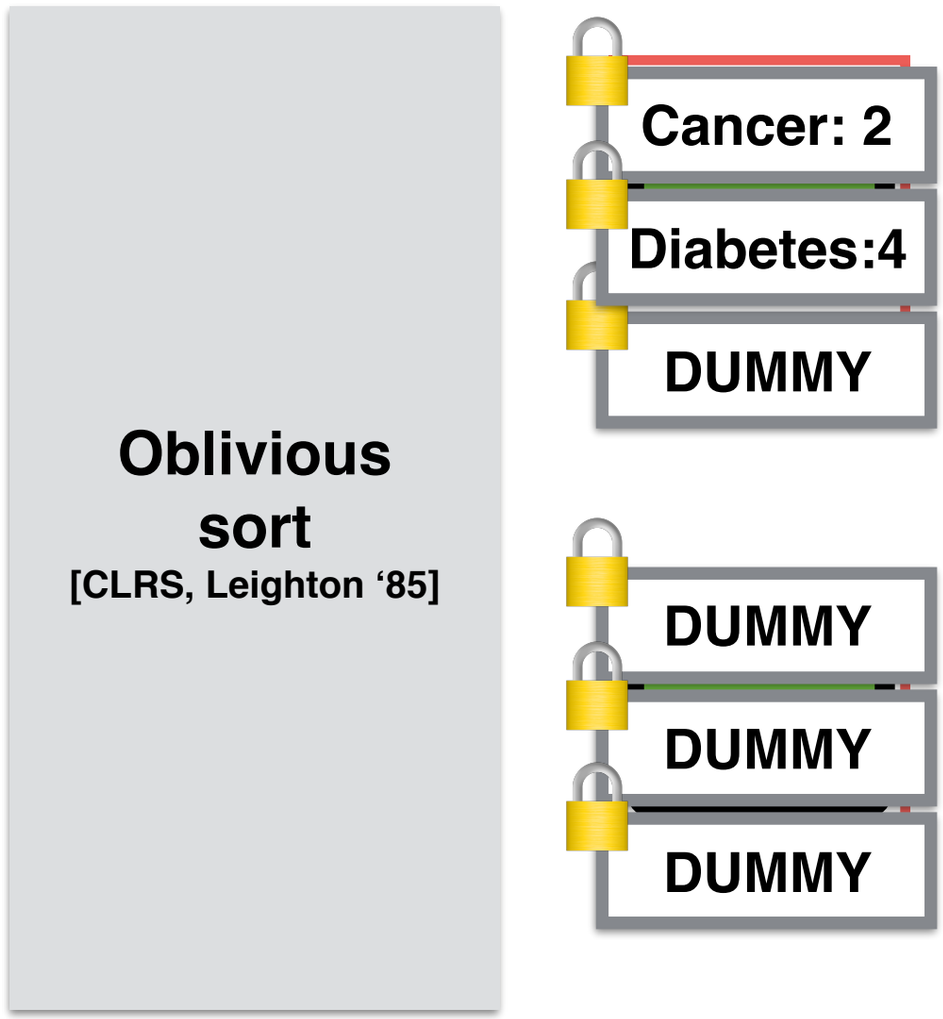

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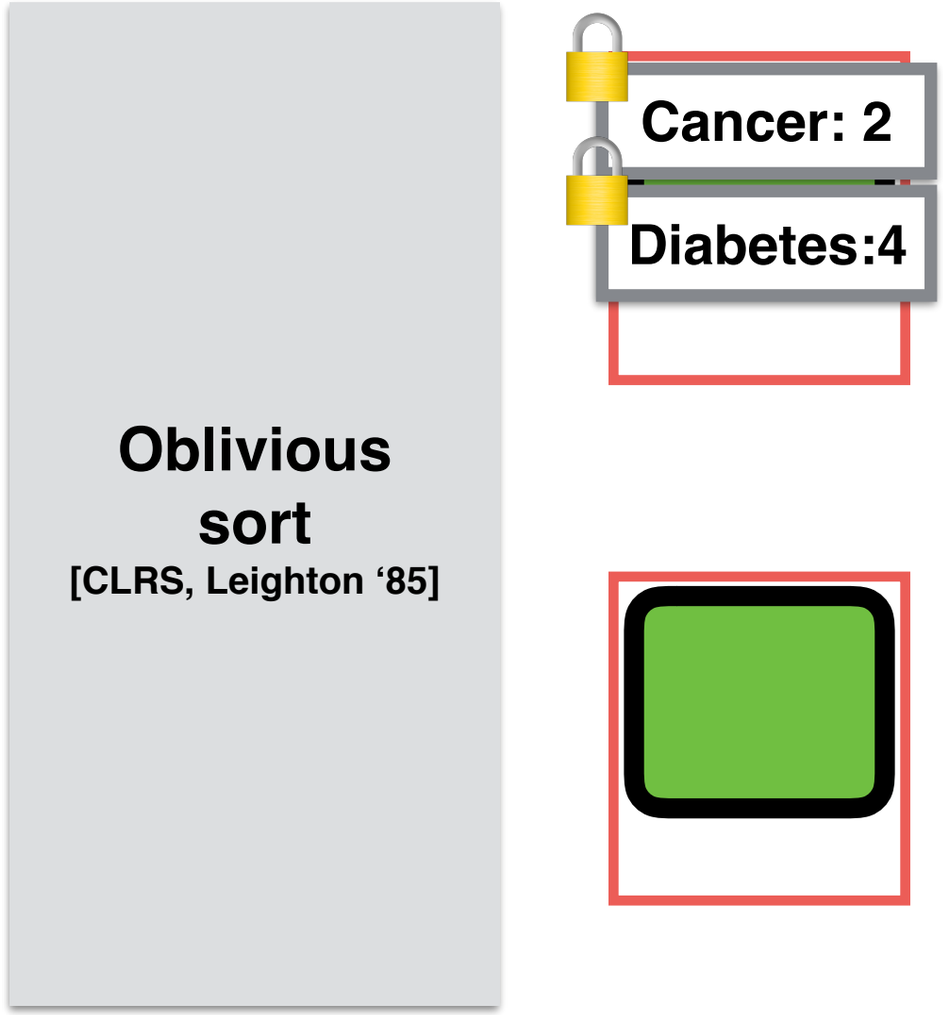

Sort

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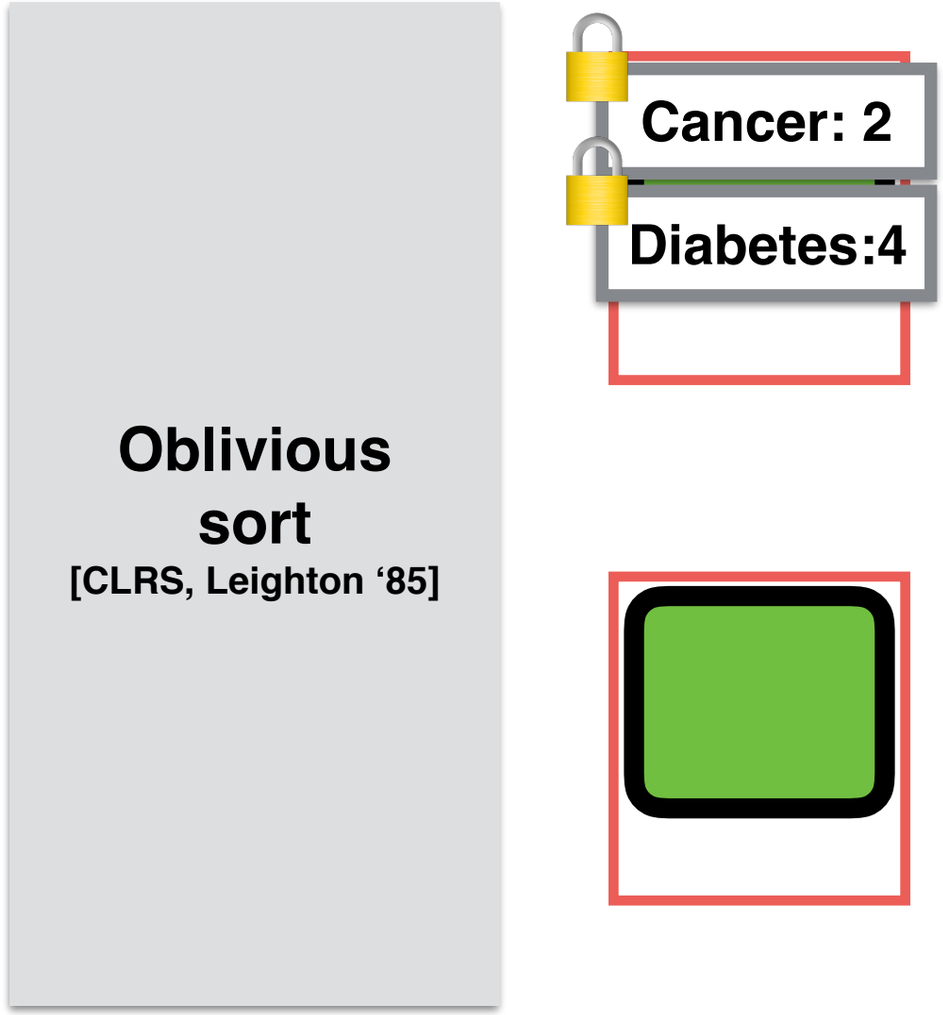
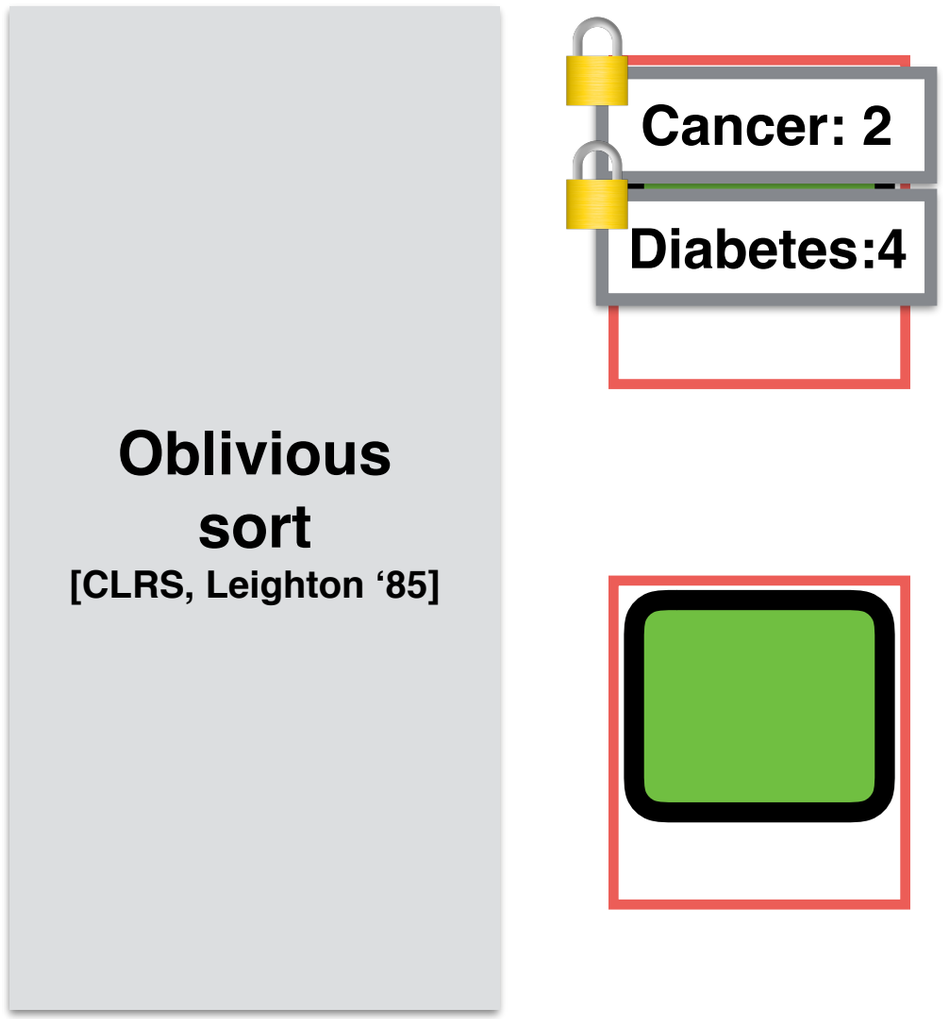


Sort

Final result

Oblivious aggregation

SELECT count(*) FROM medical GROUP BY disease



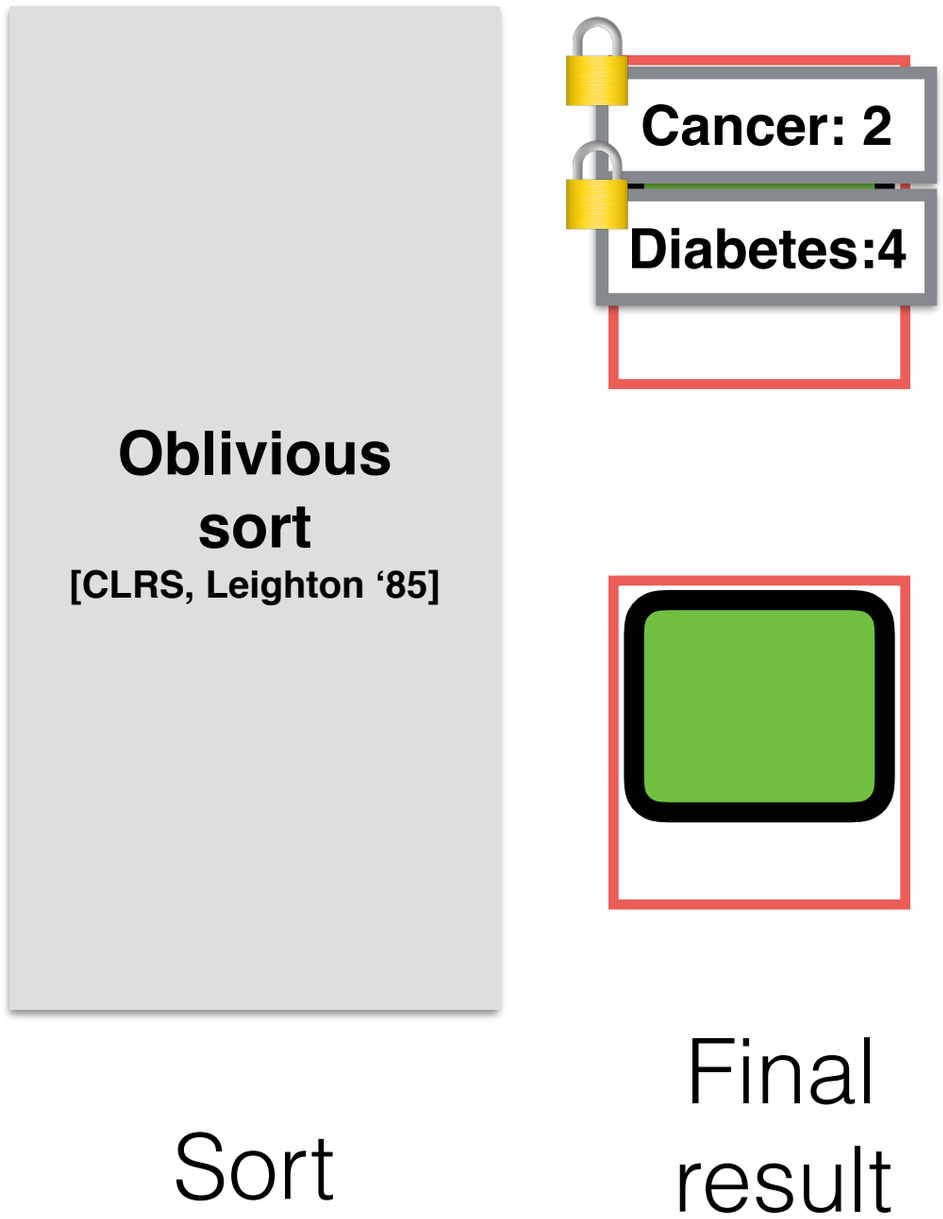
Sort

Final result

Aggregation has <u>two</u> sorts…

Oblivious aggregation

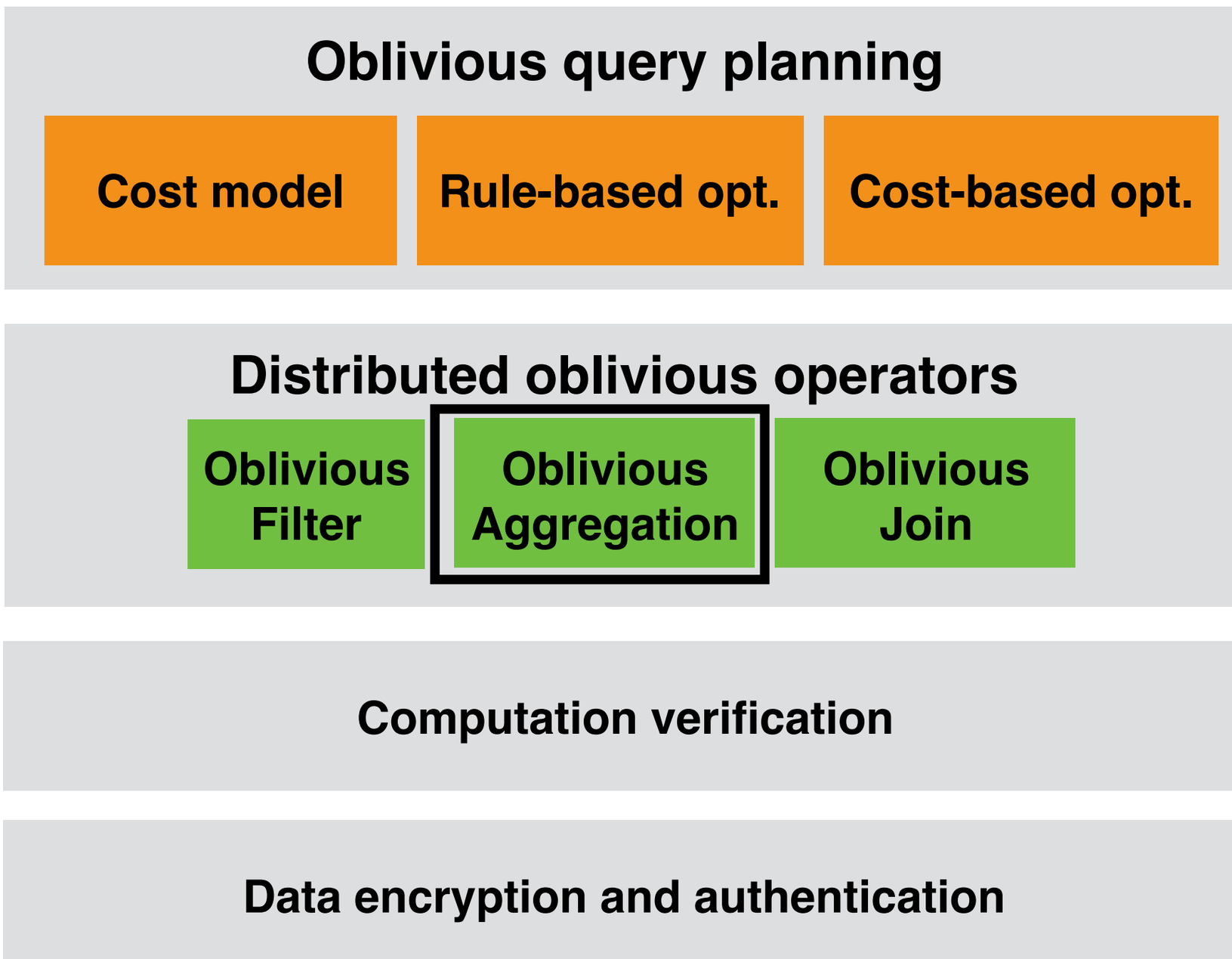
SELECT count(*) FROM medical GROUP BY disease



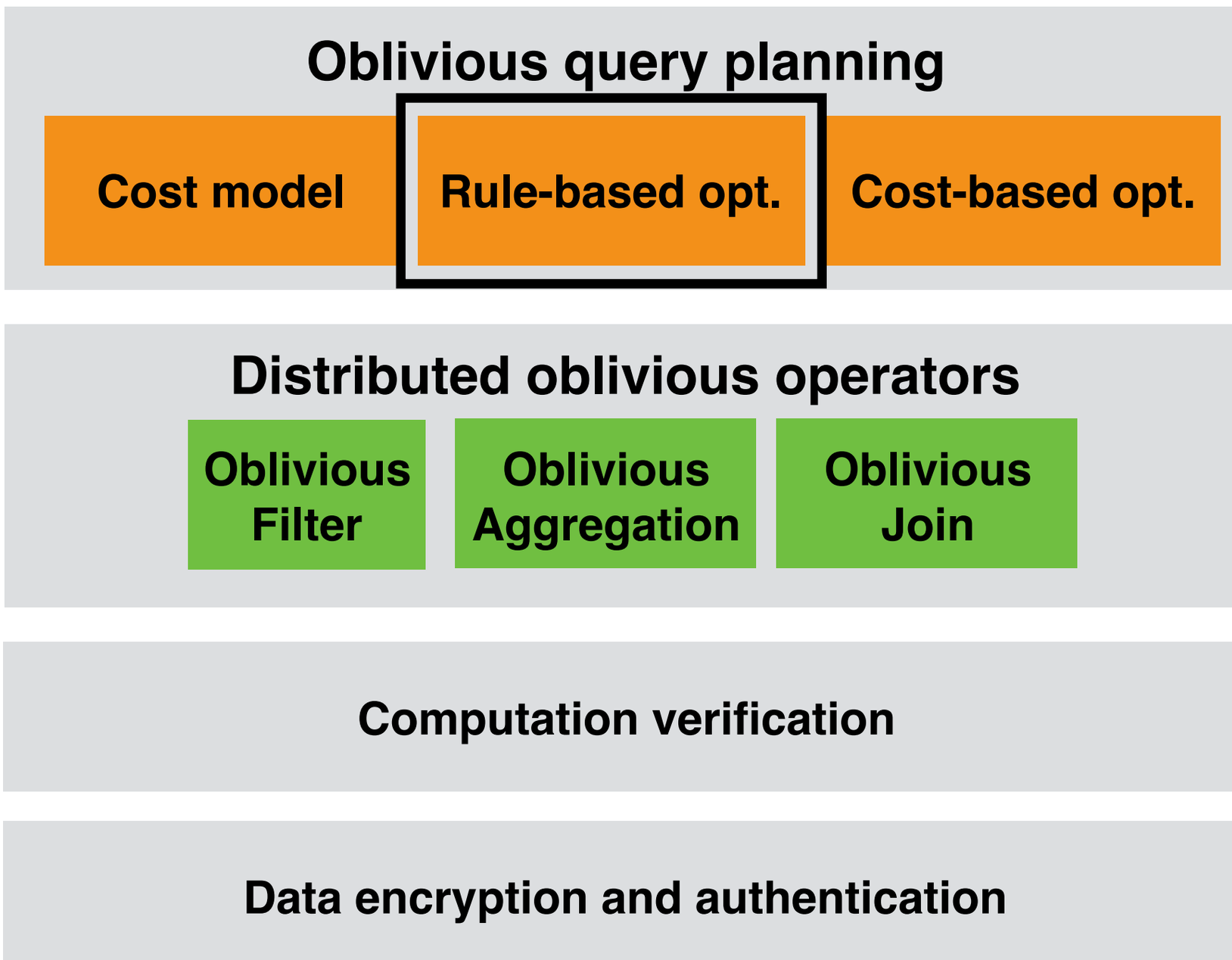
Aggregation has <u>two</u> sorts…

Can we do better?

Opaque components



Opaque components



Rule-based optimization

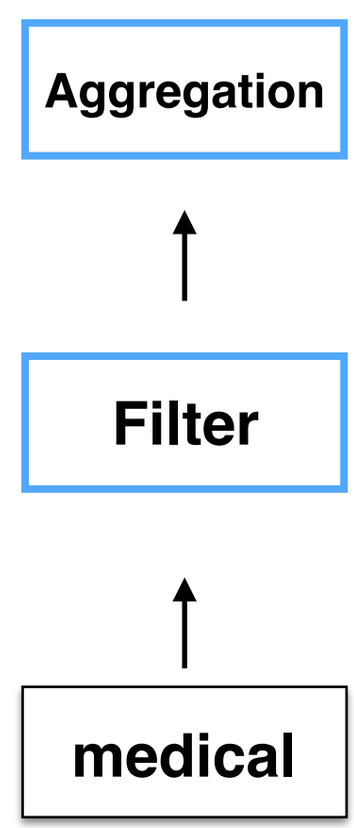
Rule-based optimization

```
SELECT count(*)
FROM medical
WHERE age > 30
GROUP BY disease
```

Rule-based optimization

Logical op.

```
SELECT count(*)
FROM medical
WHERE age > 30
GROUP BY disease
```



Insight 1

Insight 1

1. Split each logical operator into smaller Opaque operators

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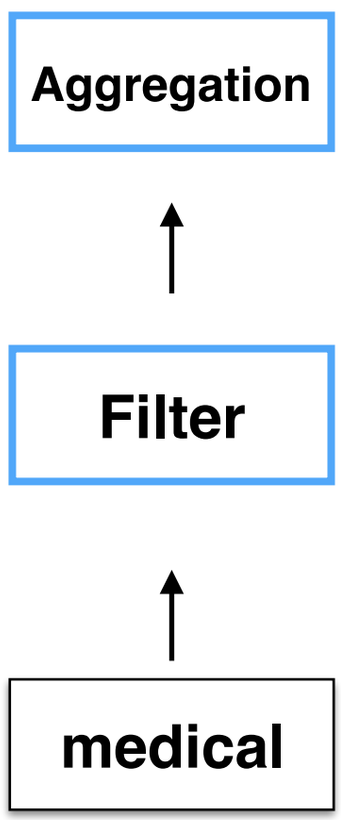
2. Take a global view across the plan to remove some Opaque operators

Rule-based optimization

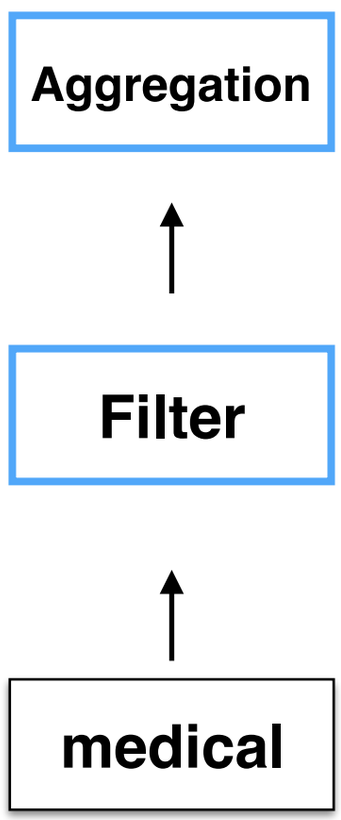
Logical op.



Rule-based optimization

Opaque op.

Logical op.



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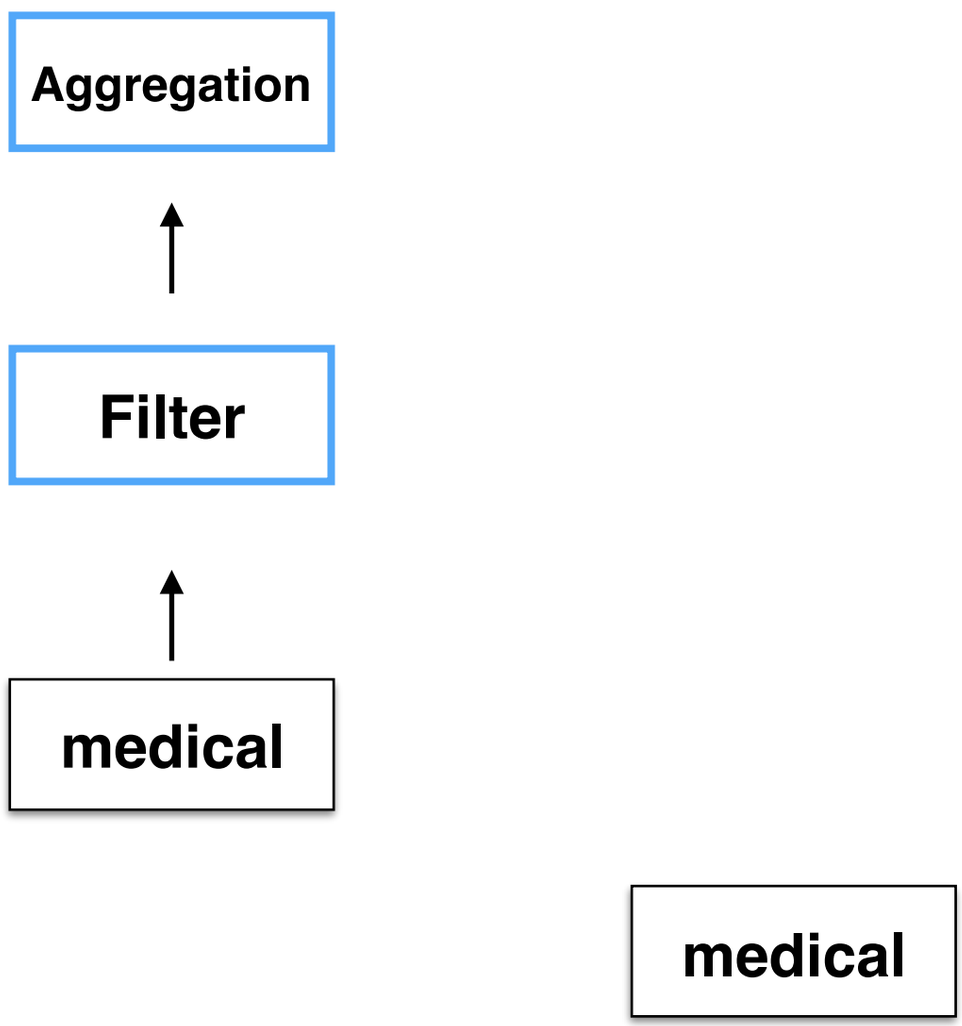

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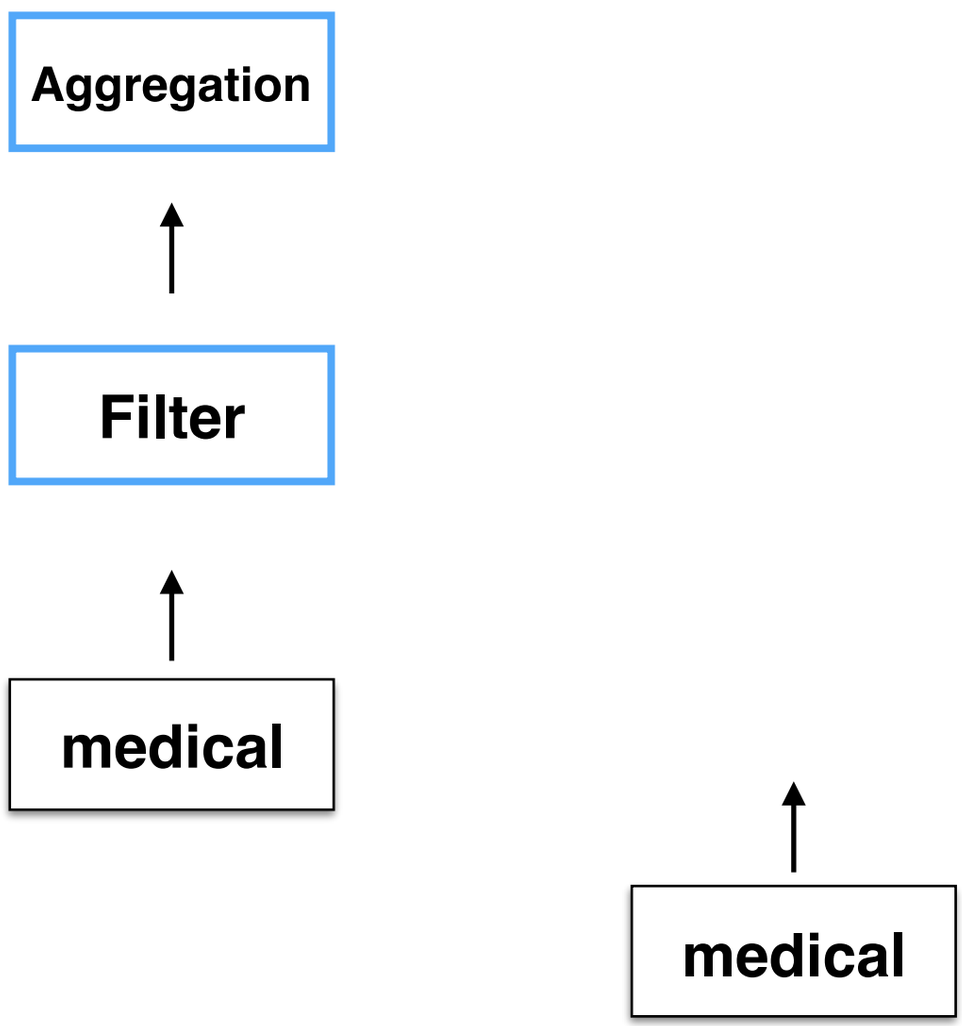

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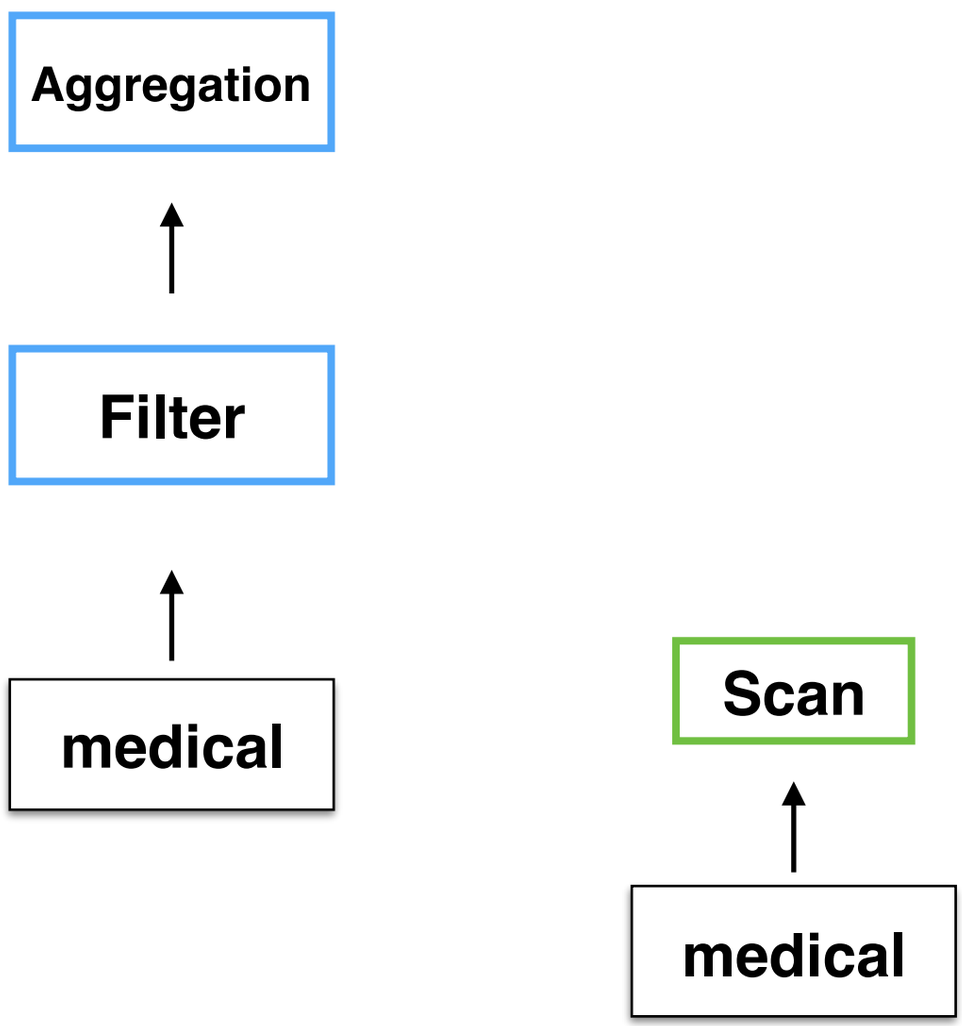

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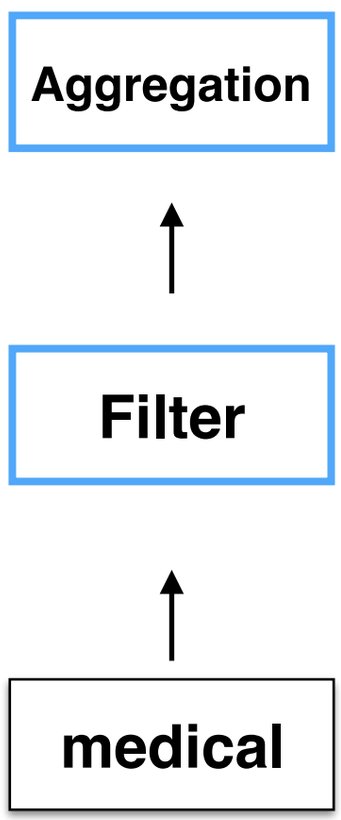

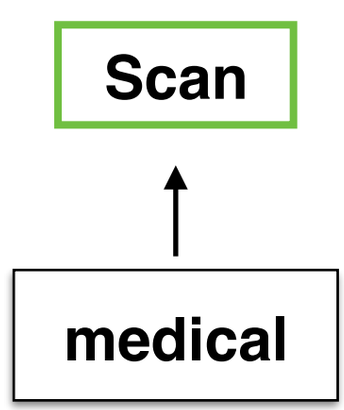

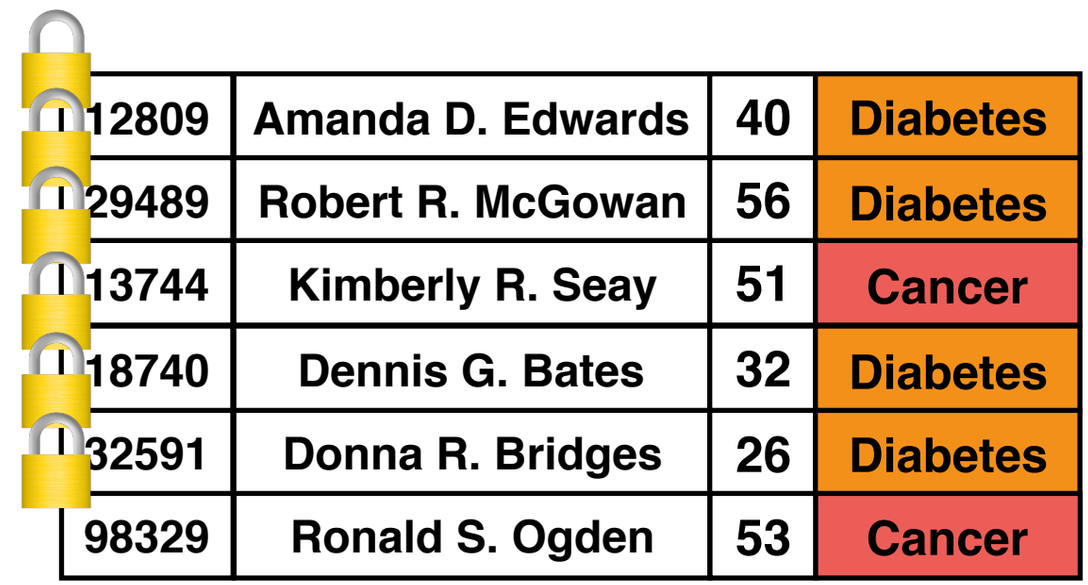

12809	Amanda D. Edwards	40	Diabetes
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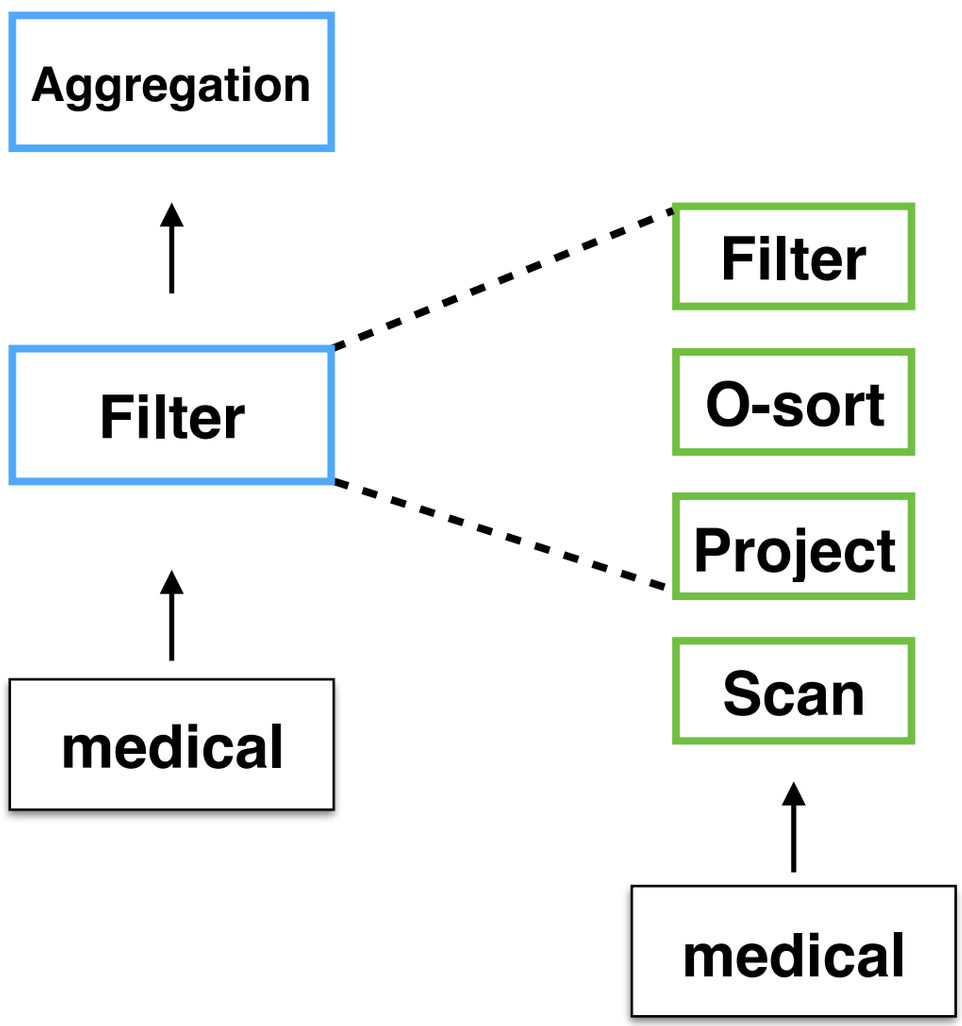

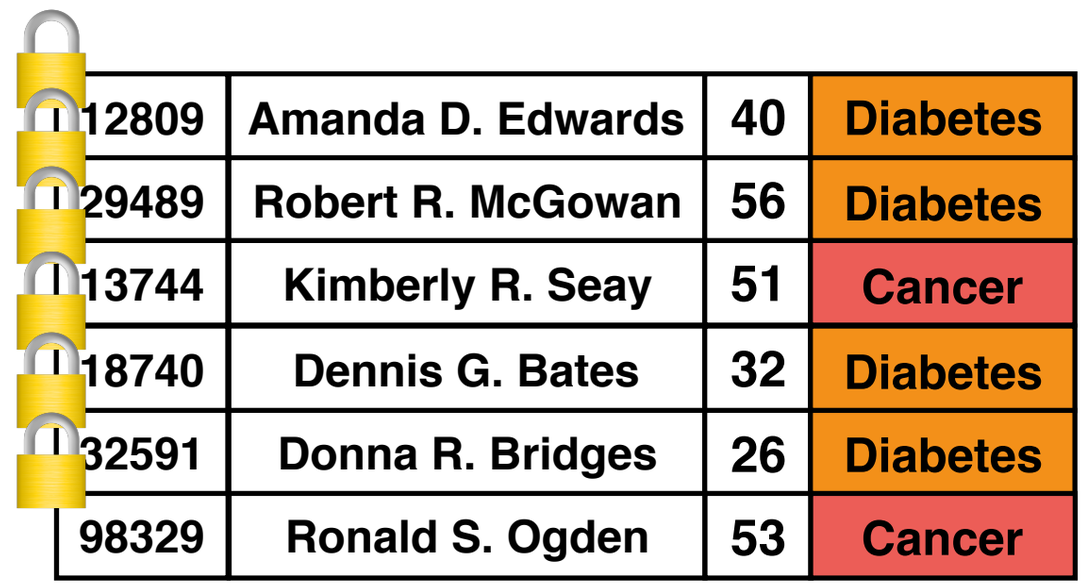

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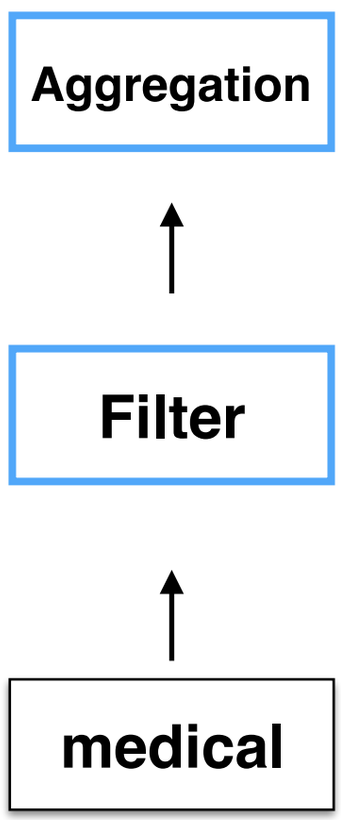

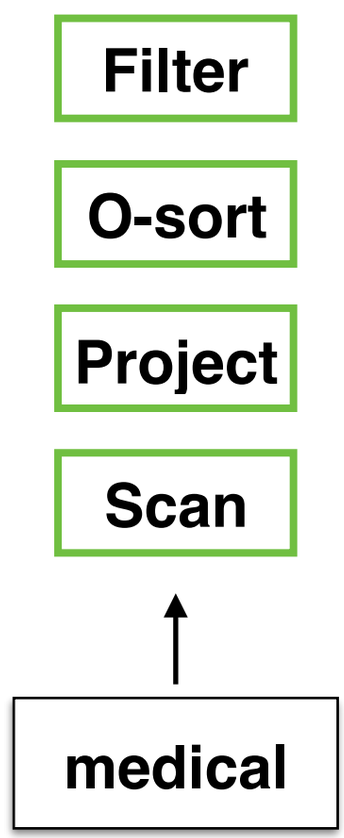

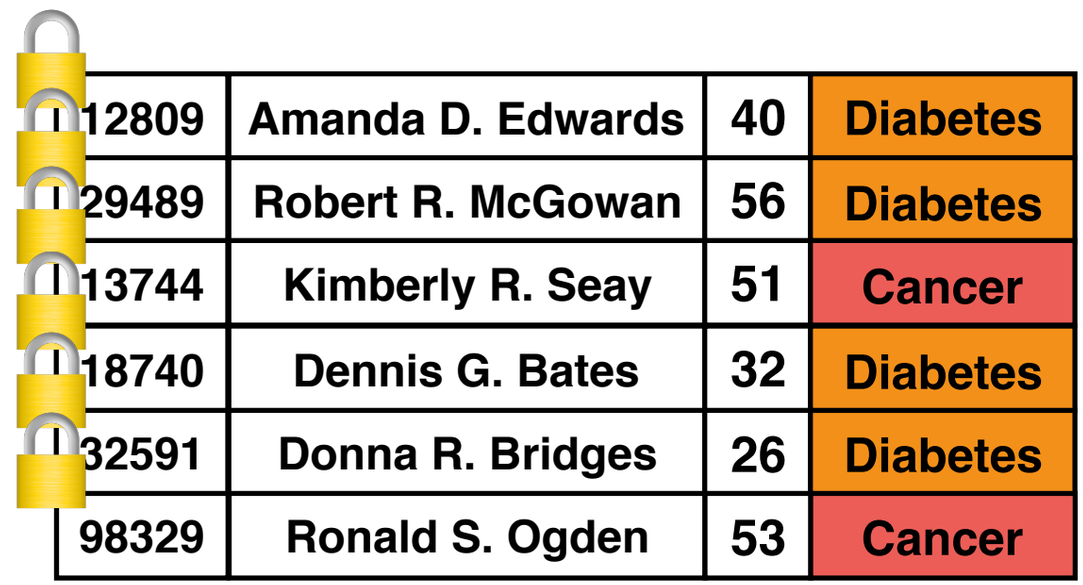

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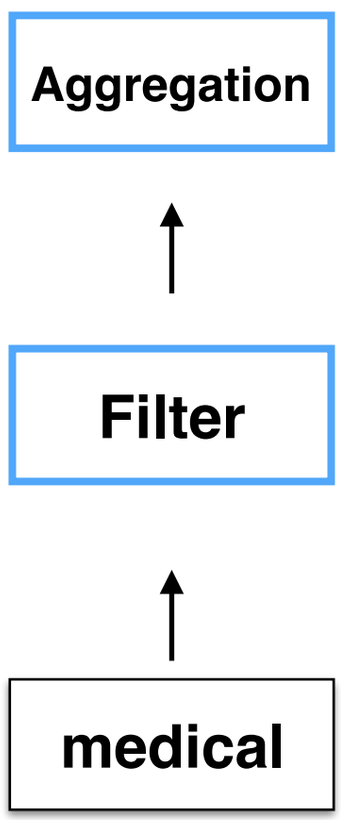

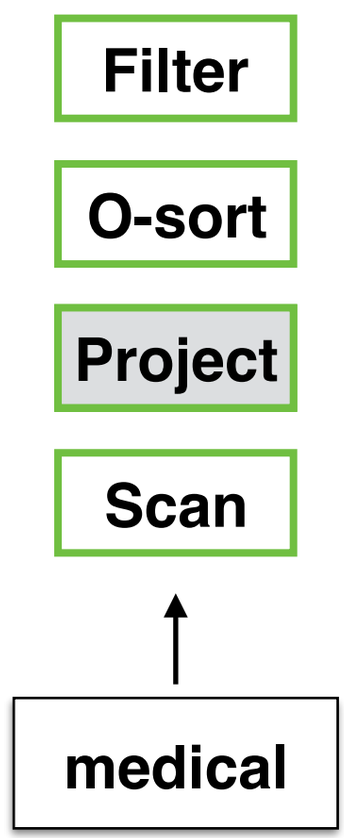

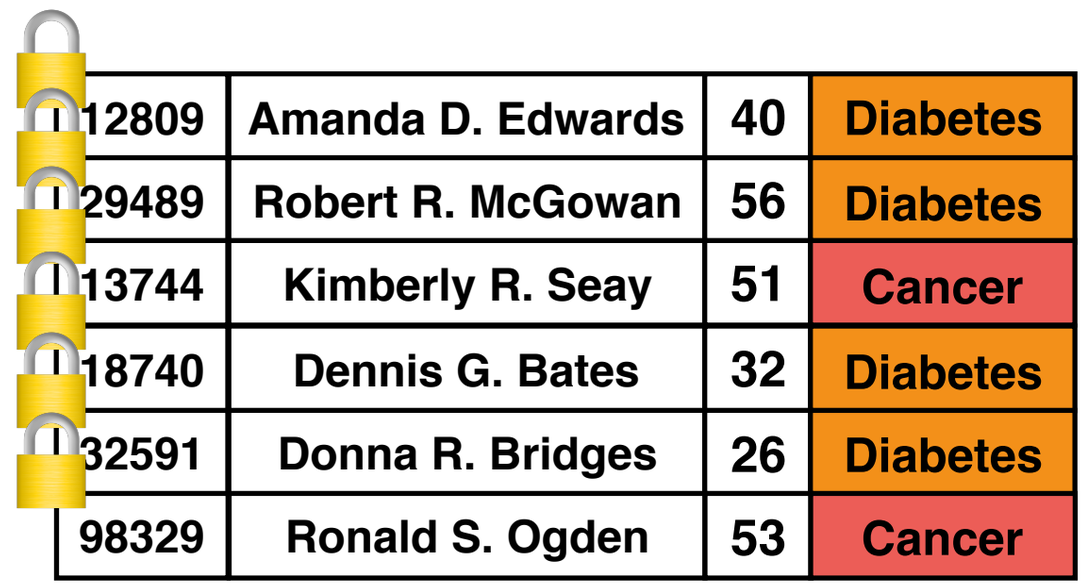

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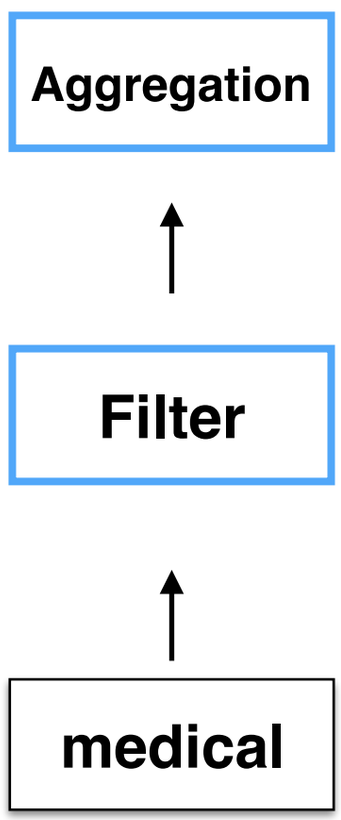

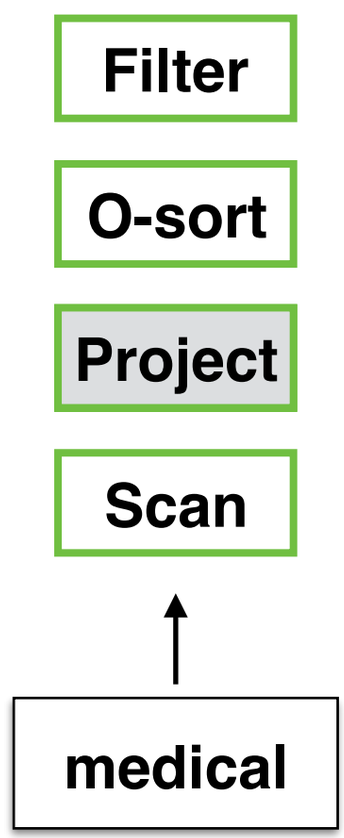

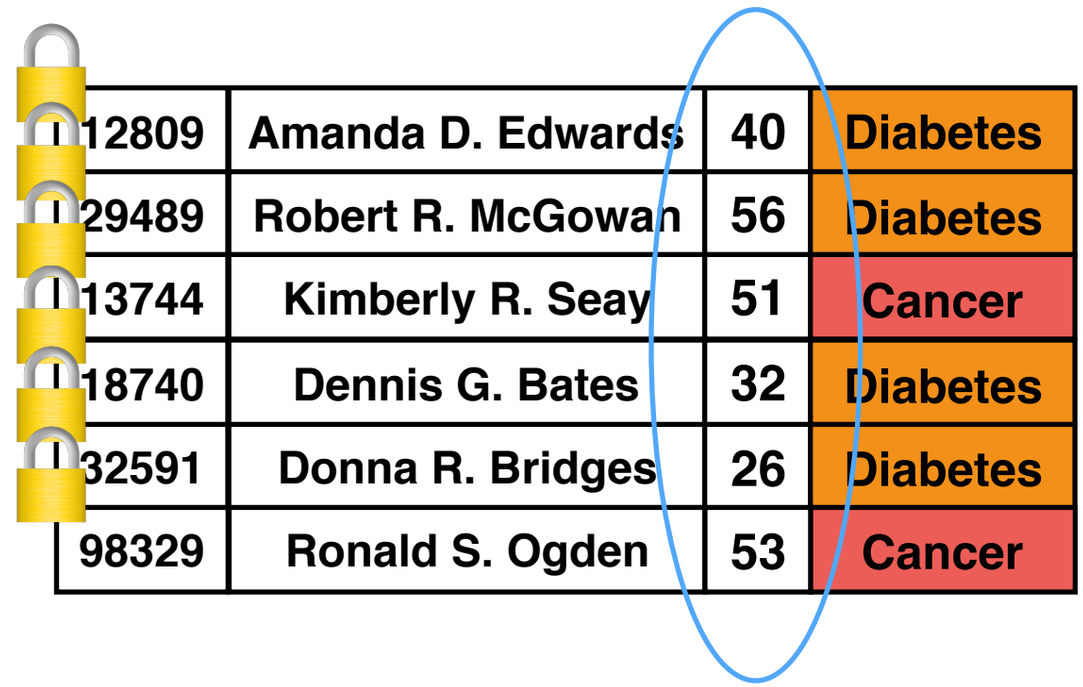

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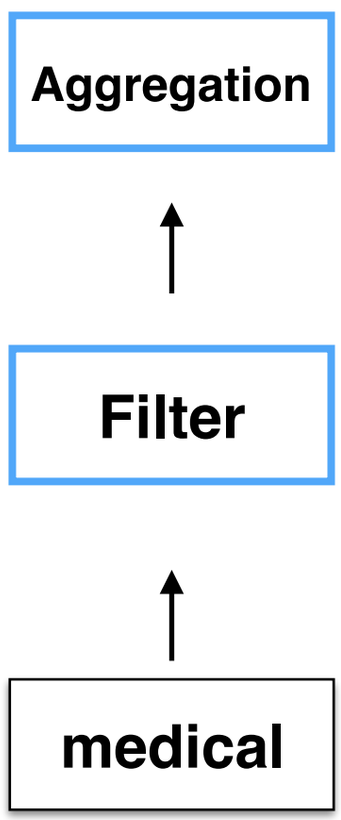

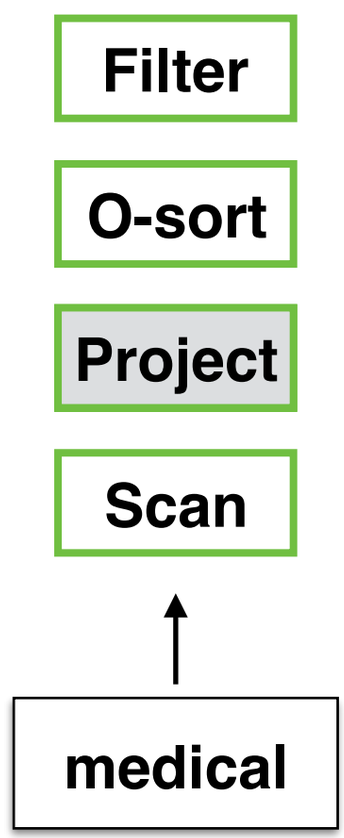

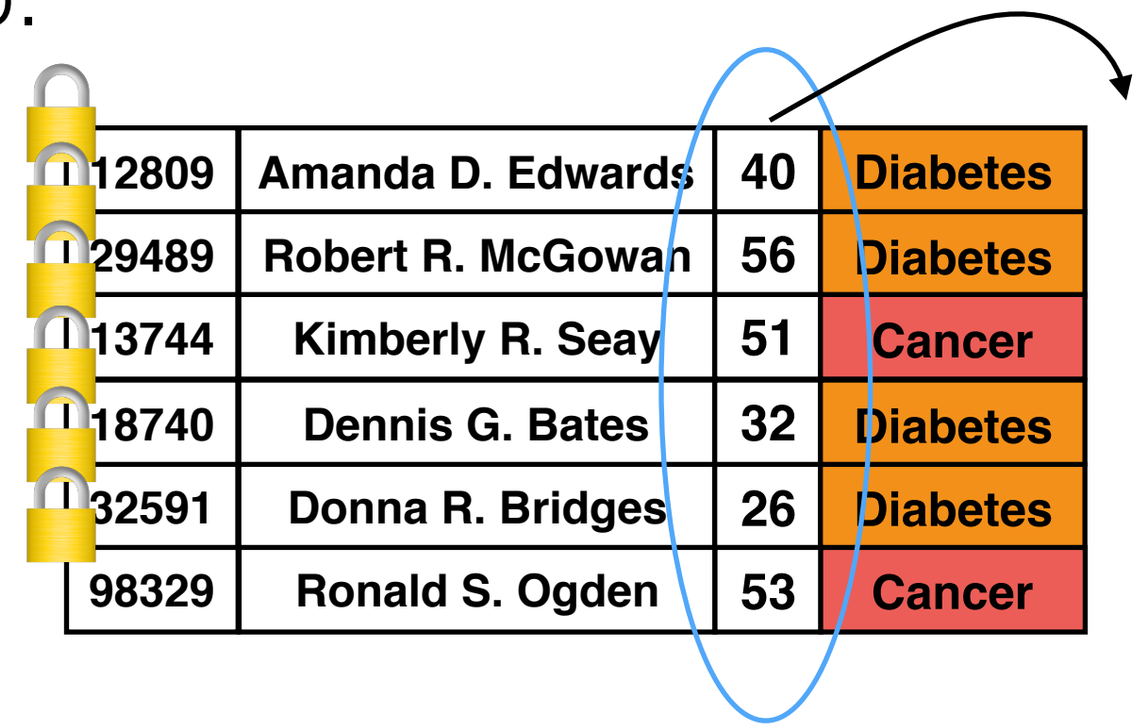

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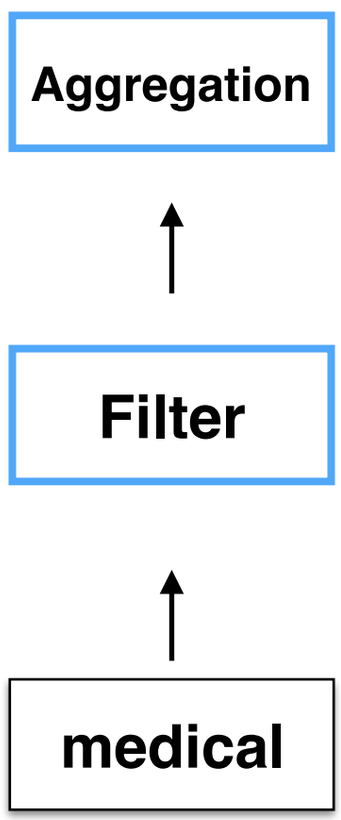

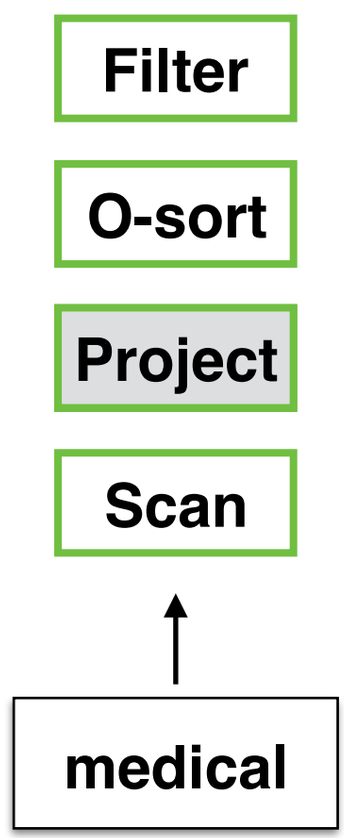

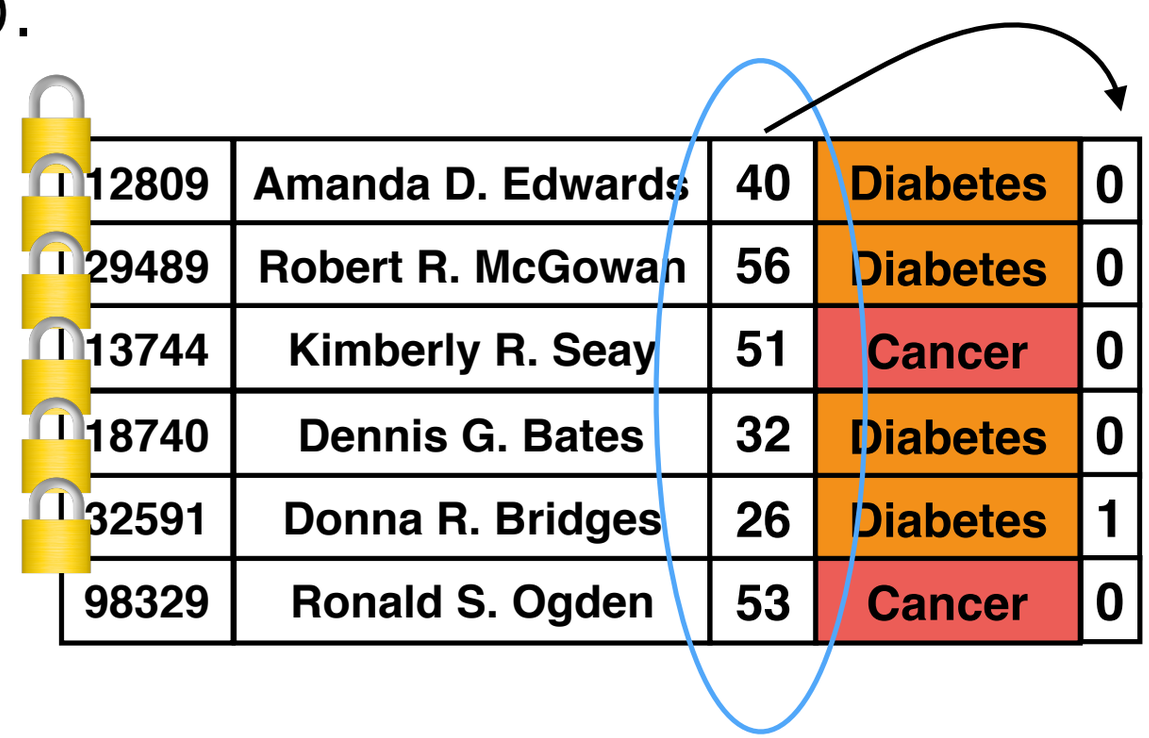

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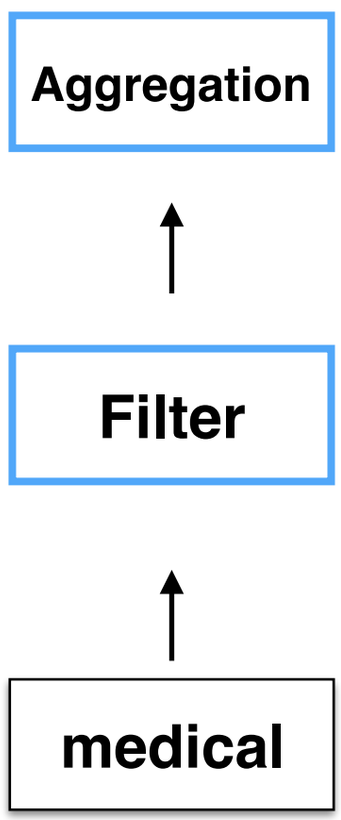
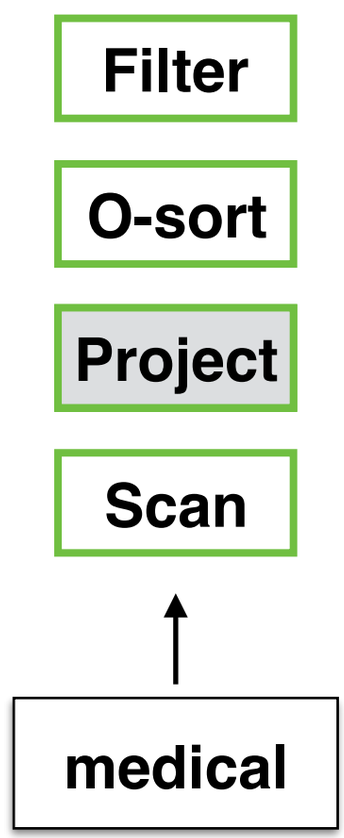
13744	Kimberly R. Seay	51	Cancer	0
18740	Dennis G. Bates	32	Diabetes	0
32591	Donna R. Bridges	26	Diabetes	1
98329	Ronald S. Ogden	53	Cancer	0

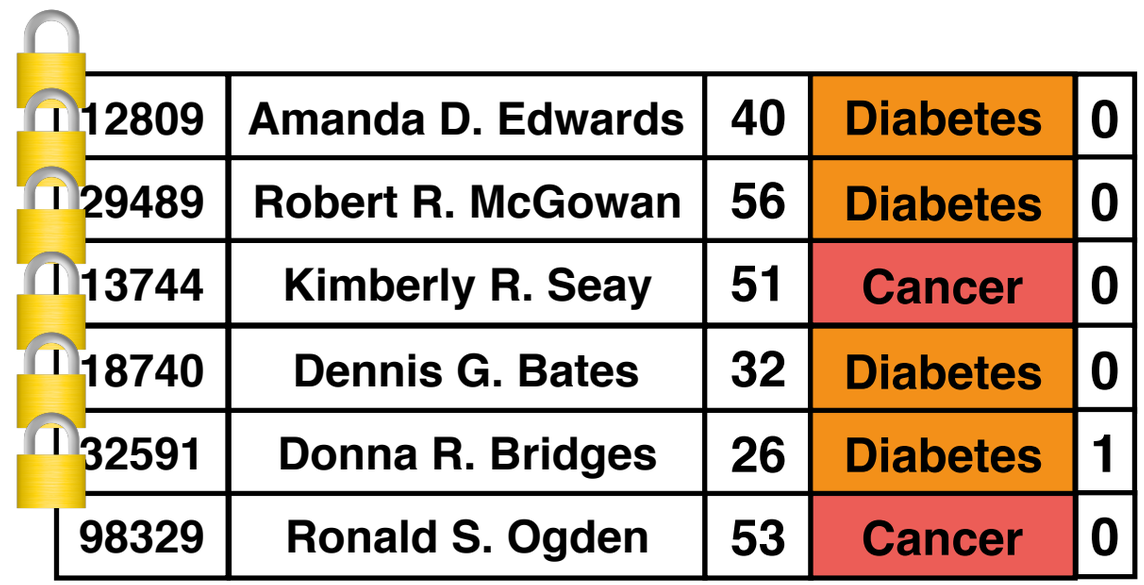
Rule-based optimization

Opaque op.

Logical op.







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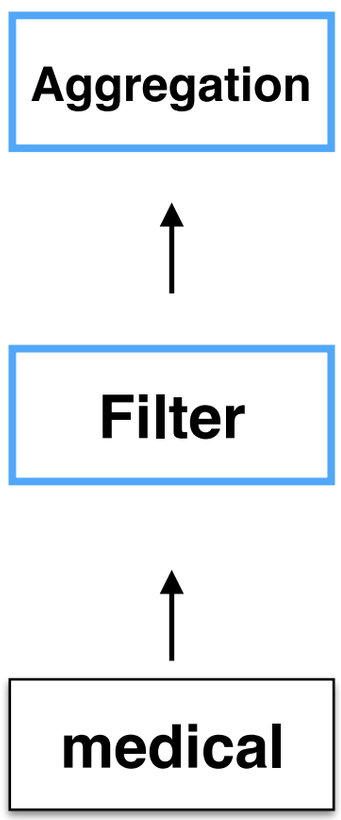
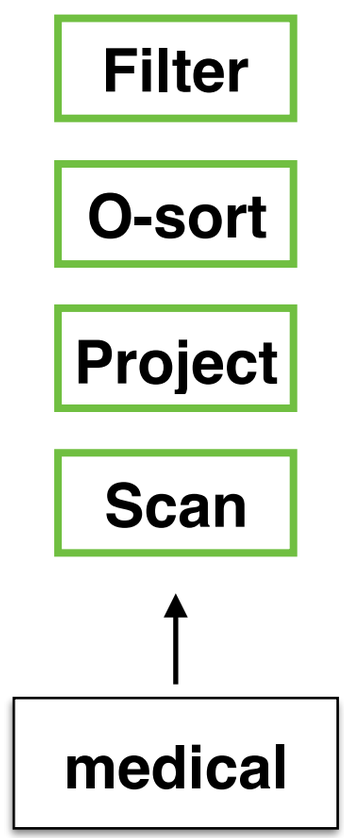
18740	Dennis G. Bates	32	Diabetes	0
32591	Donna R. Bridges	26	Diabetes	1
98329	Ronald S. Ogden	53	Cancer	0

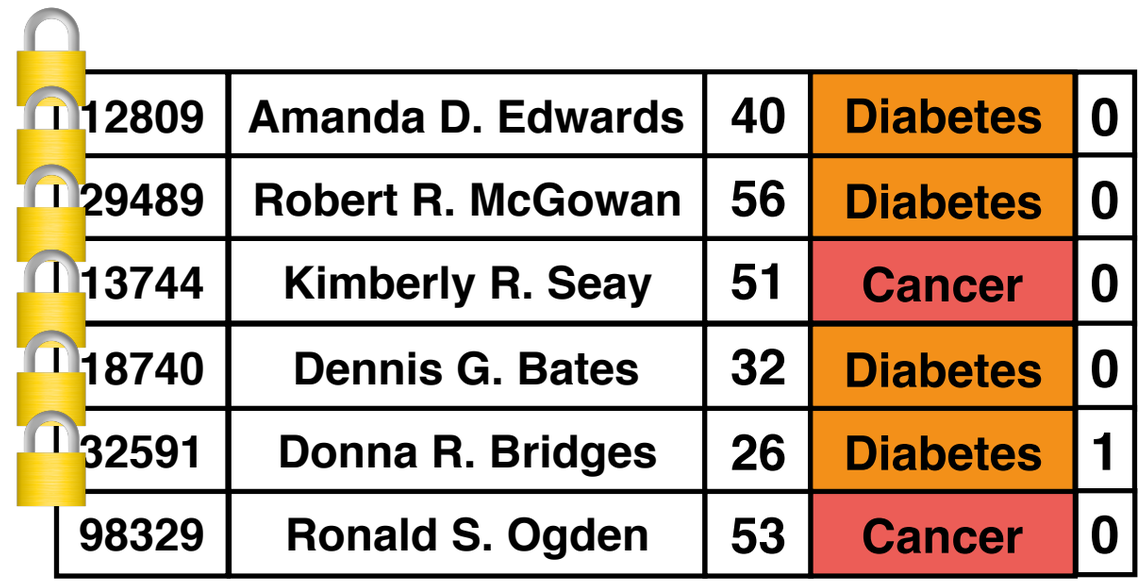
Rule-based optimization

Opaque op.

Logical op.







12809	Amanda D. Edwards	40	Diabetes	0
29489	Robert R. McGowan	56	Diabetes	0
13744	Kimberly R. Seay	51	Cancer	0
18740	Dennis G. Bates	32	Diabetes	0
32591	Donna R. Bridges	26	Diabetes	1
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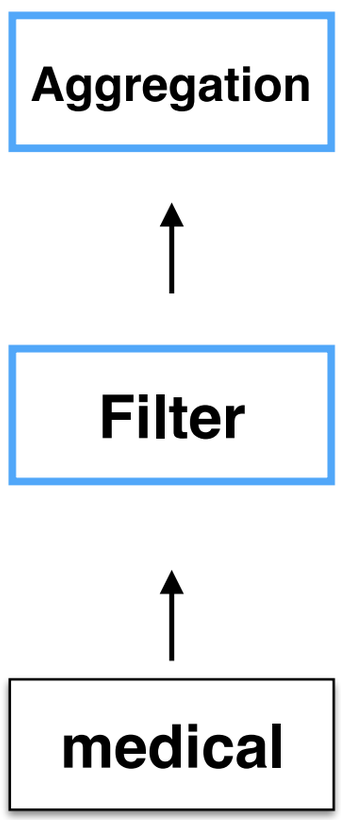
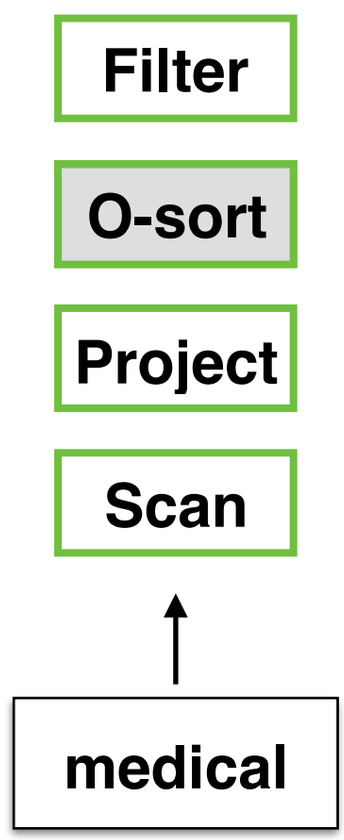
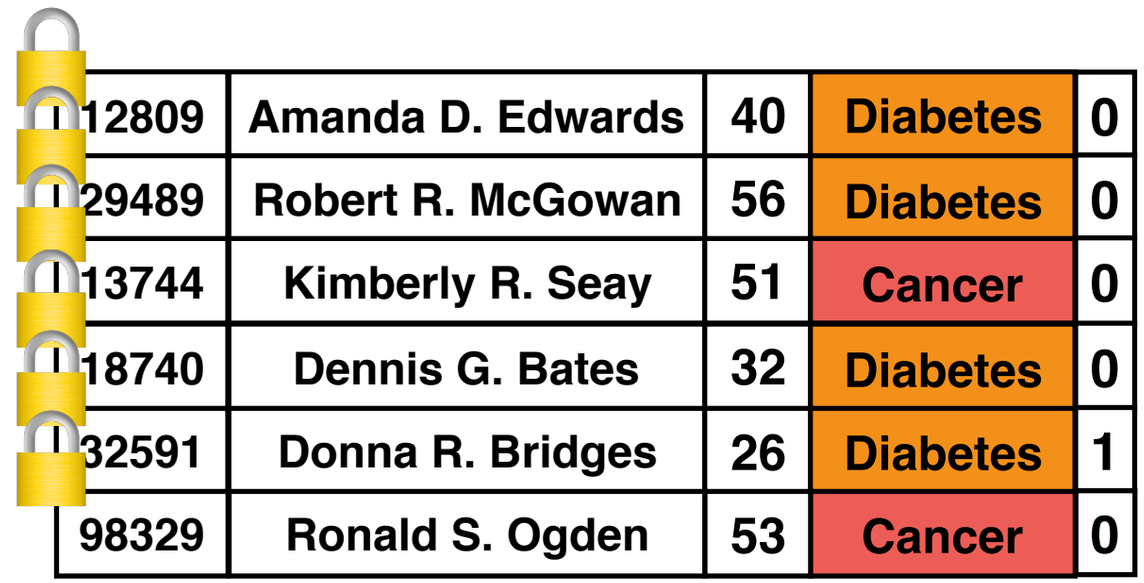
Logical op.







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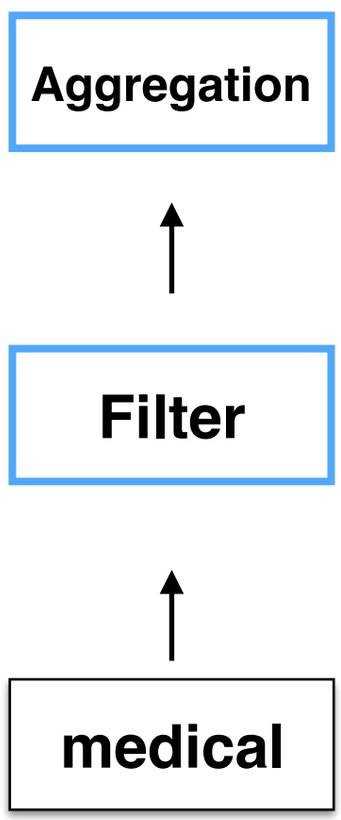

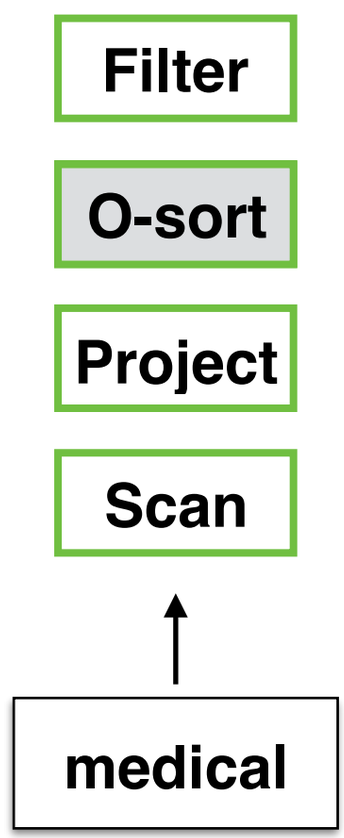

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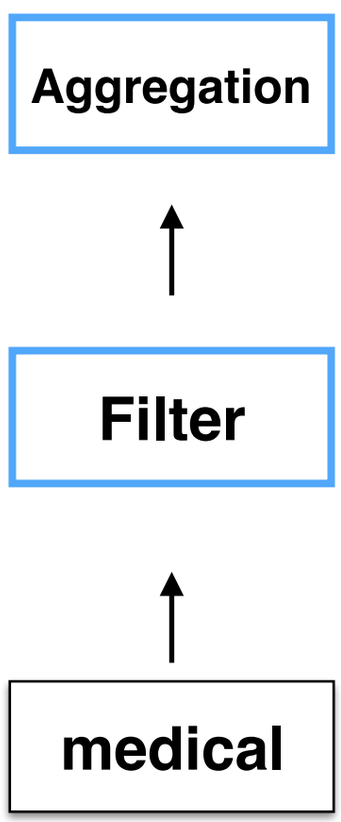

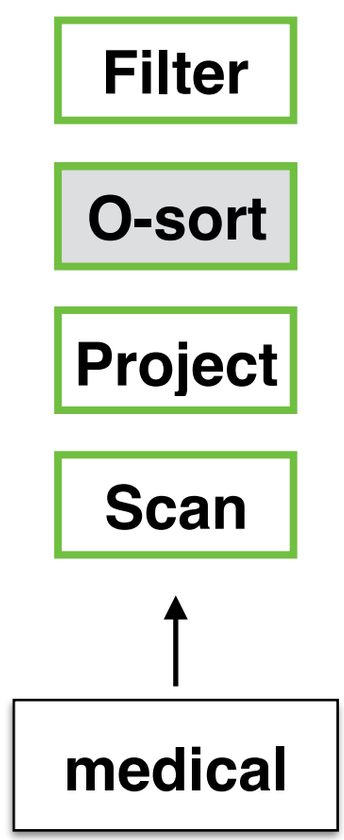

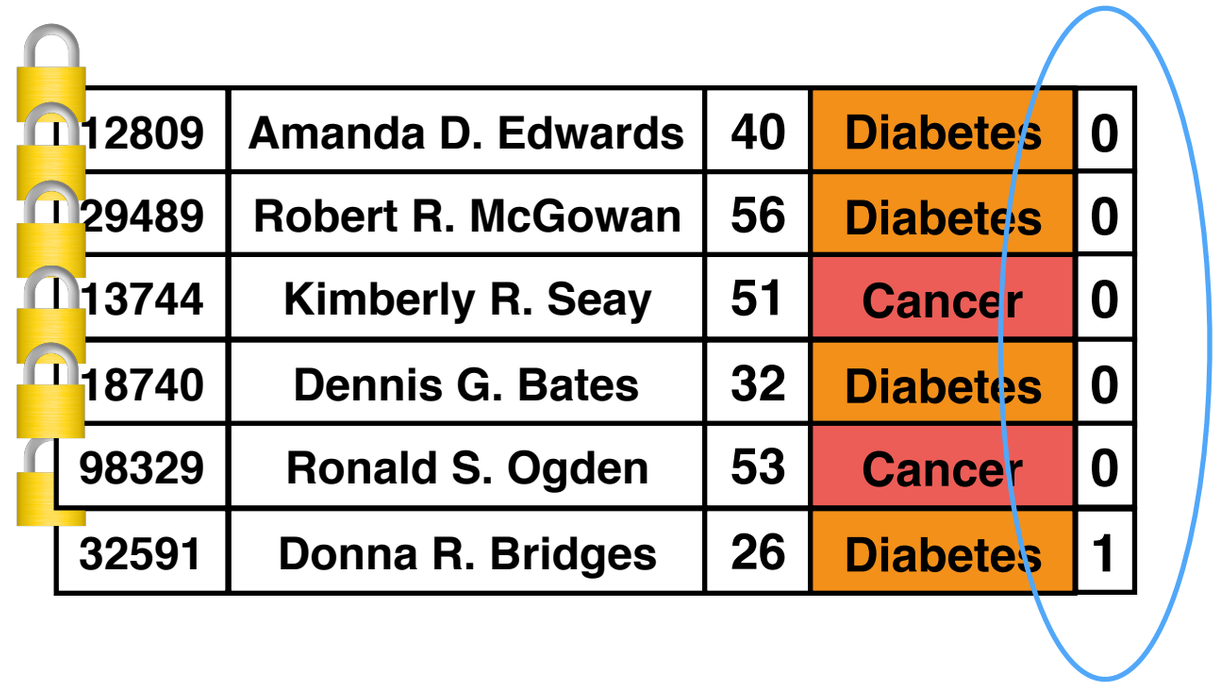

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Rule-based optimization

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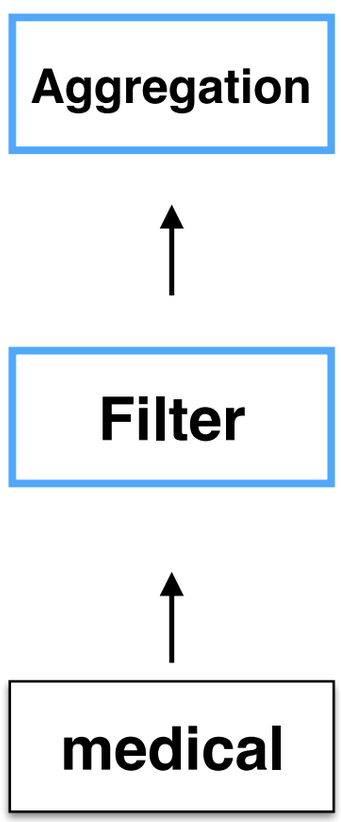

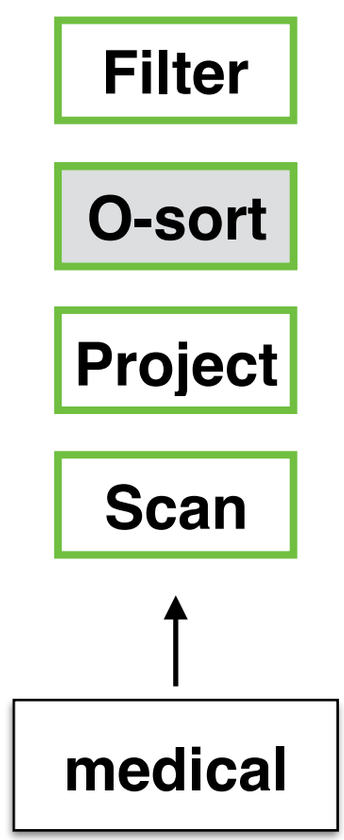

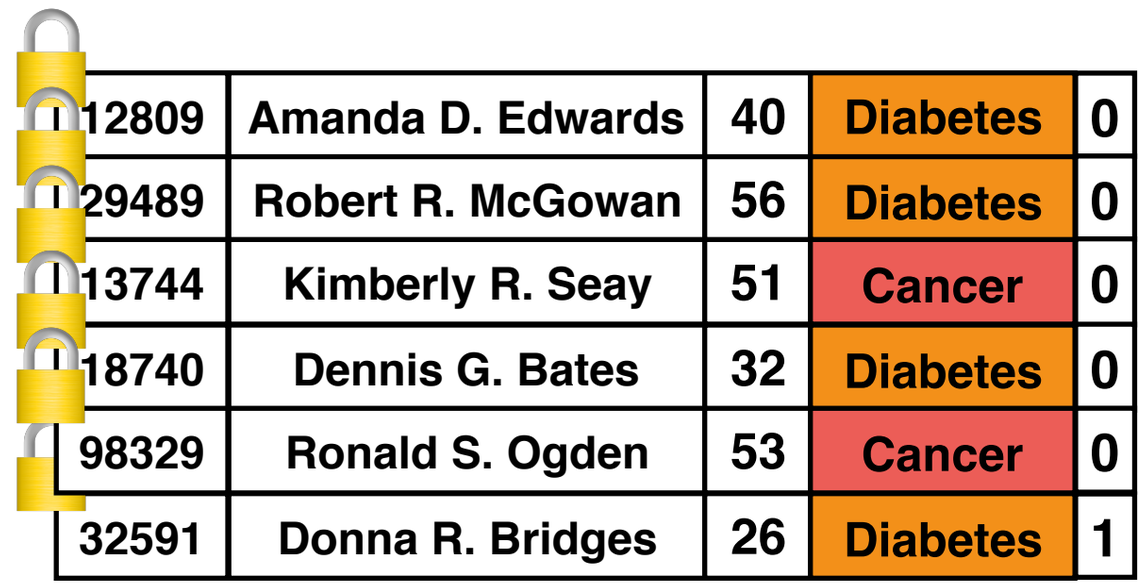

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Rule-based optimization

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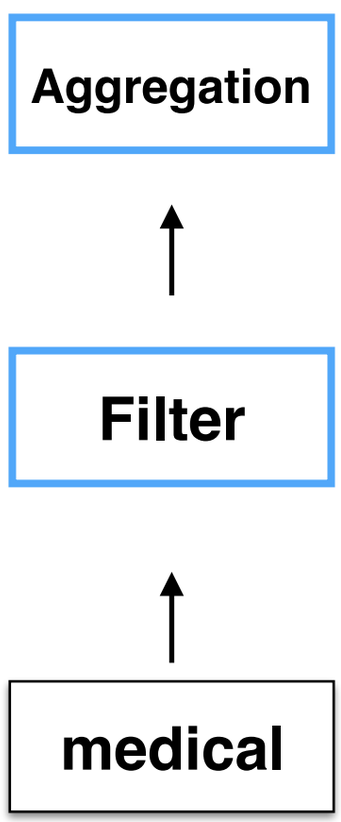

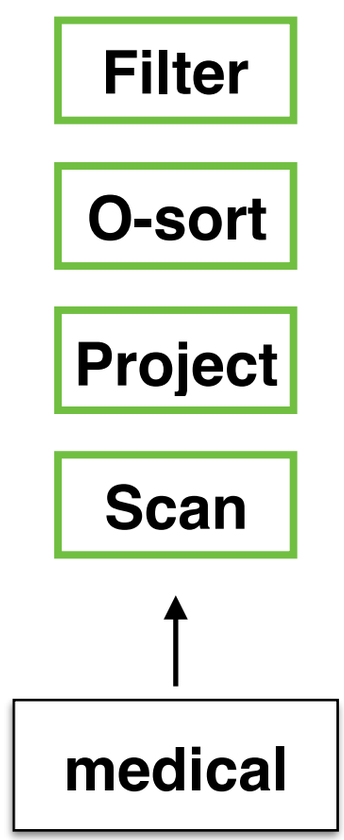

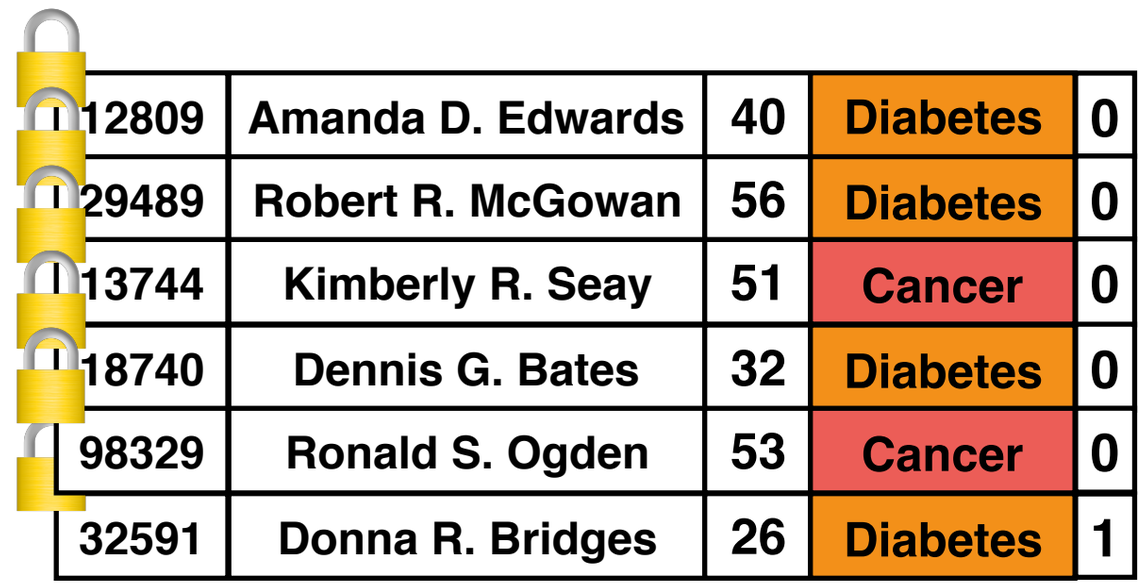

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Rule-based optimization

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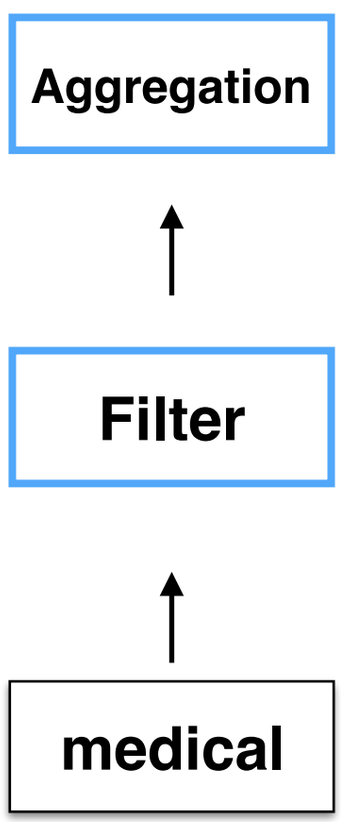

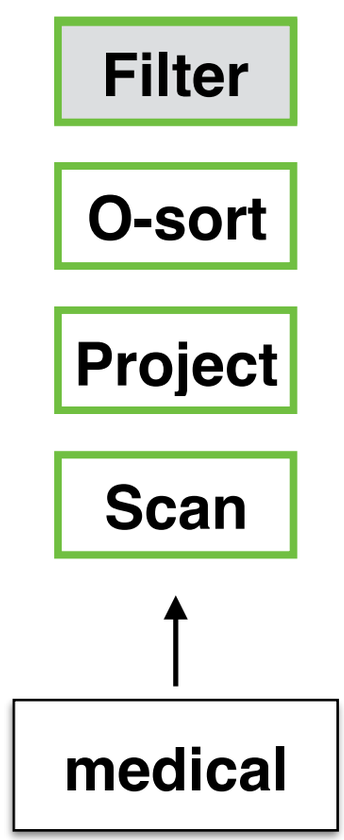

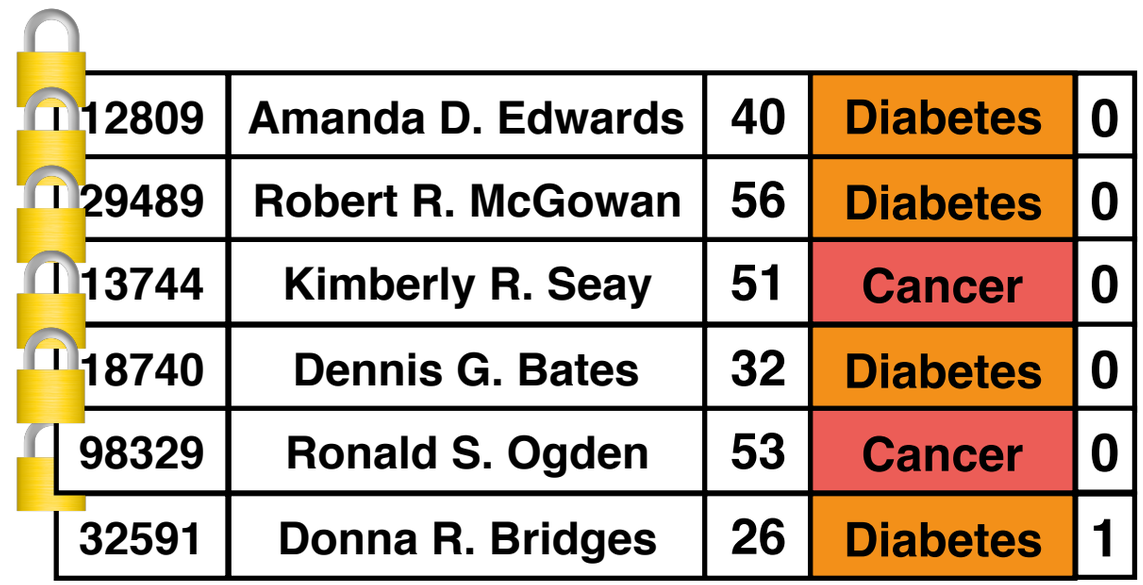

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Rule-based optimization

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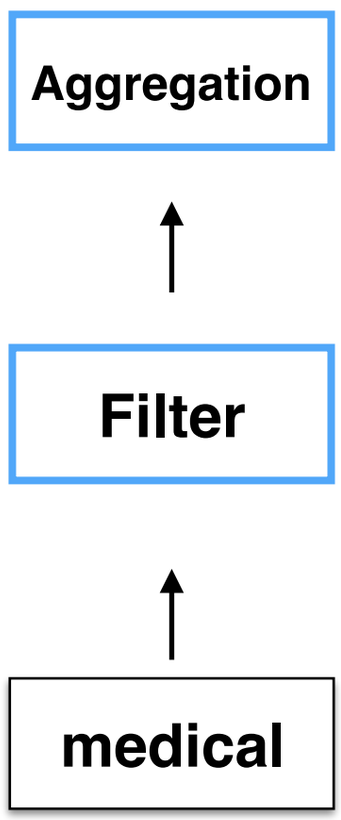

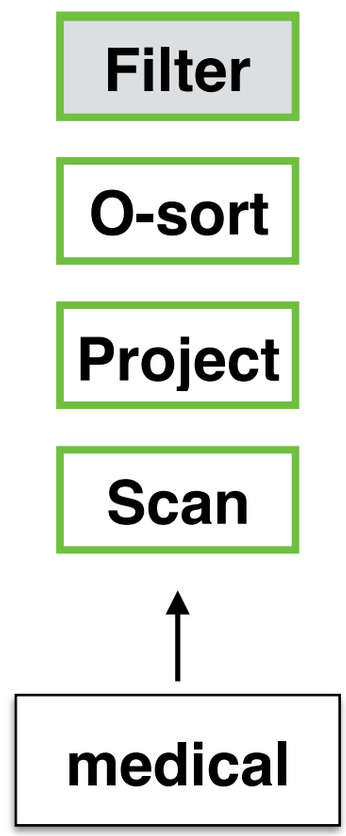

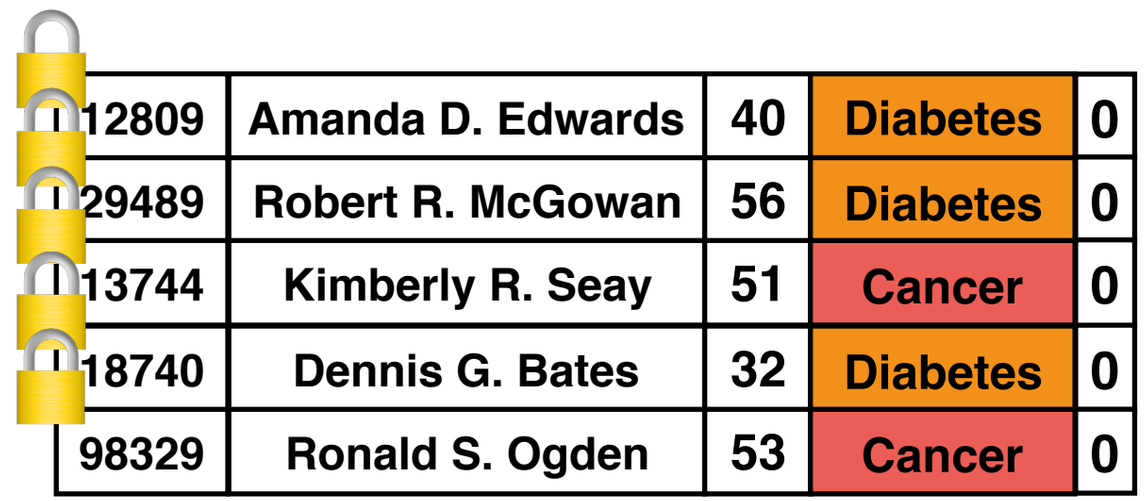

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Rule-based optimization

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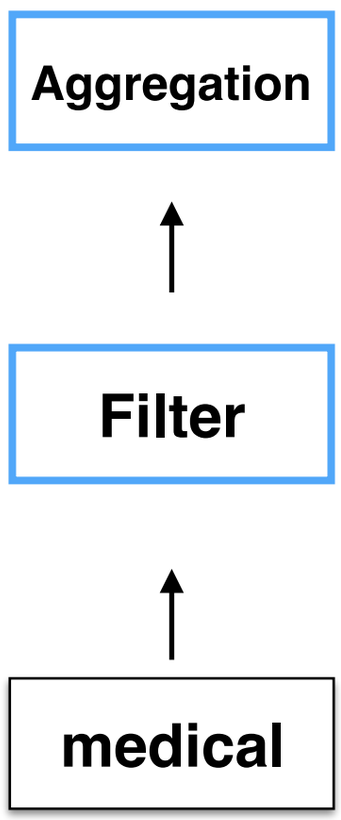

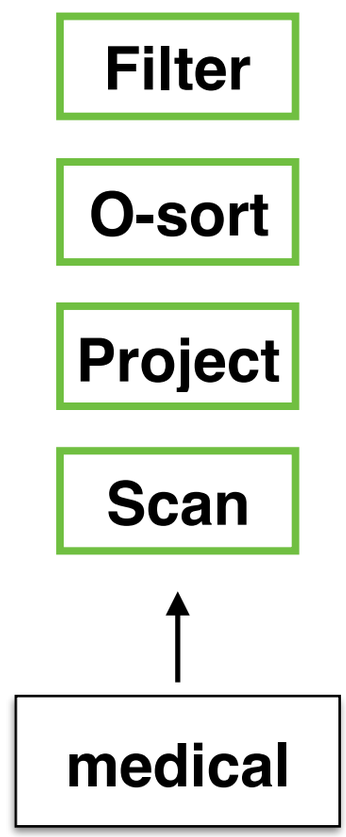

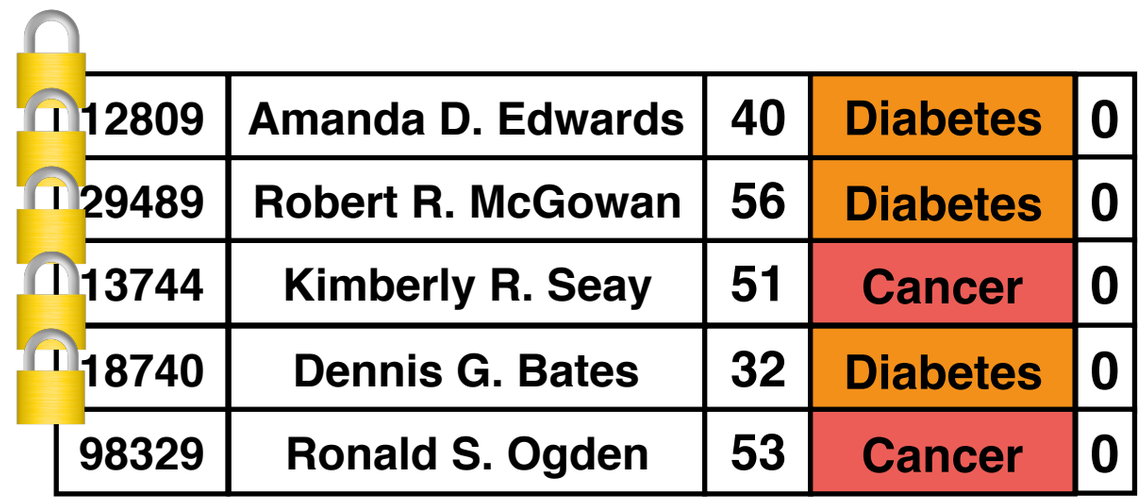

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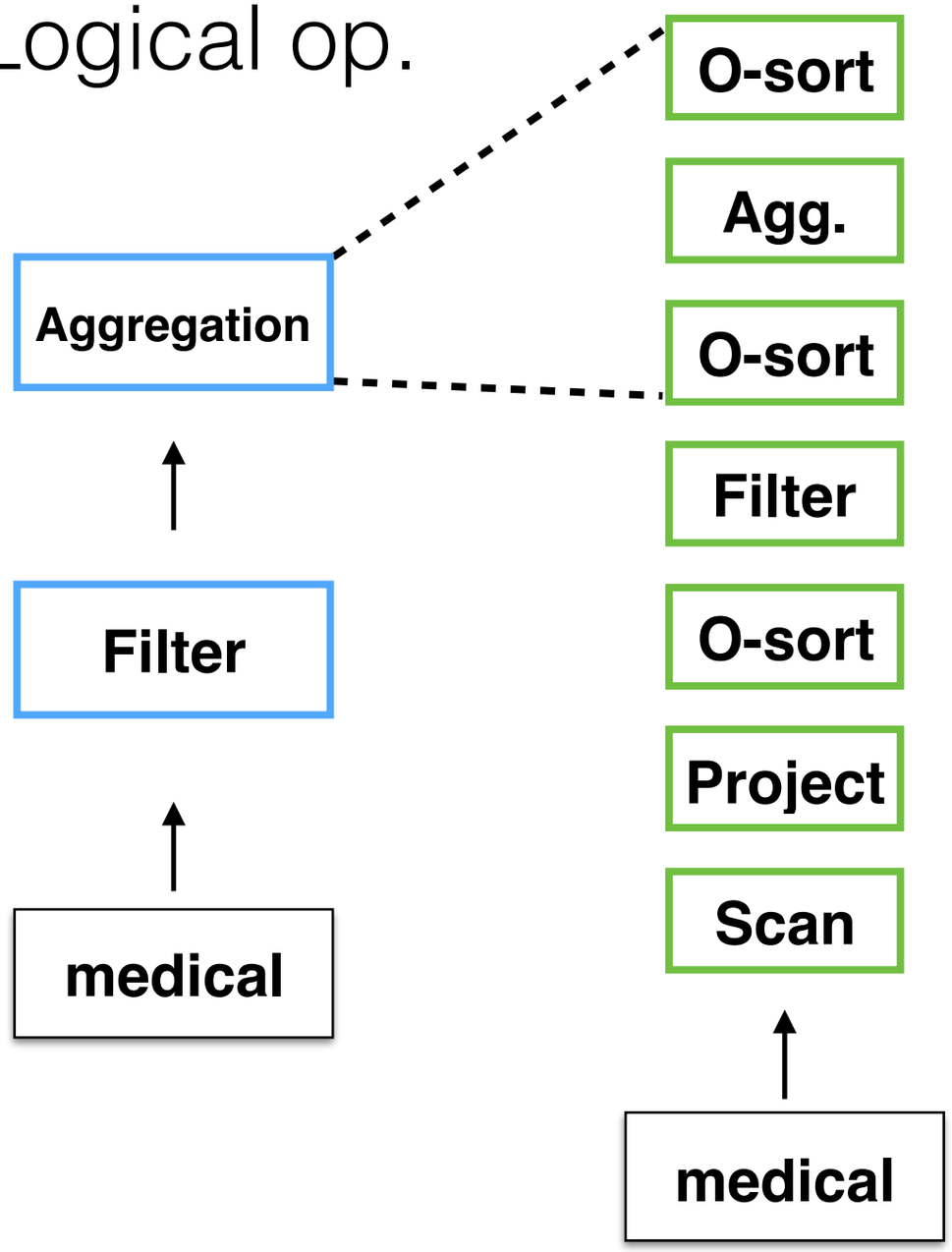

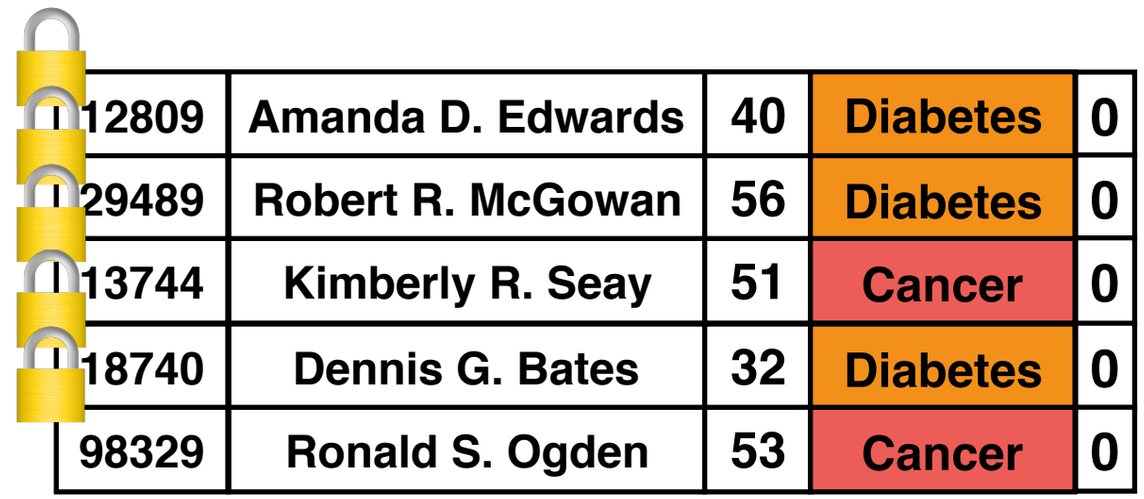

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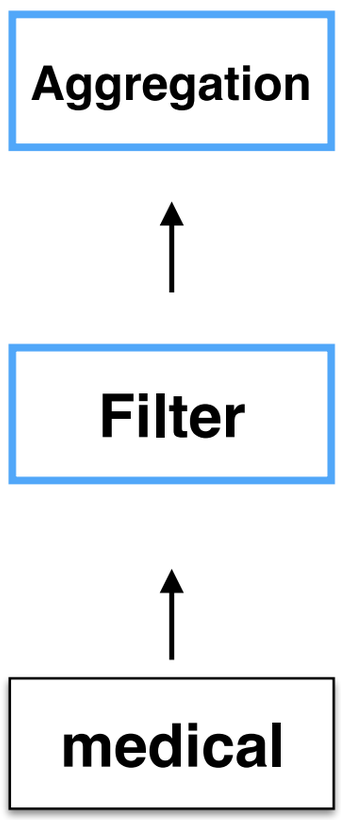
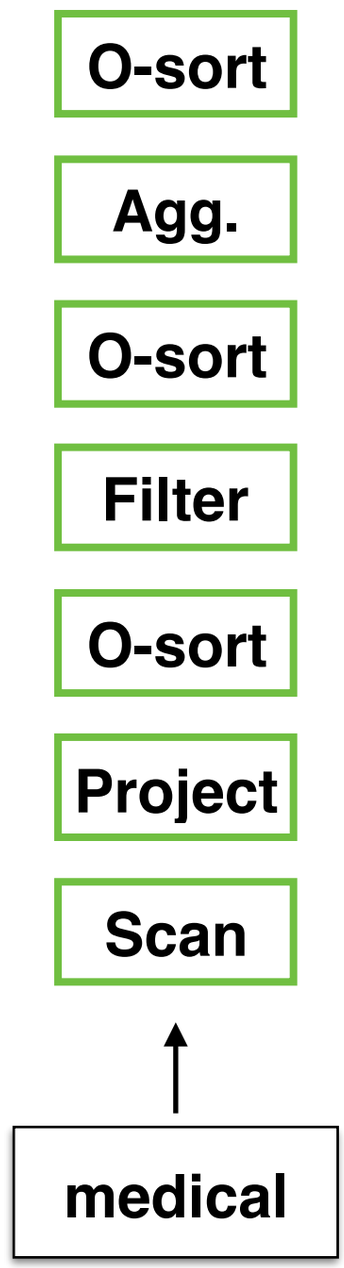
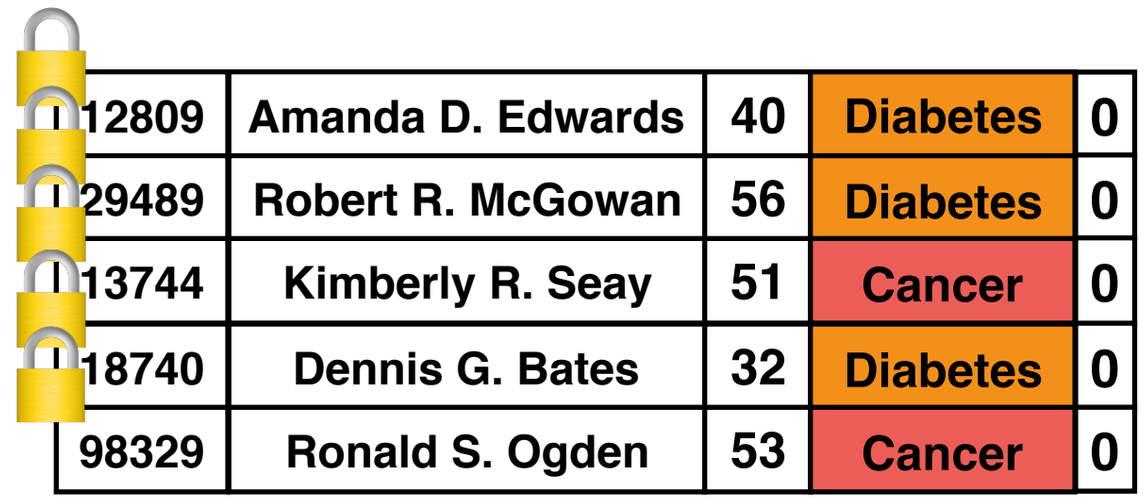
Rule-based optimization

Logical op.



Opaque op.





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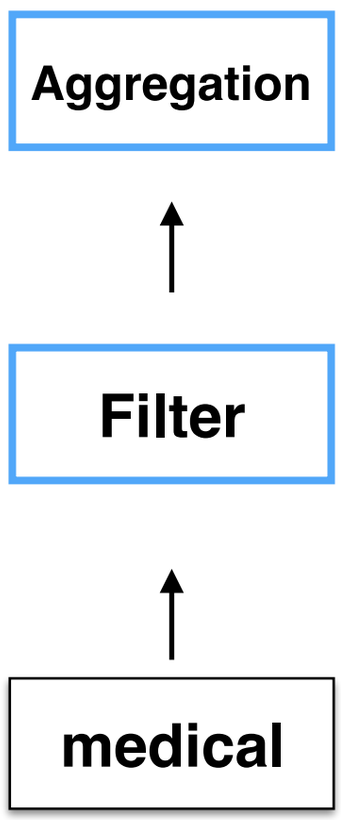

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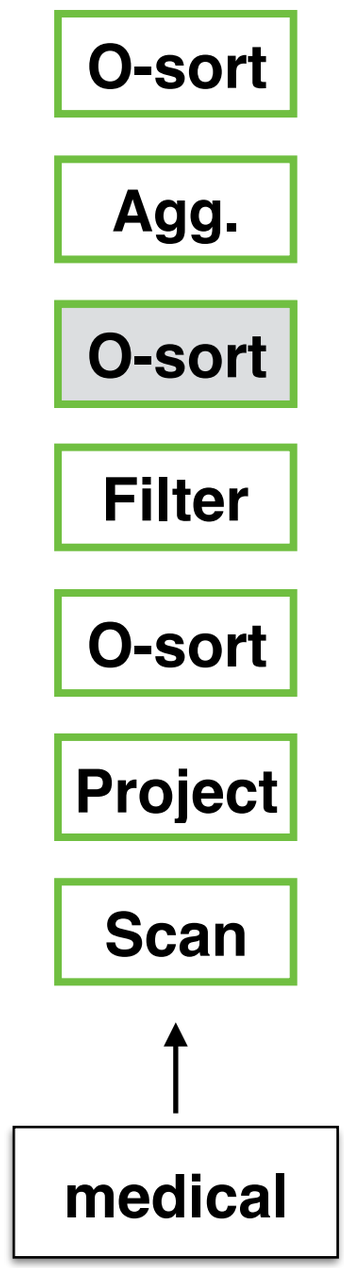

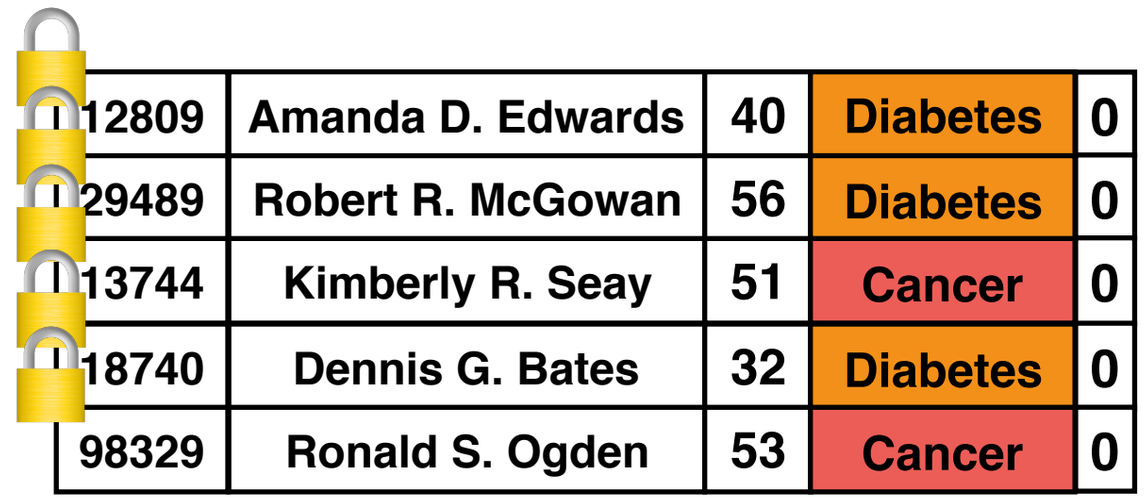

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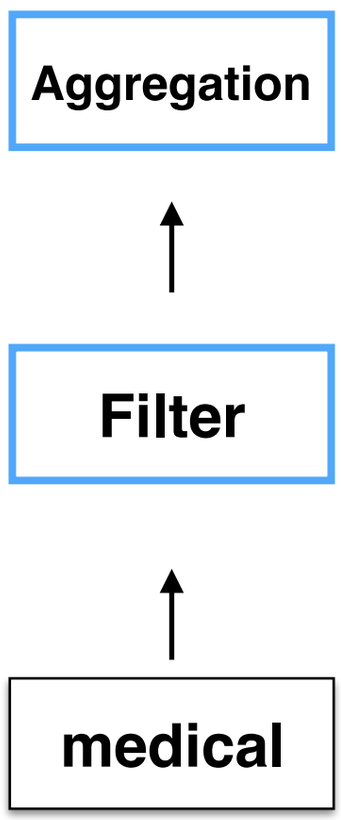

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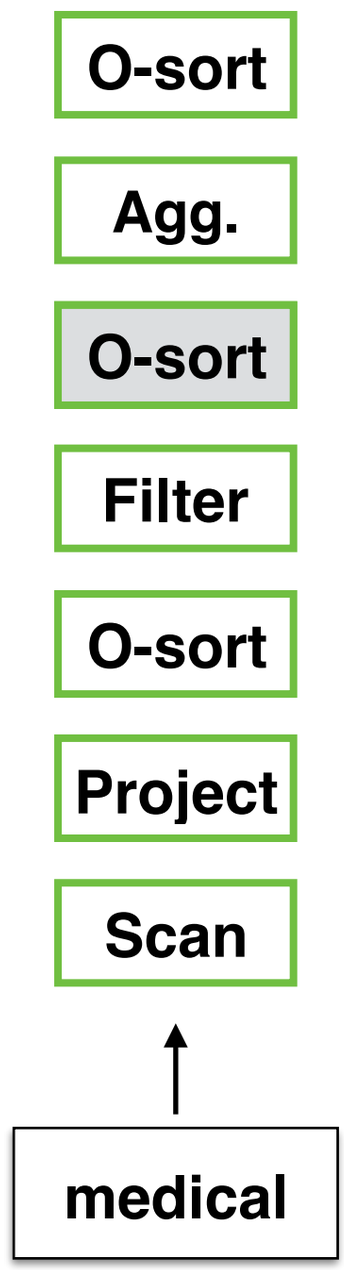

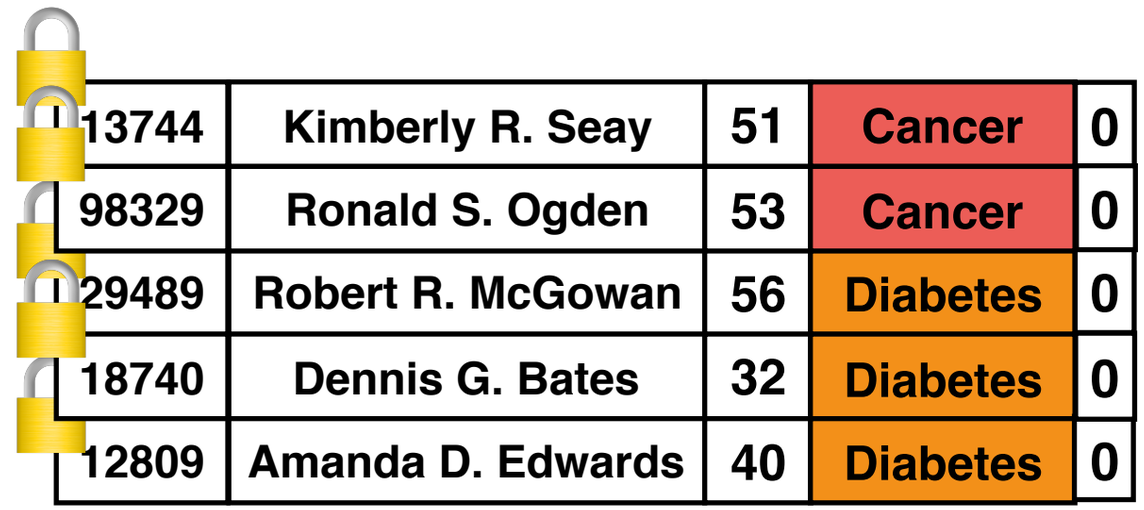

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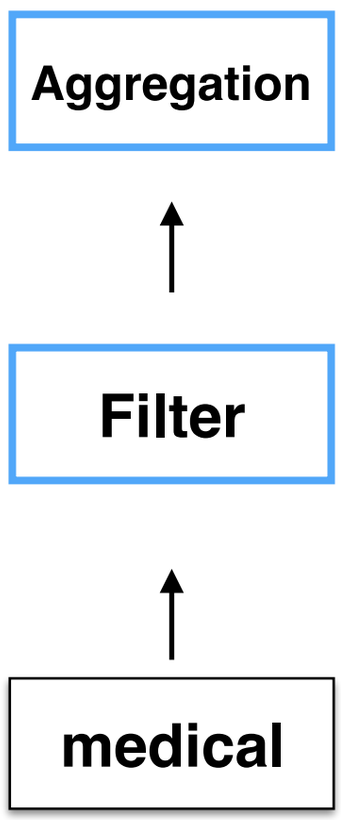

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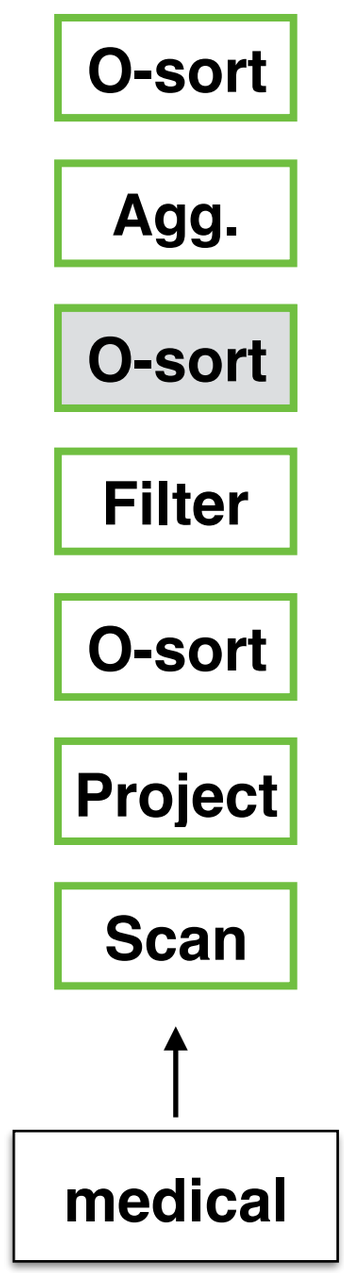

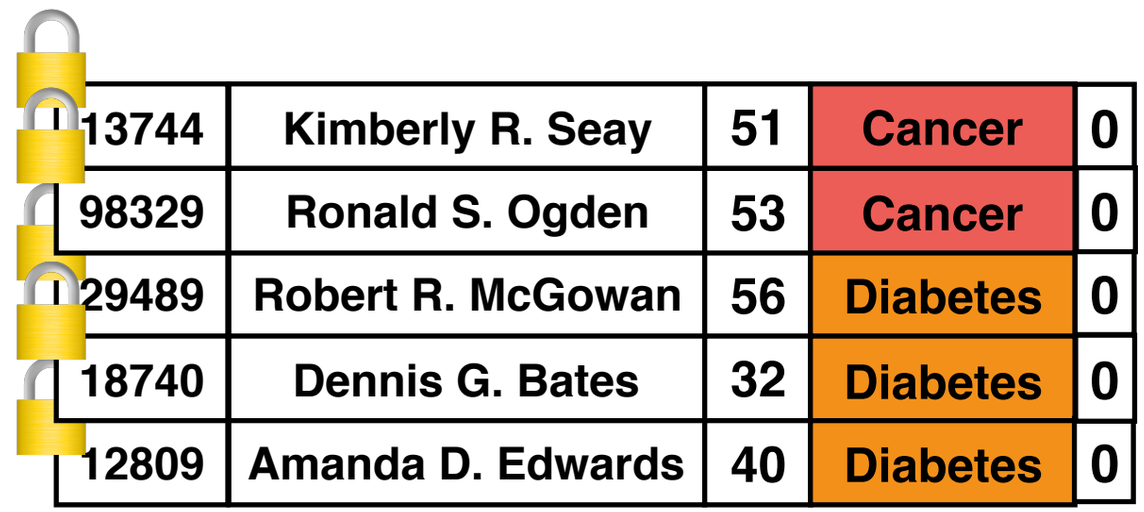

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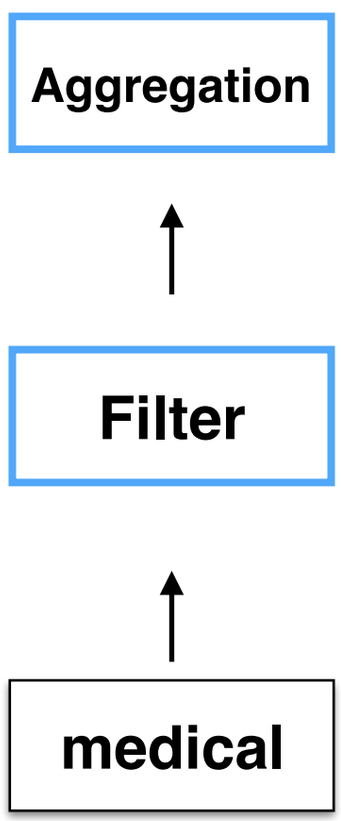
Can we remove any sort?

Rule-based optimization

Logical op.



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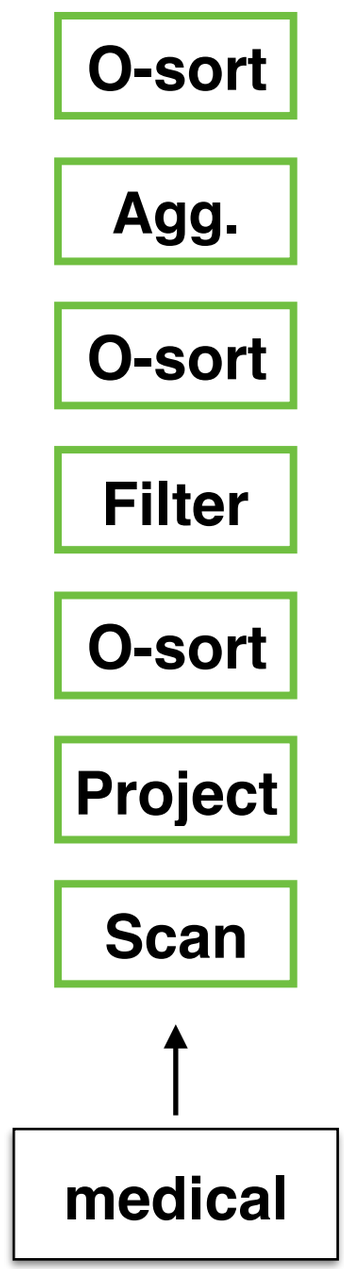
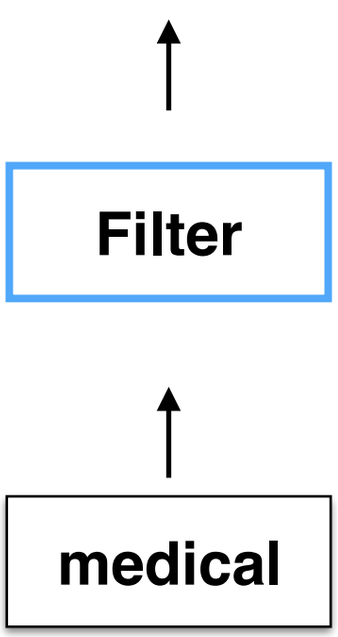
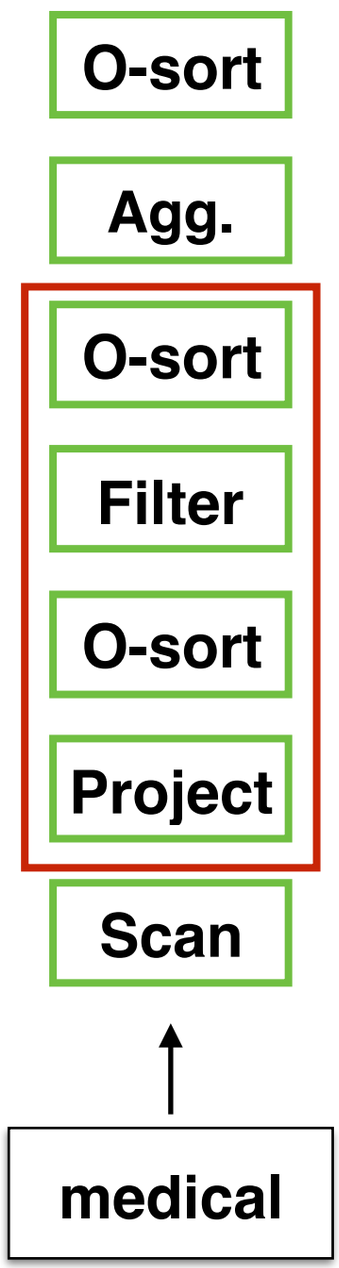


Rule-based optimization

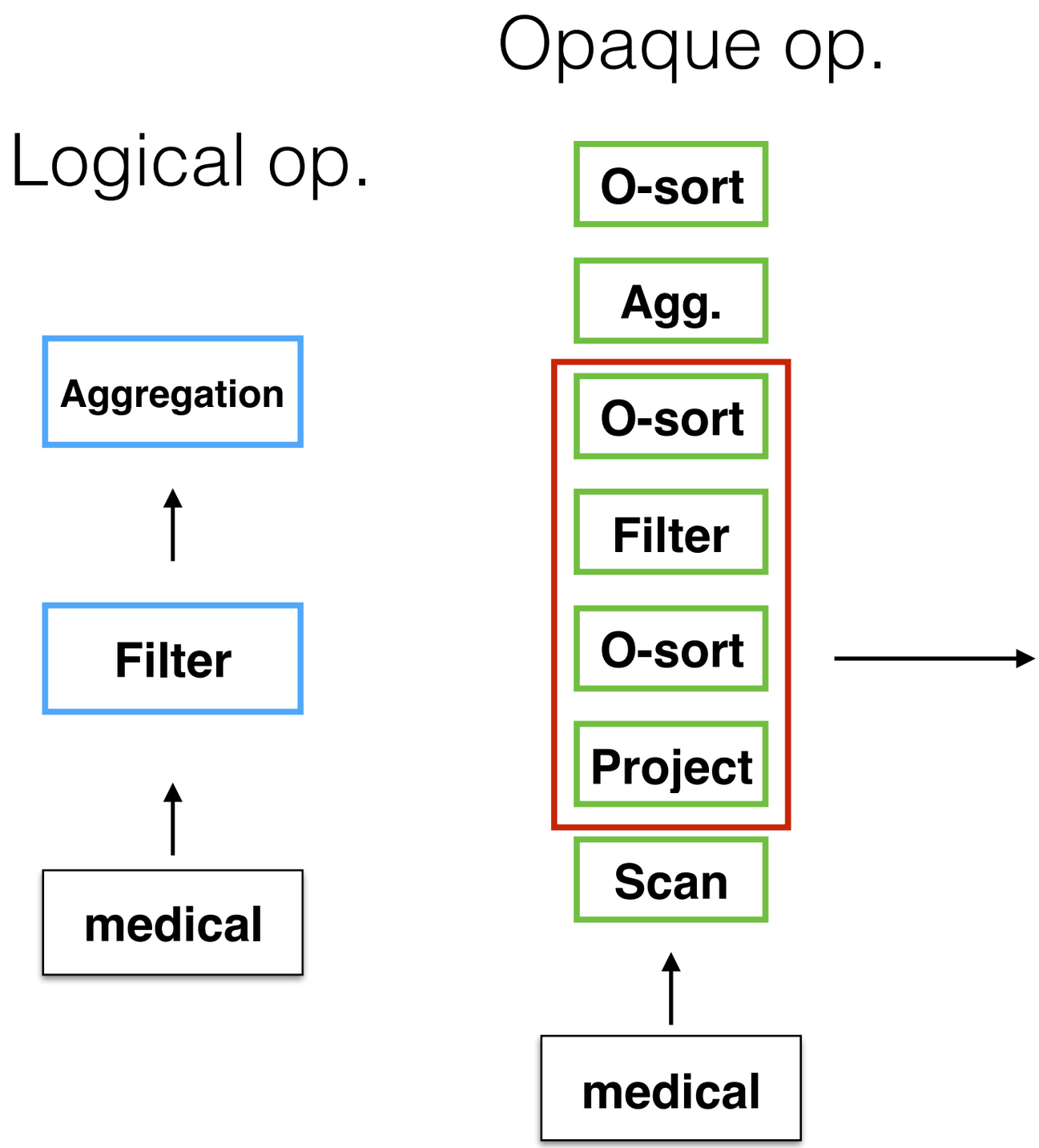
Logical op.



Opaque op.

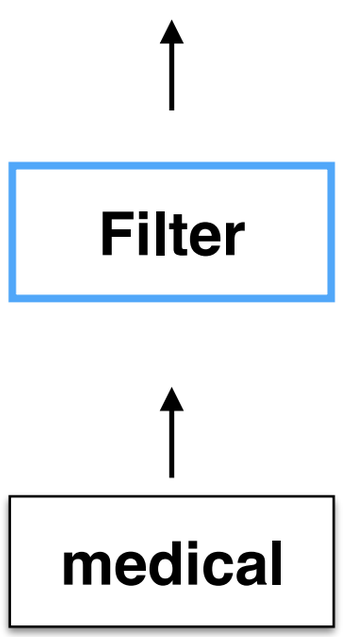


Rule-based optimization



Rule-based optimization

Logical op.



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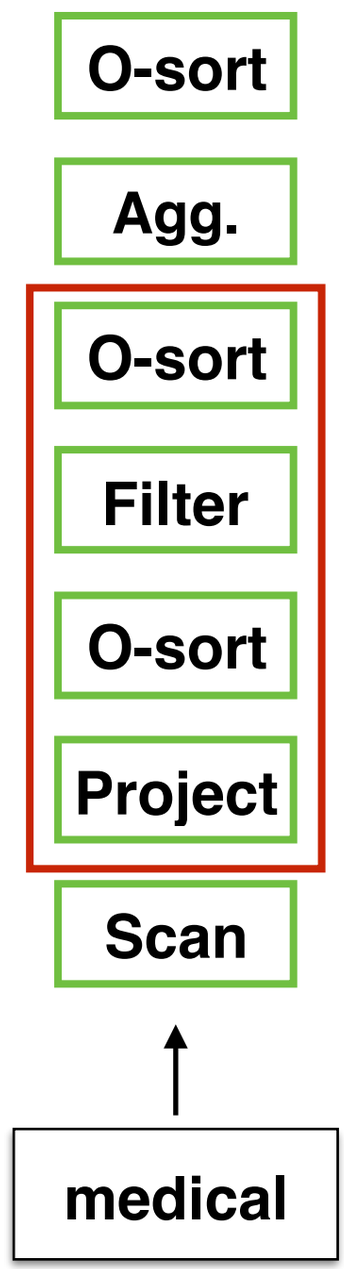
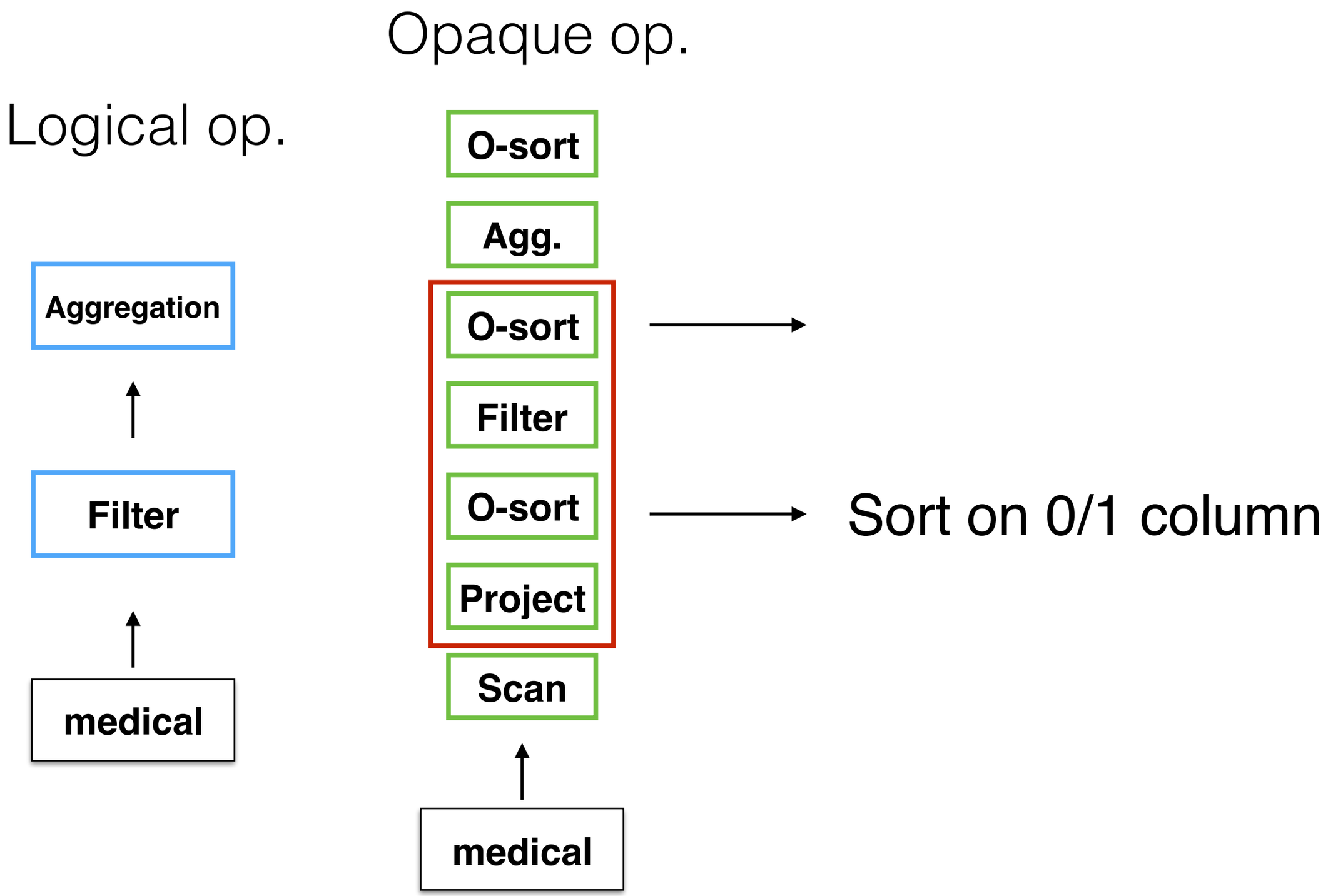


Sort on 0/1 column

Rule-based optimization



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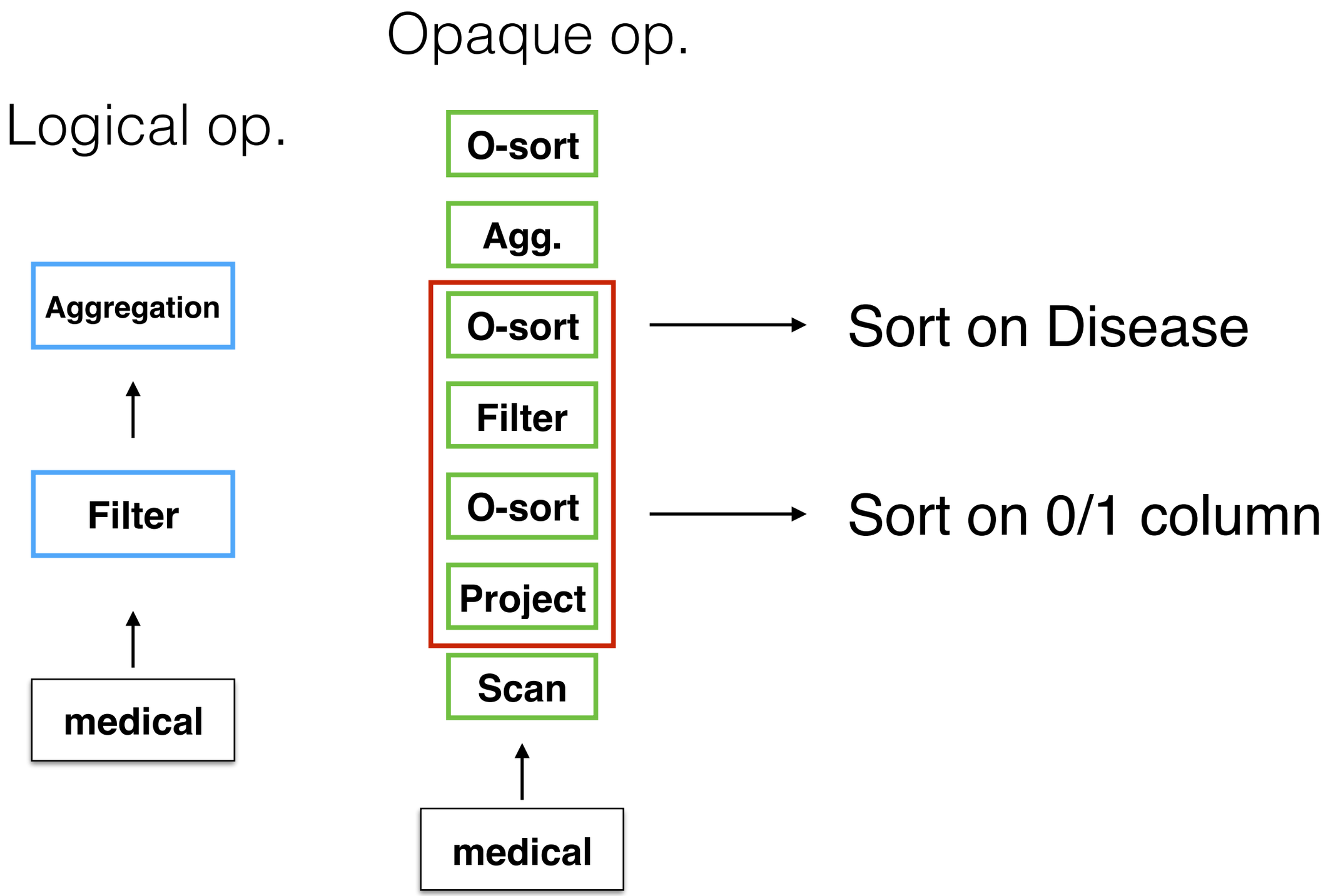
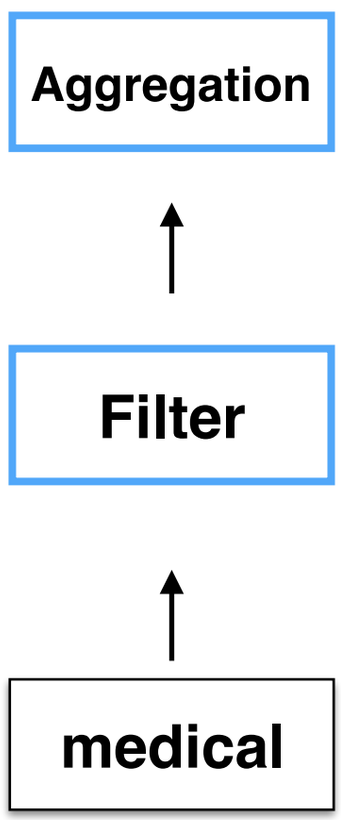
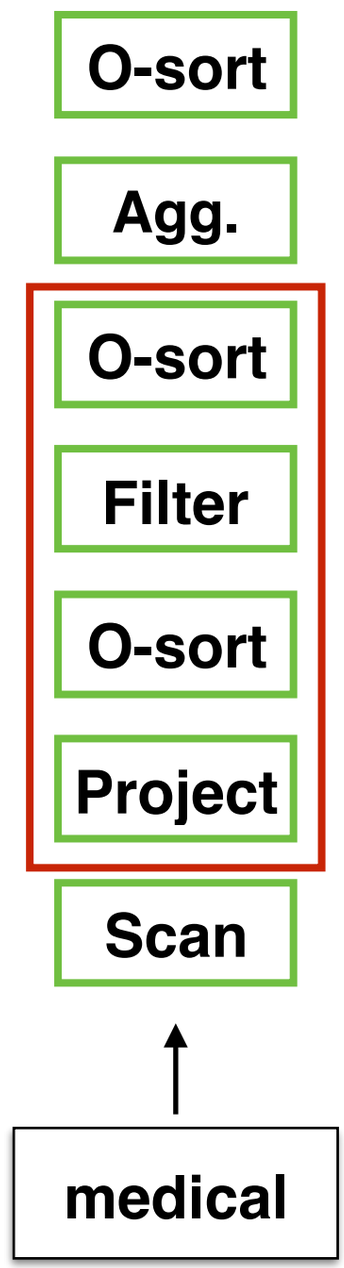


Rule-based optimization

Logical op.



Opaque op.

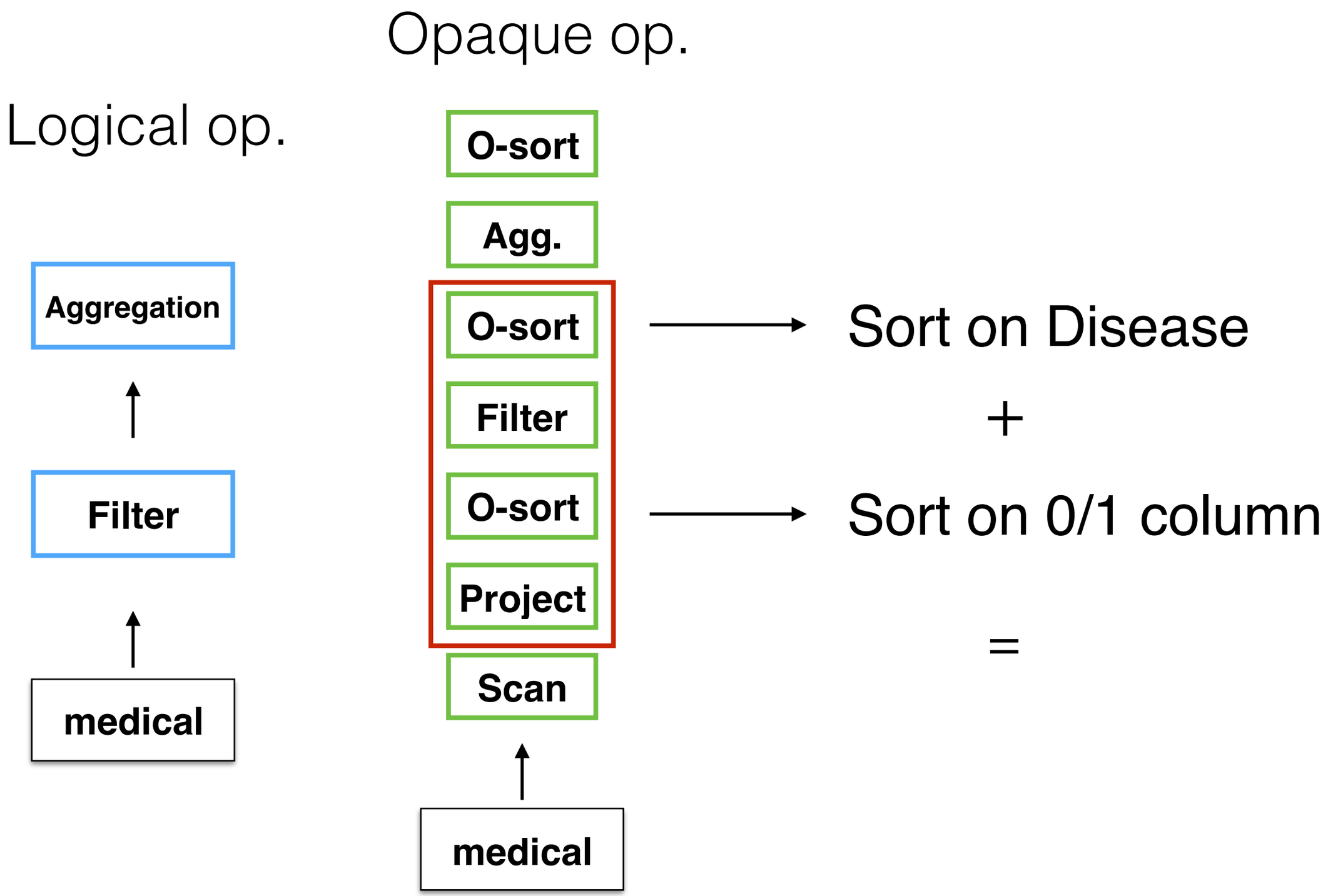


Sort on Disease

+

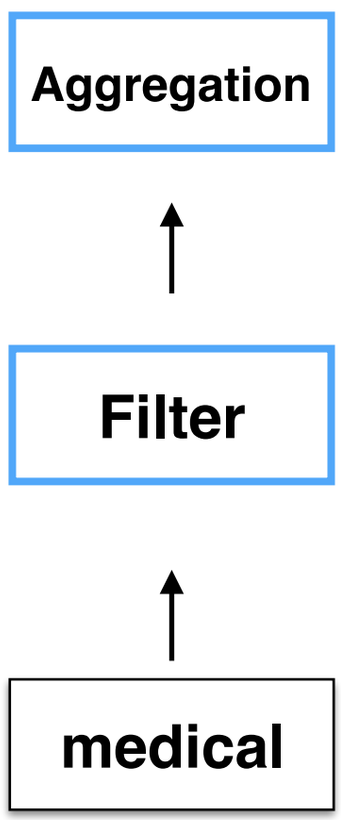
Sort on 0/1 column

Rule-based optimization



Rule-based optimization

Logical op.



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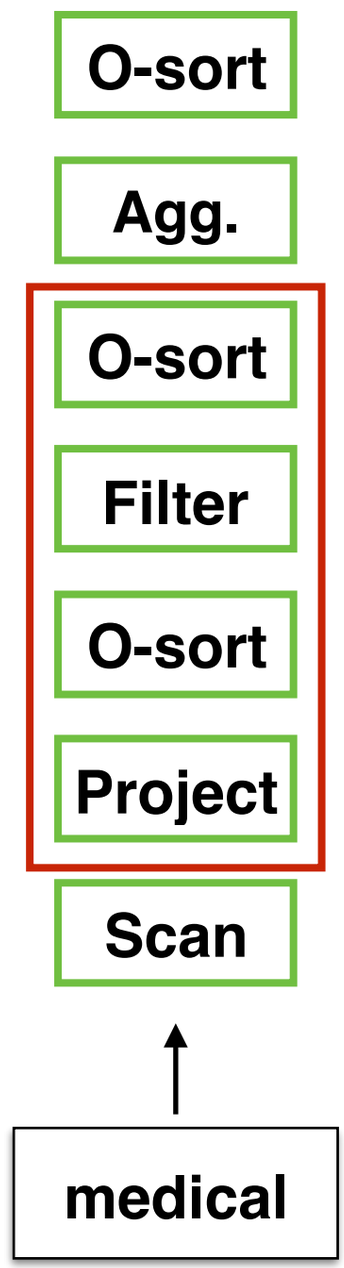


Sort on Disease

+

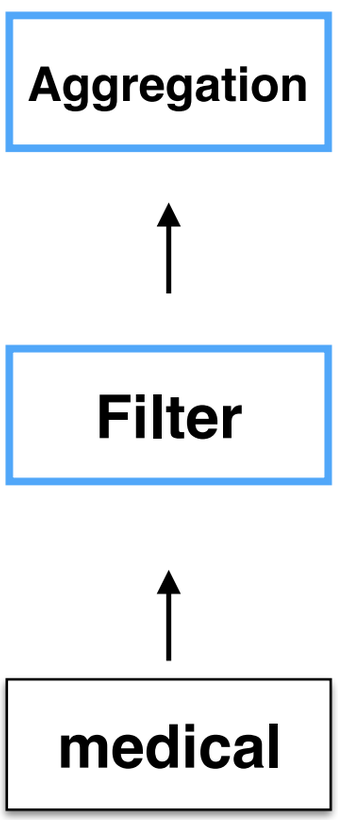
Sort on 0/1 column

=

Sort on (0/1, Disease)

Rule-based optimization

Logical op.



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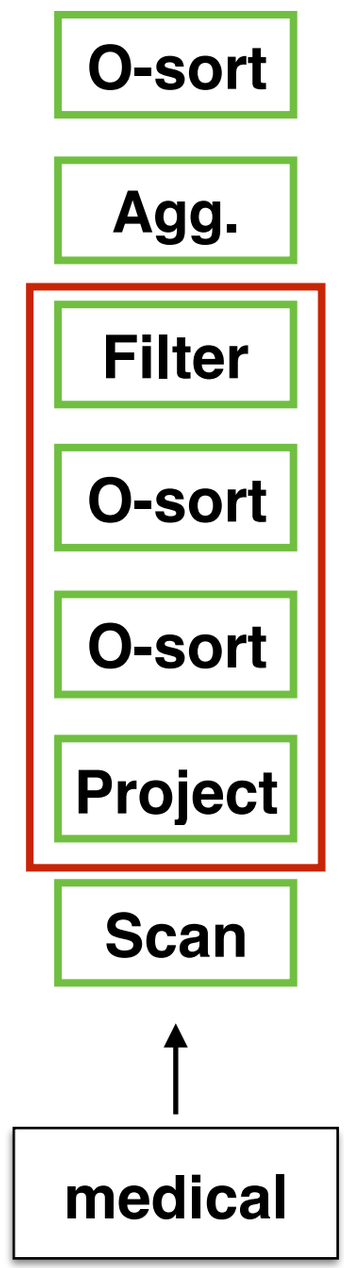
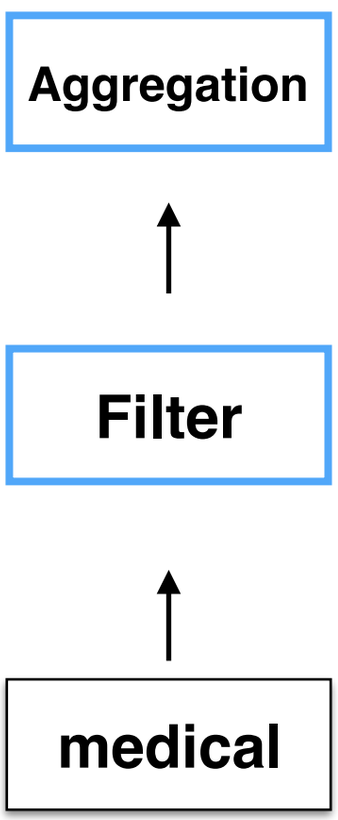


Rule-based optimization

Logical op.



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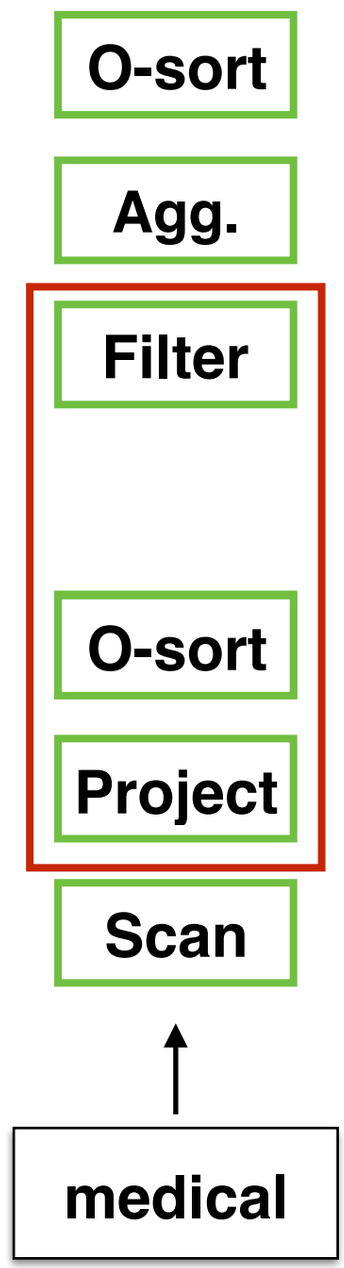
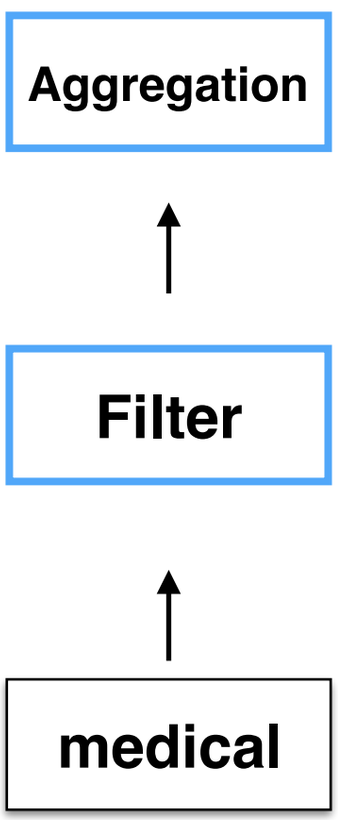


Rule-based optimization

Logical op.



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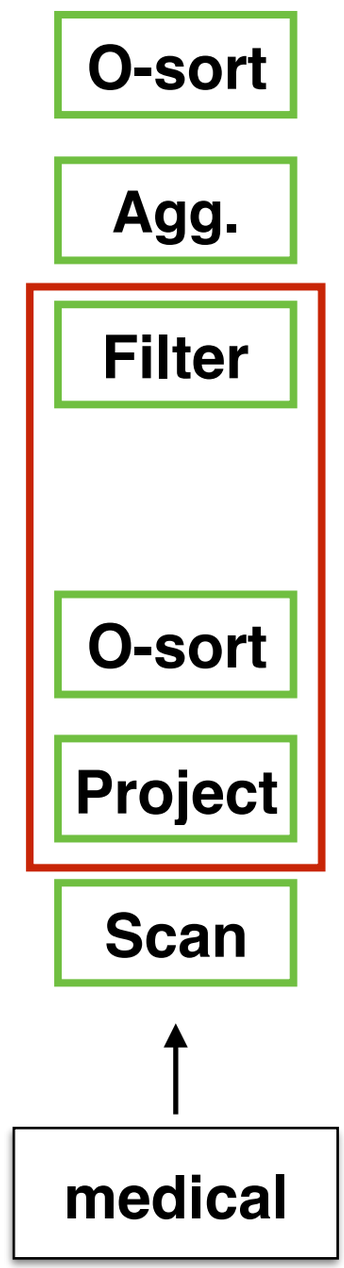
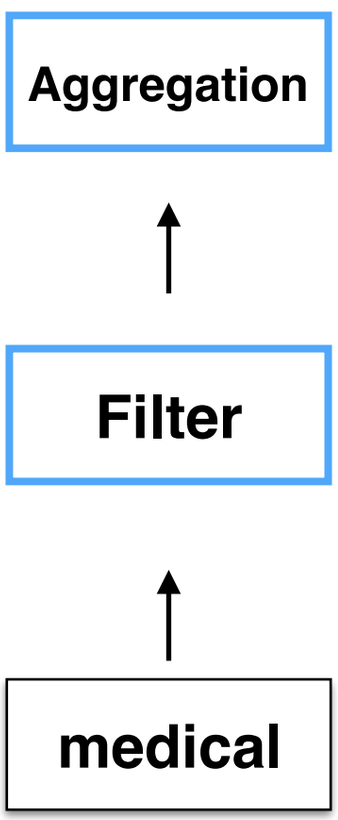


Rule-based optimization

Logical op.



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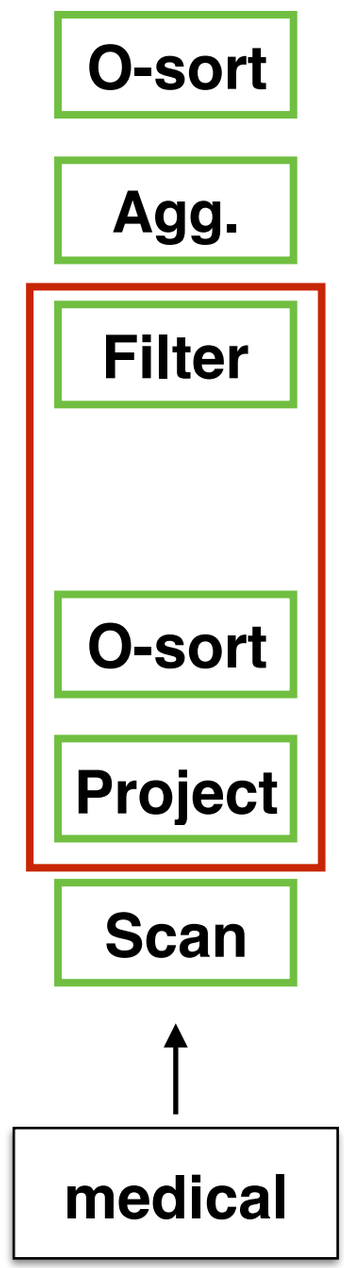
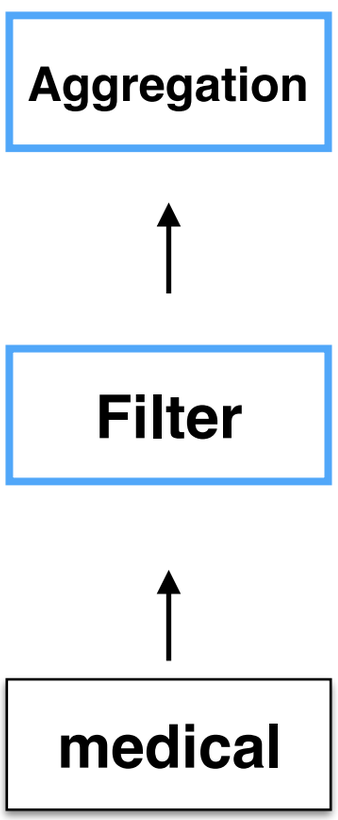


Rule-based optimization

Logical op.



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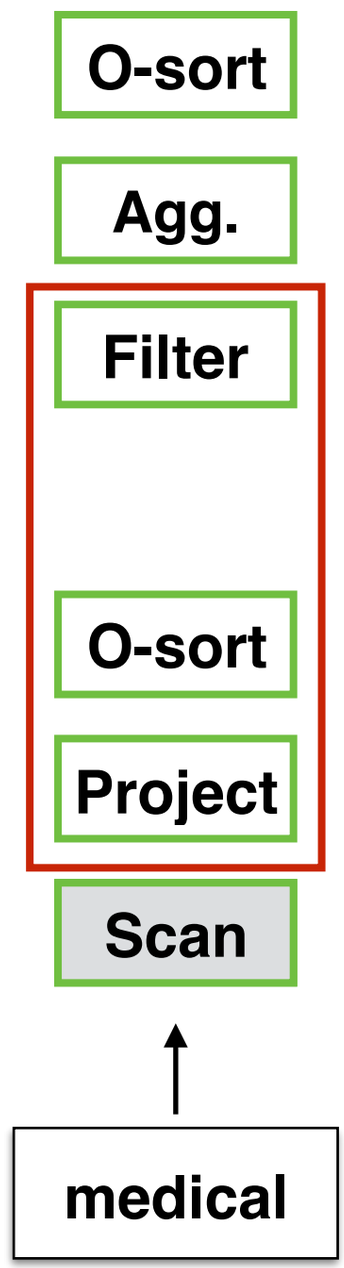
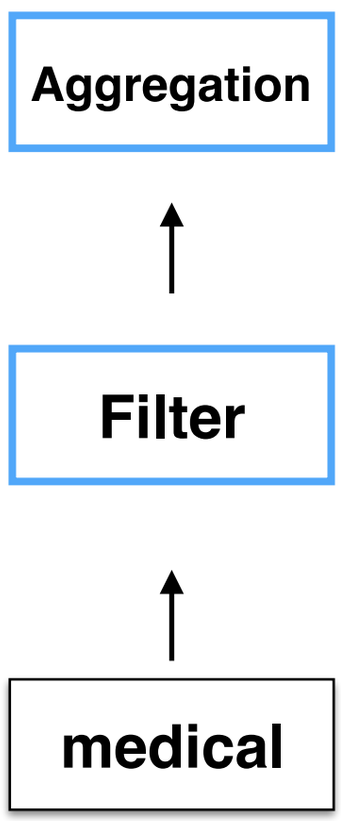


Rule-based optimization

Logical op.



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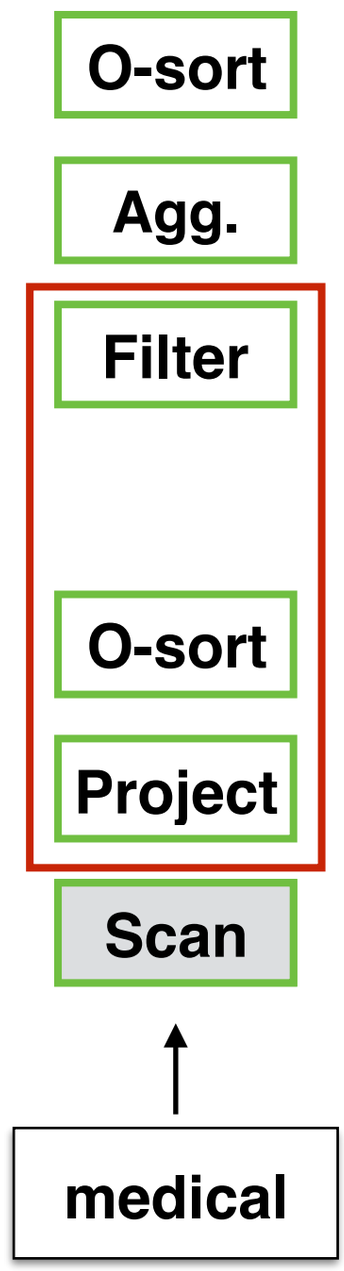
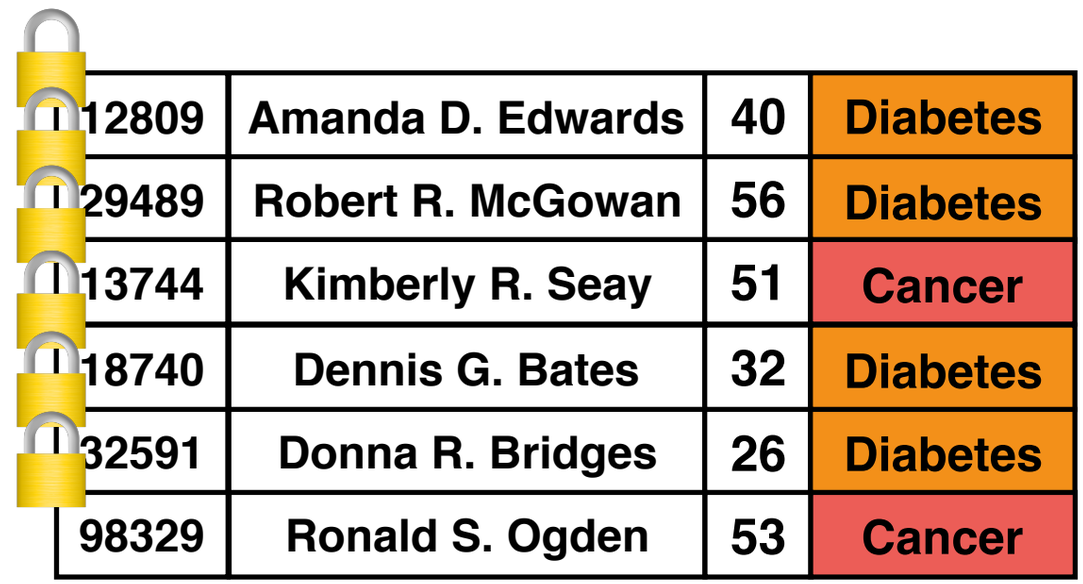
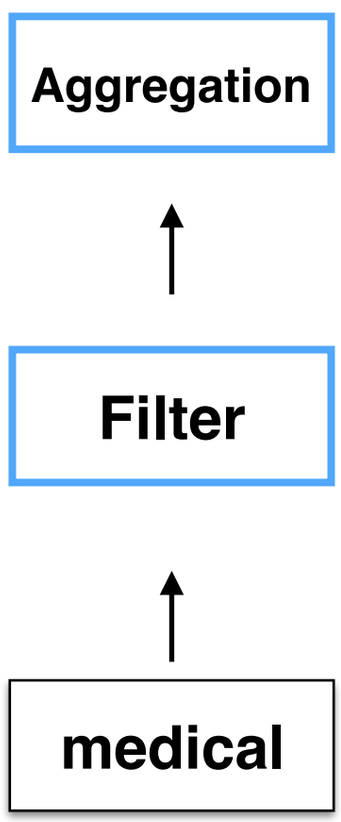




12809	Amanda D. Edwards	40	Diabetes
29489	Robert R. McGowan	56	Diabetes
13744	Kimberly R. Seay	51	Cancer
18740	Dennis G. Bates	32	Diabetes
32591	Donna R. Bridges	26	Diabetes
98329	Ronald S. Ogden	53	Cancer

Rule-based optimization

Logical op.



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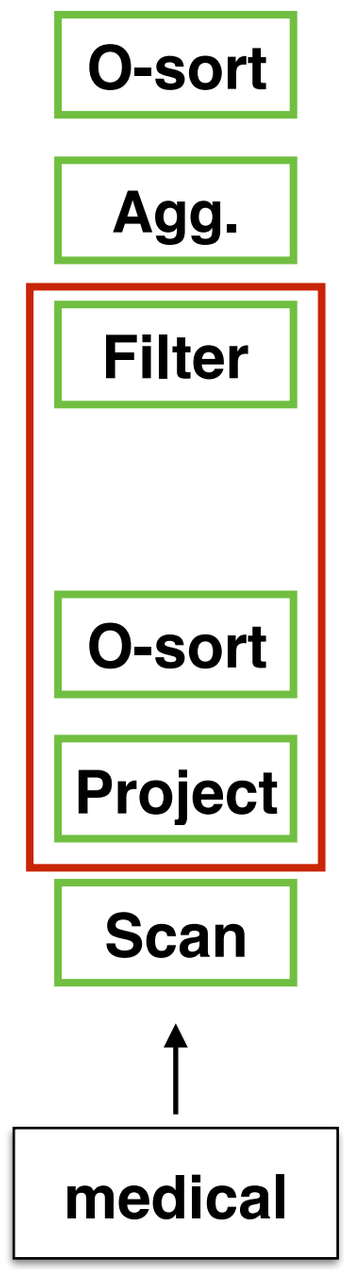

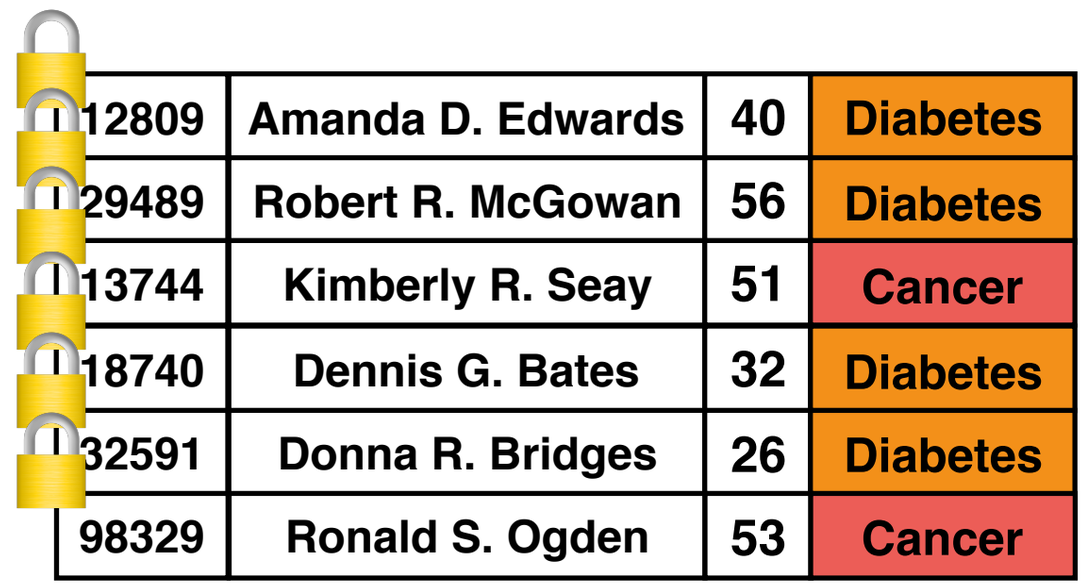

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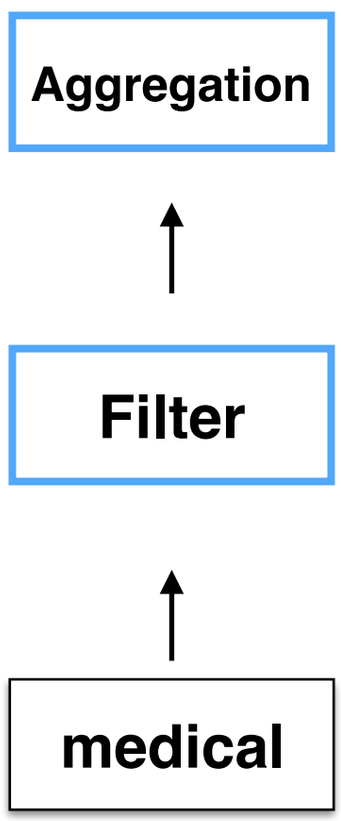
Rule-based optimization

Logical op.



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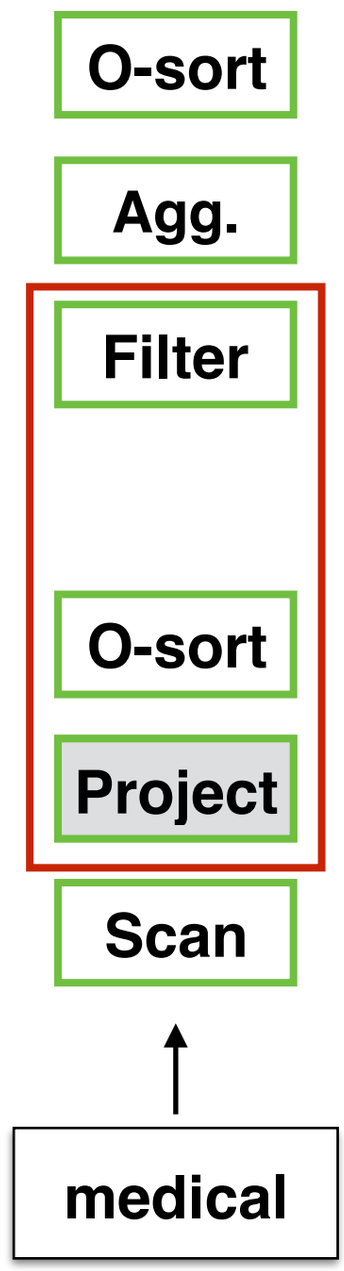

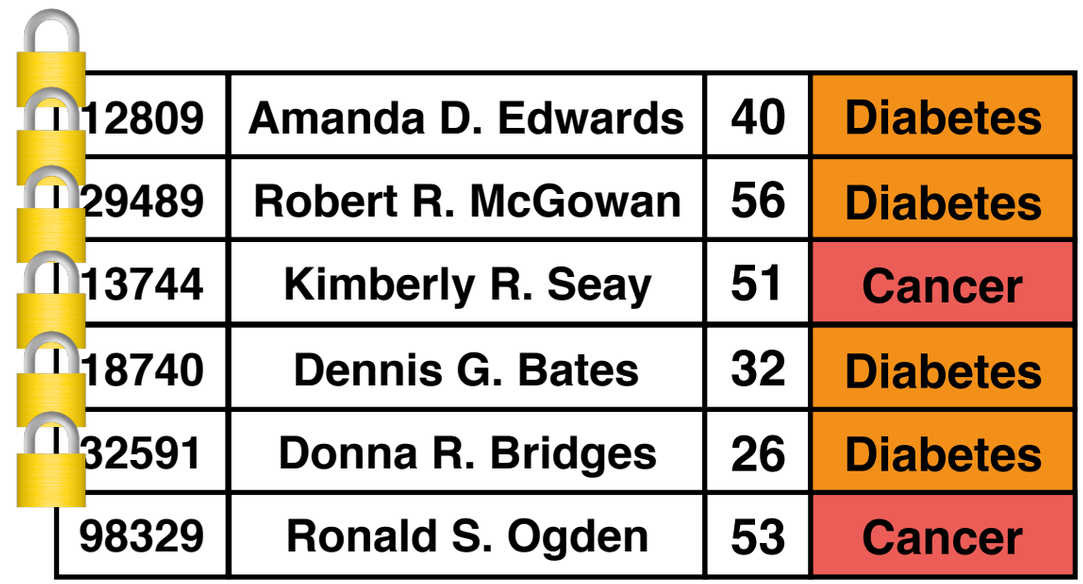

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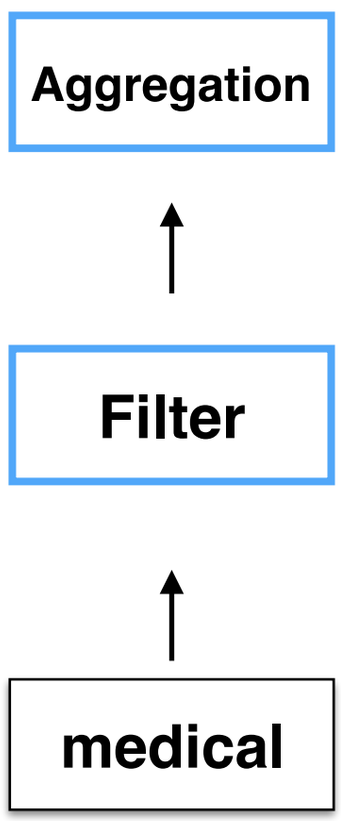
Rule-based optimization

Logical op.



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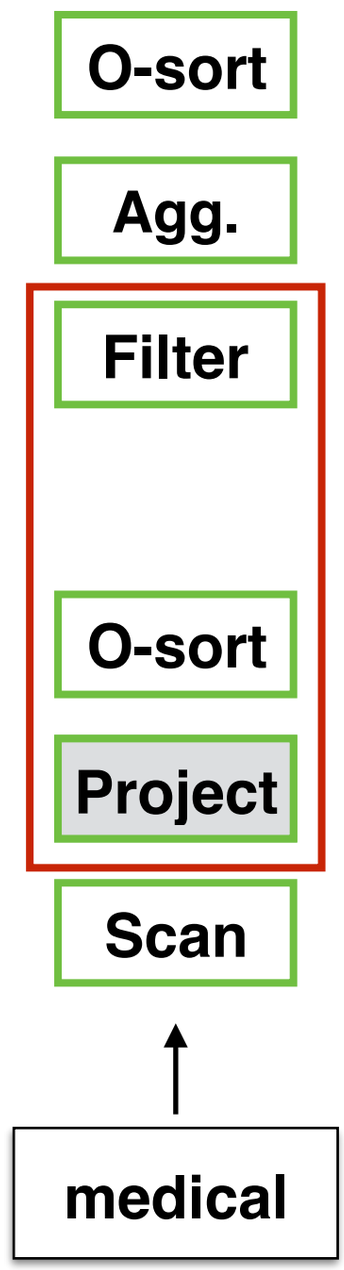
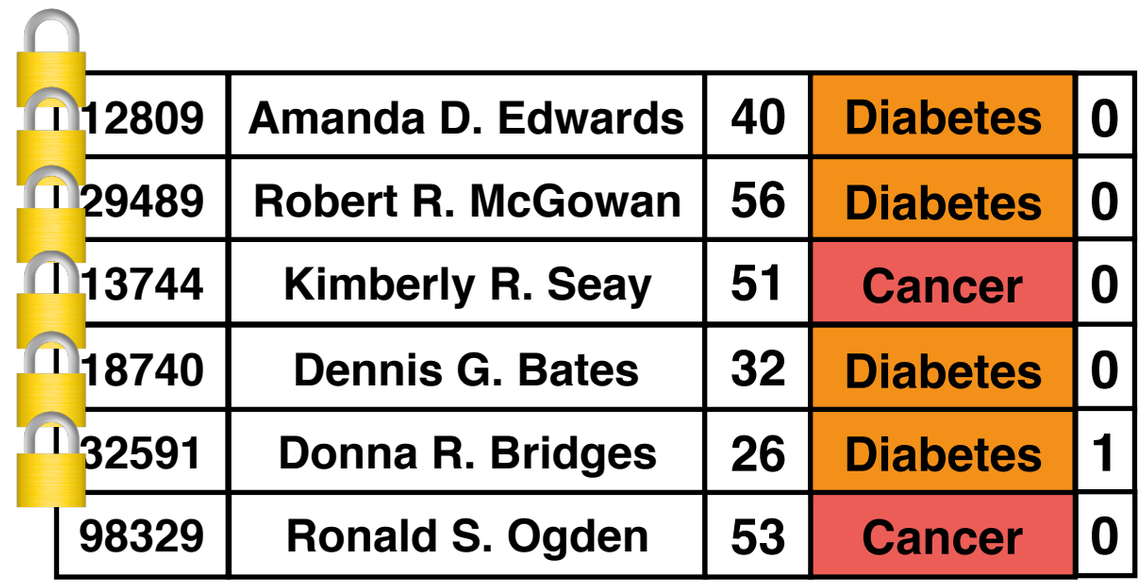
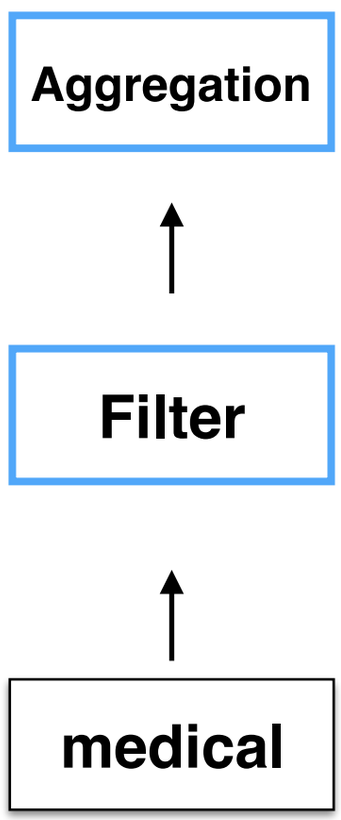




12809	Amanda D. Edwards	40	Diabetes	0
29489	Robert R. McGowan	56	Diabetes	0
13744	Kimberly R. Seay	51	Cancer	0
18740	Dennis G. Bates	32	Diabetes	0
32591	Donna R. Bridges	26	Diabetes	1
98329	Ronald S. Ogden	53	Cancer	0

Rule-based optimization

Logical op.



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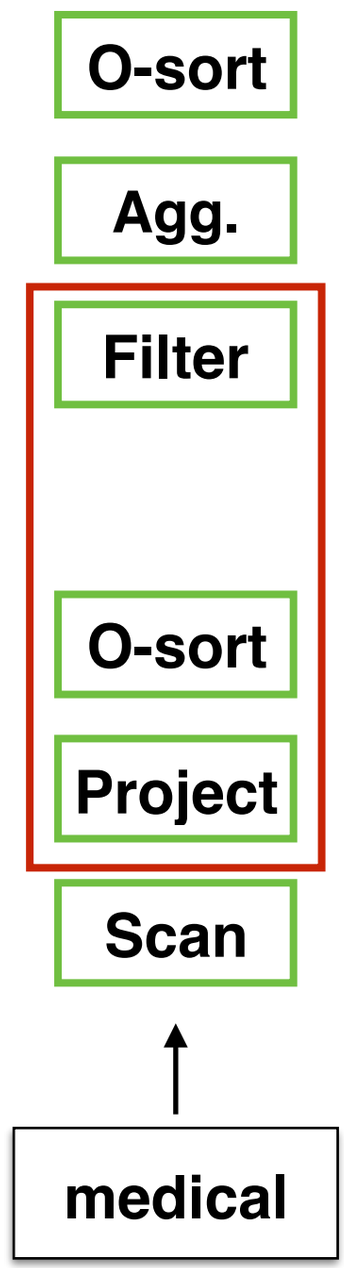

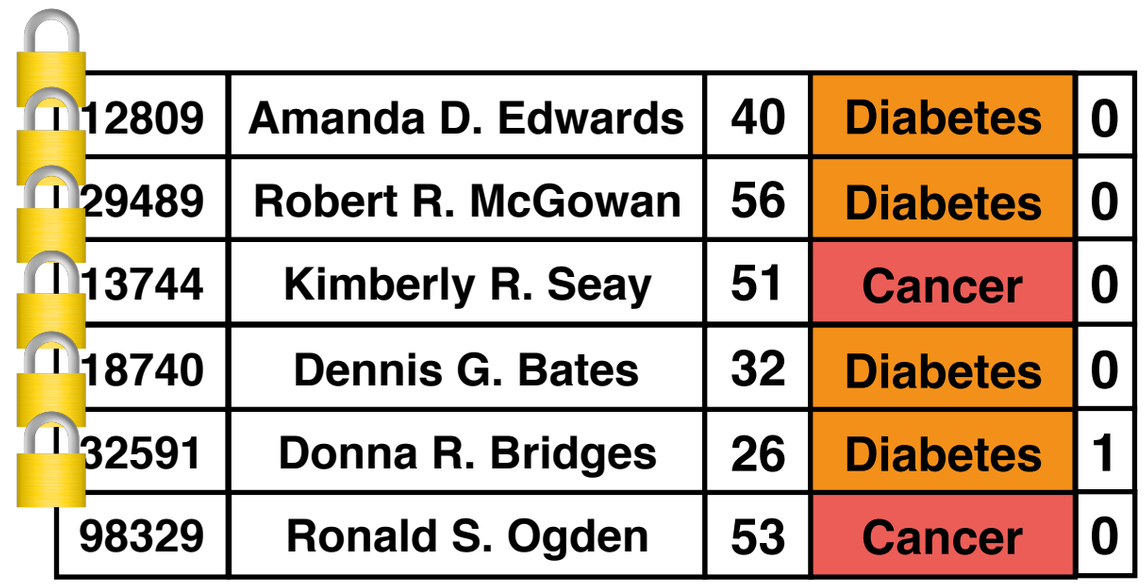

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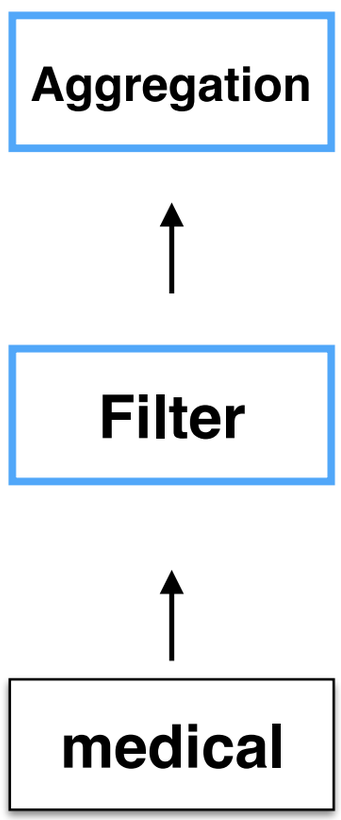
32591	Donna R. Bridges	26	Diabetes	1
98329	Ronald S. Ogden	53	Cancer	0

Rule-based optimization

Logical op.



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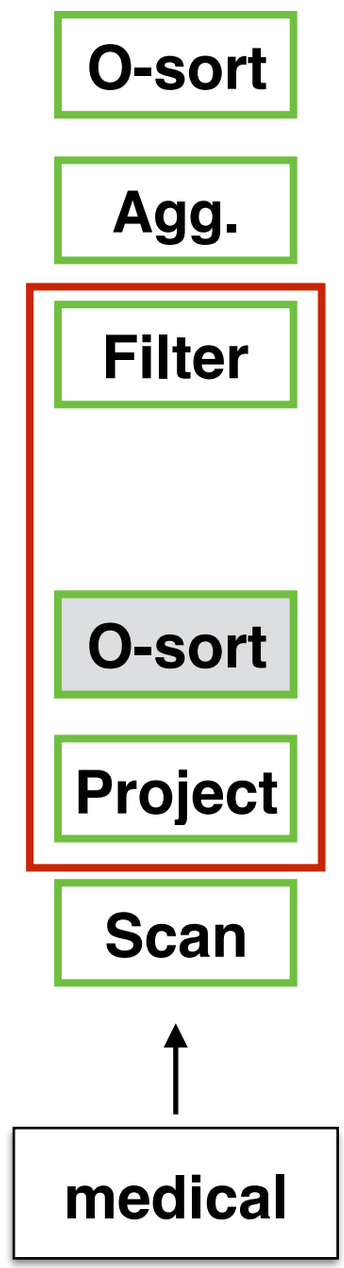
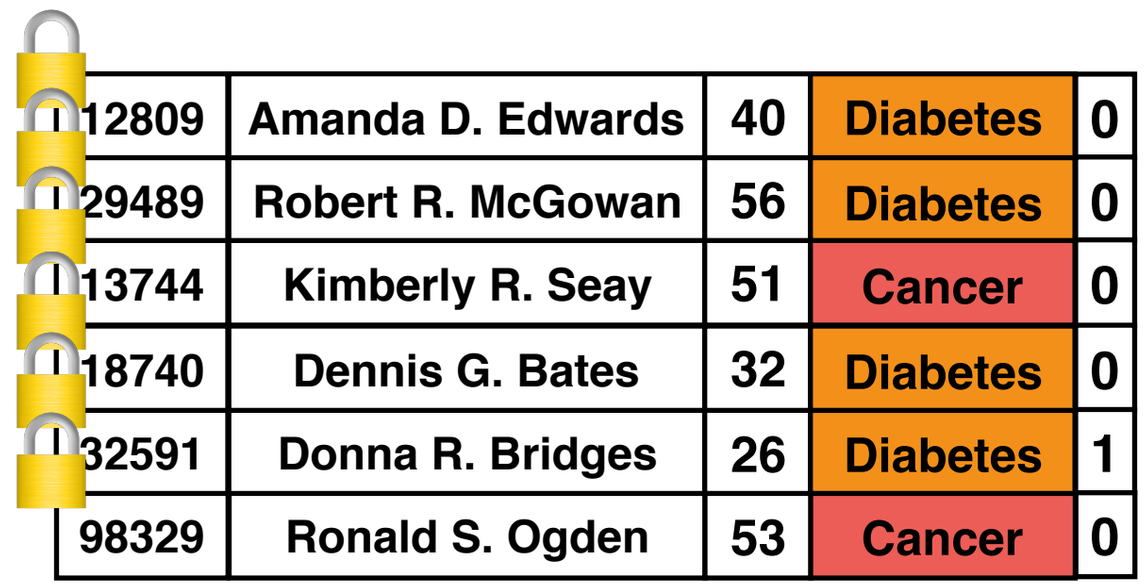


multi-column sort



12809	Amanda D. Edwards	40	Diabetes	0
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13744	Kimberly R. Seay	51	Cancer	0
18740	Dennis G. Bates	32	Diabetes	0
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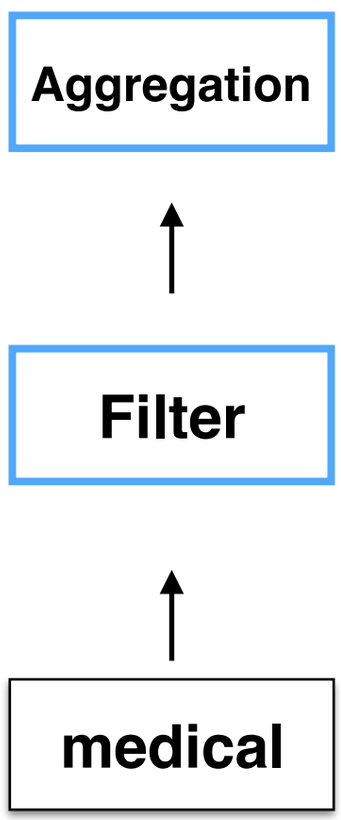
98329	Ronald S. Ogden	53	Cancer	0

Rule-based optimization

Logical op.



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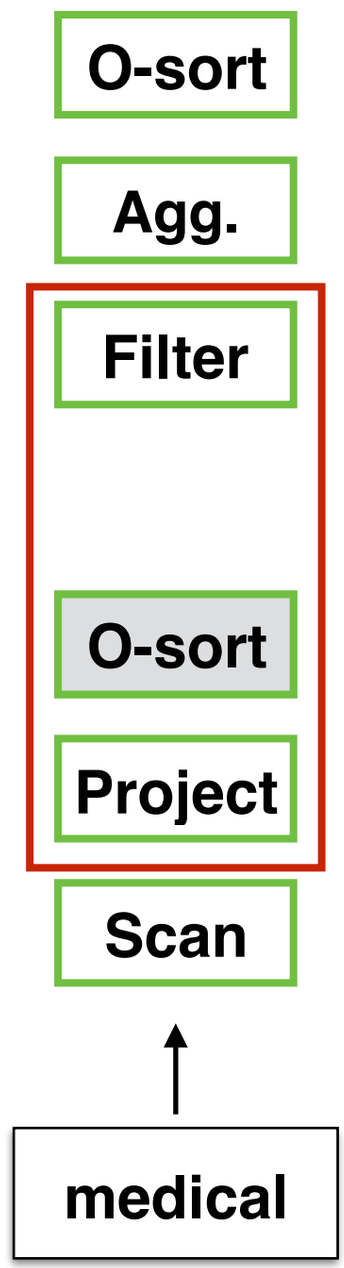

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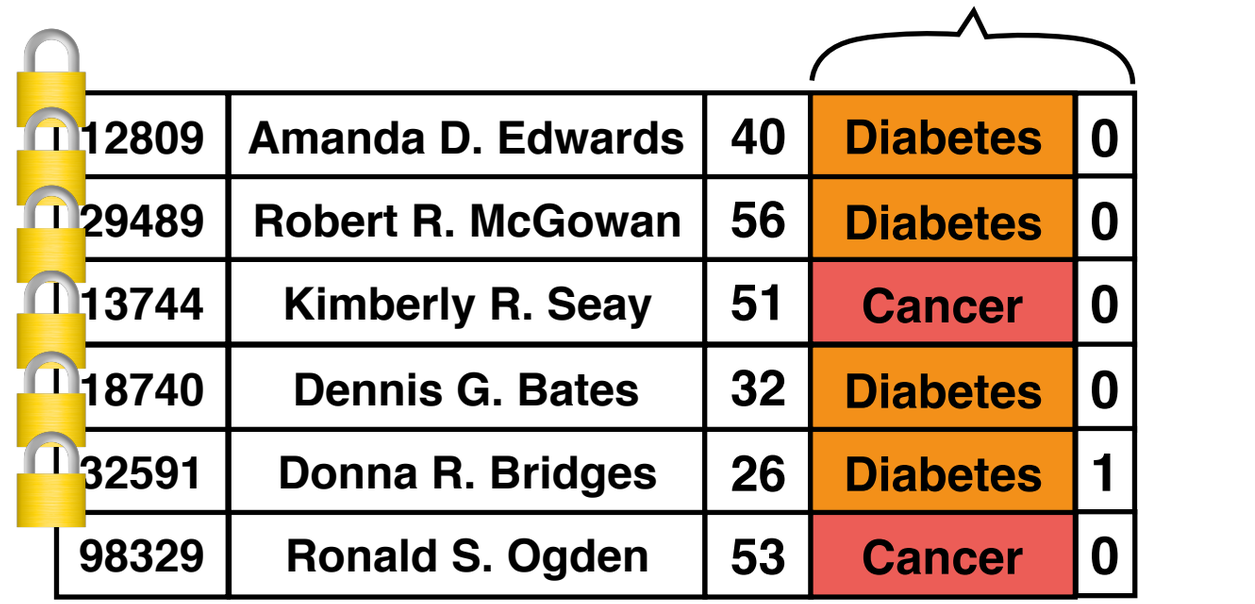

12809	Amanda D. Edwards	40	Diabetes	0
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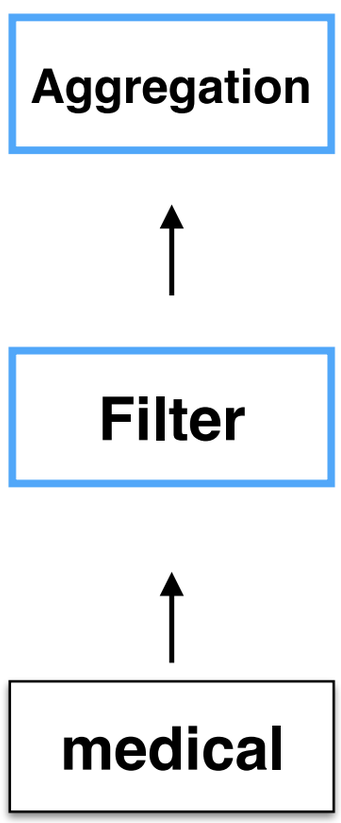
Rule-based optimization

Logical op.



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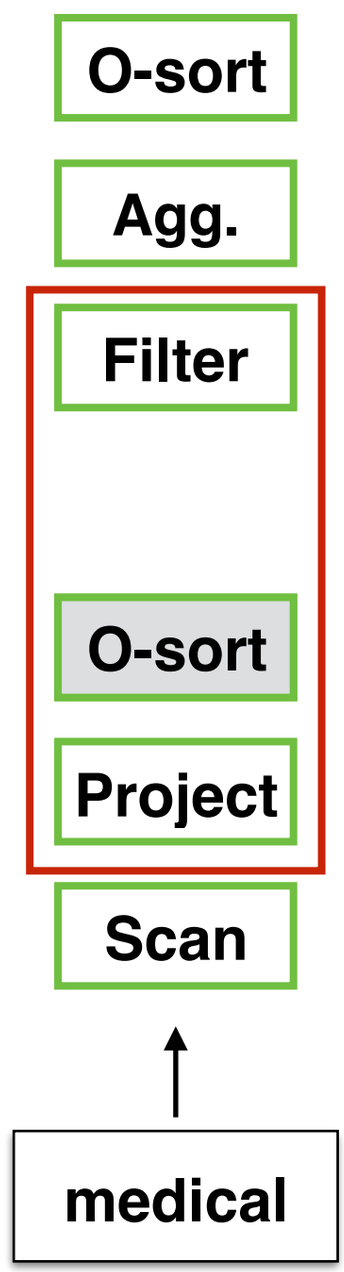

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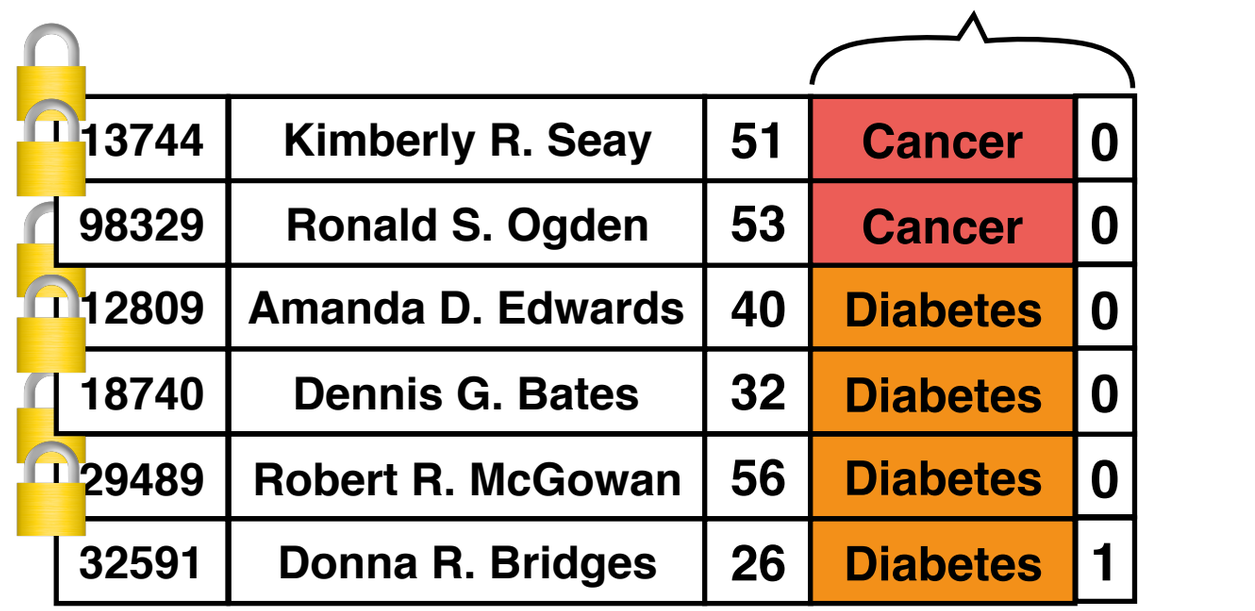

13744	Kimberly R. Seay	51	Cancer	0
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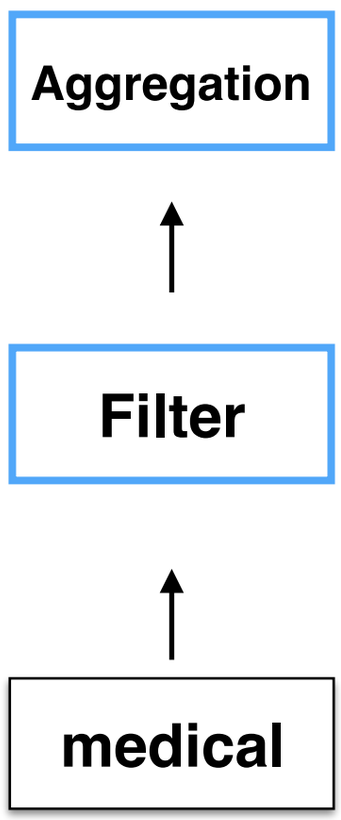
Rule-based optimization

Logical op.



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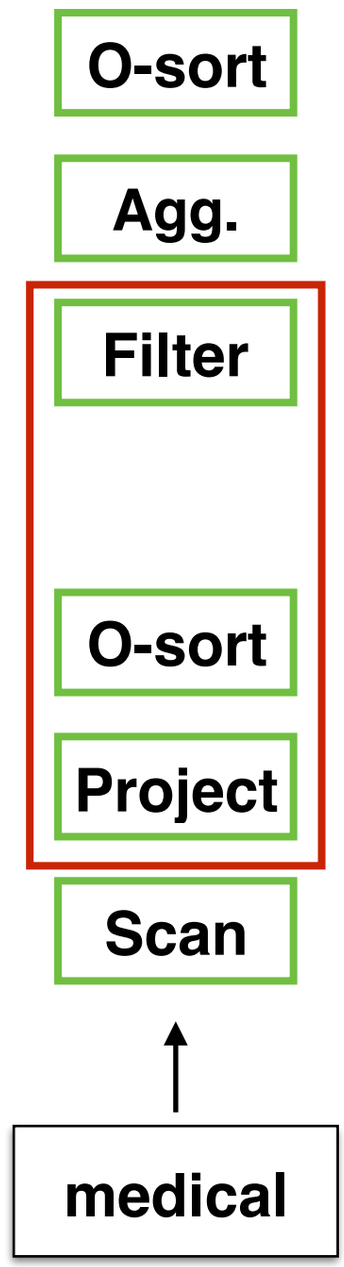
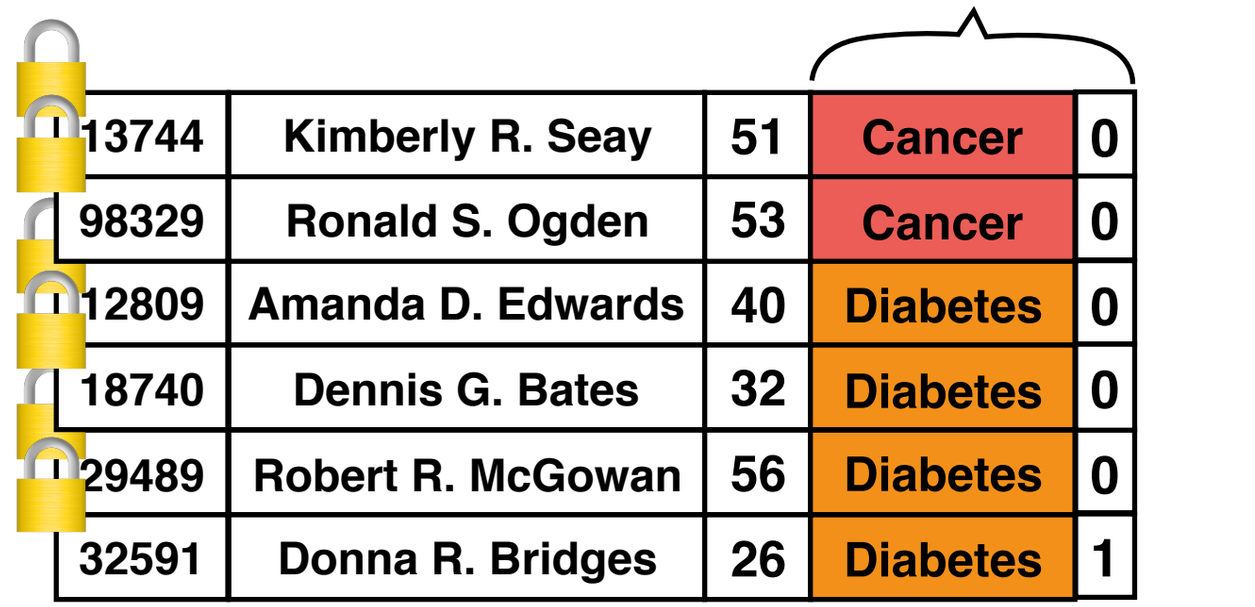


multi-column sort



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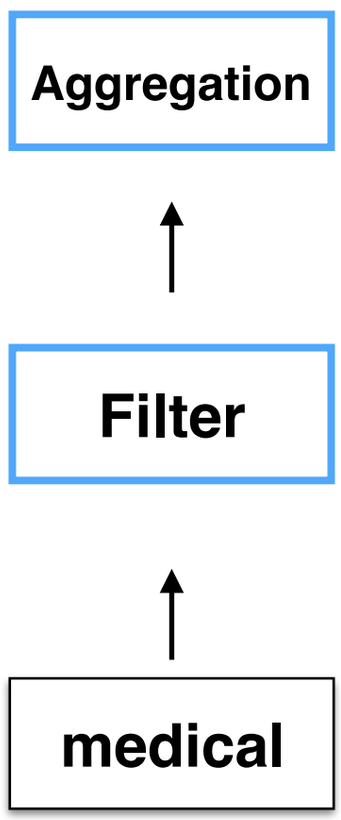
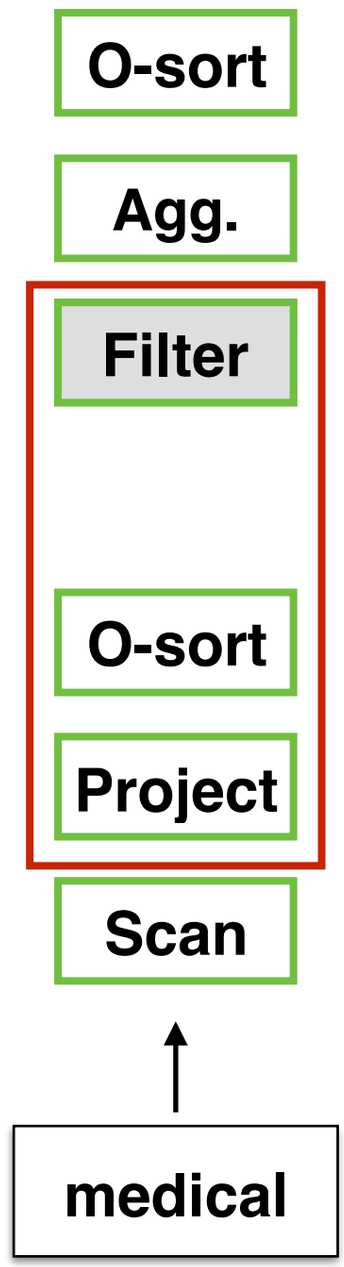
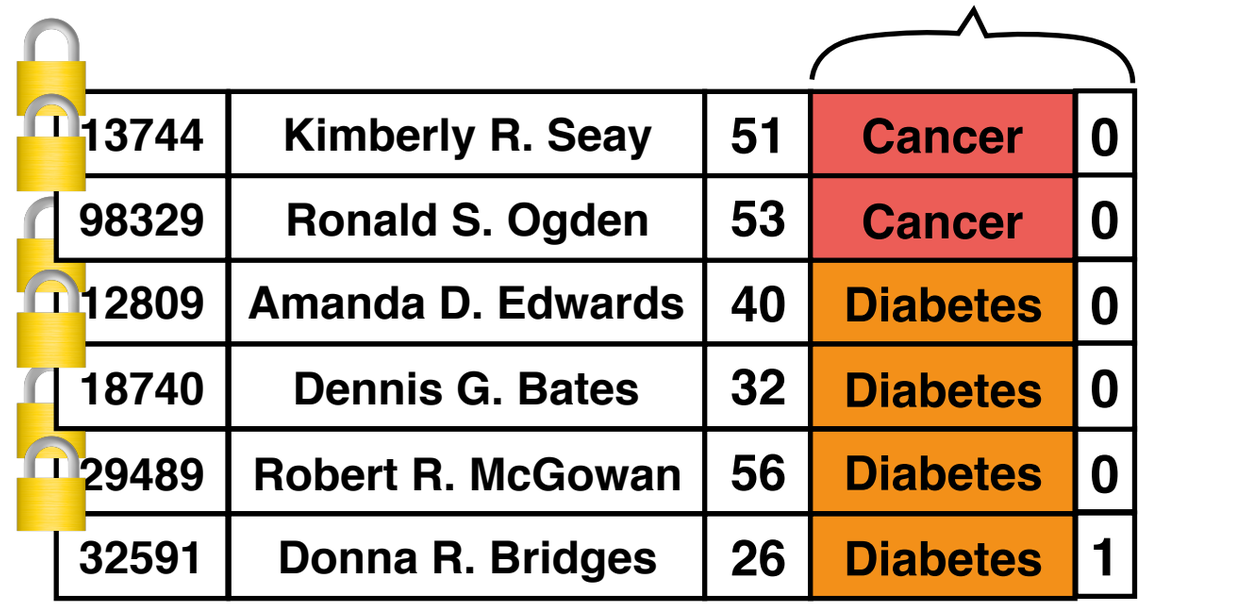
Logical op.



Opaque op.



multi-column sort



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18740	Dennis G. Bates	32	Diabetes	0
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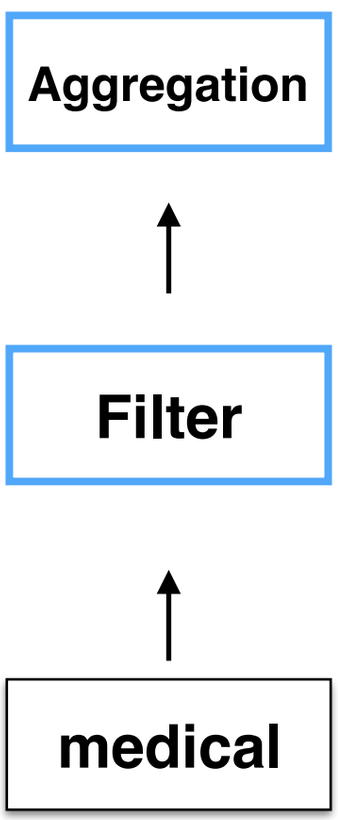
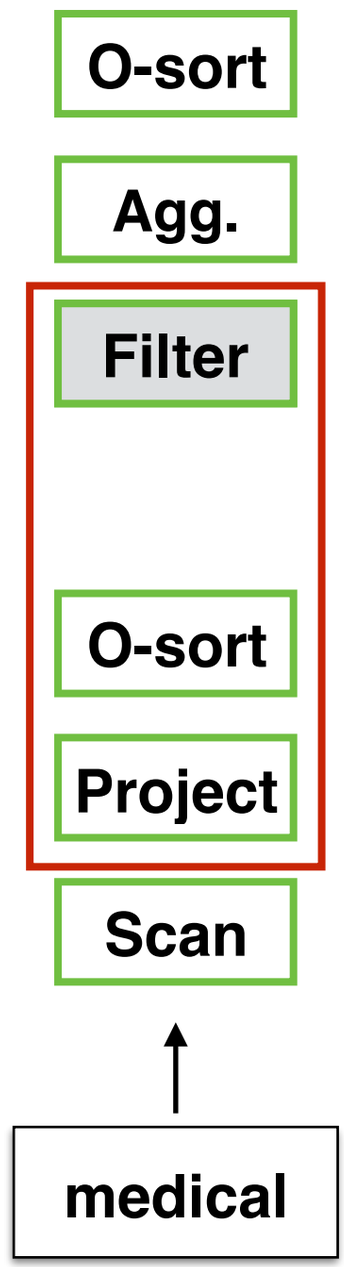
Rule-based optimization

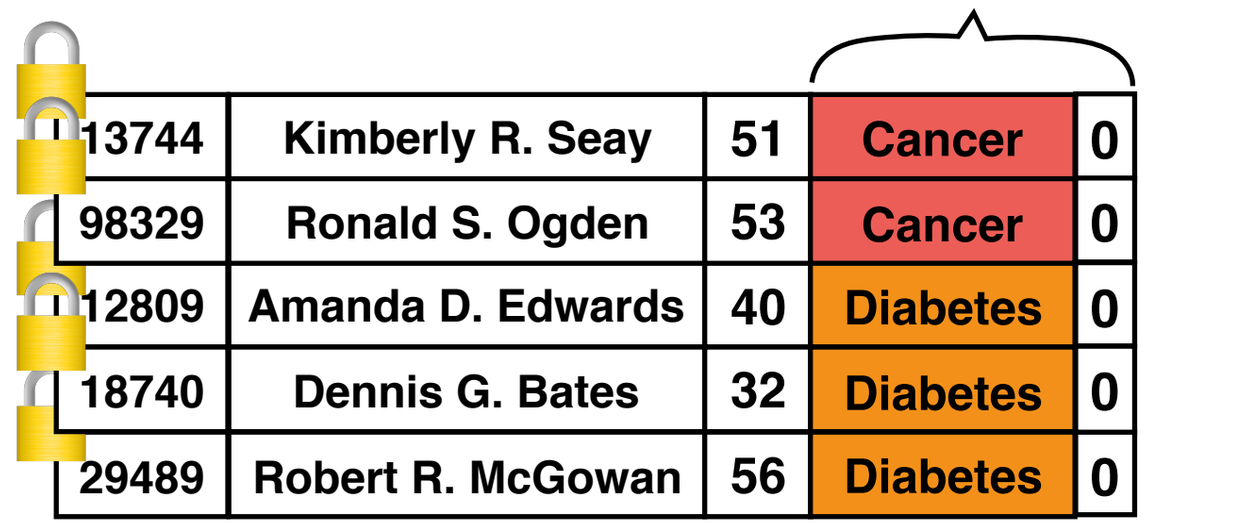
Logical op.



Opaque op.



multi-column sort



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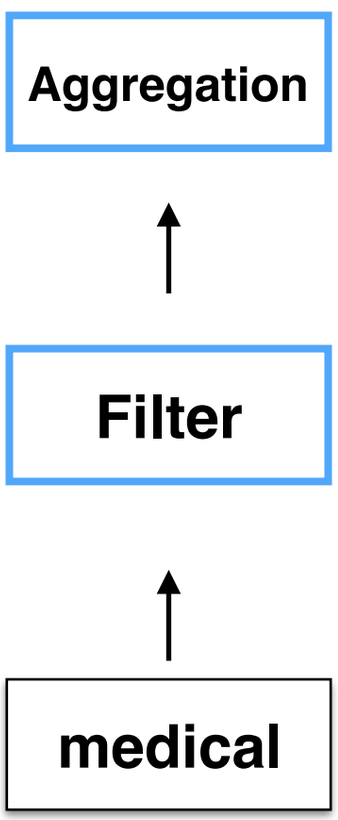

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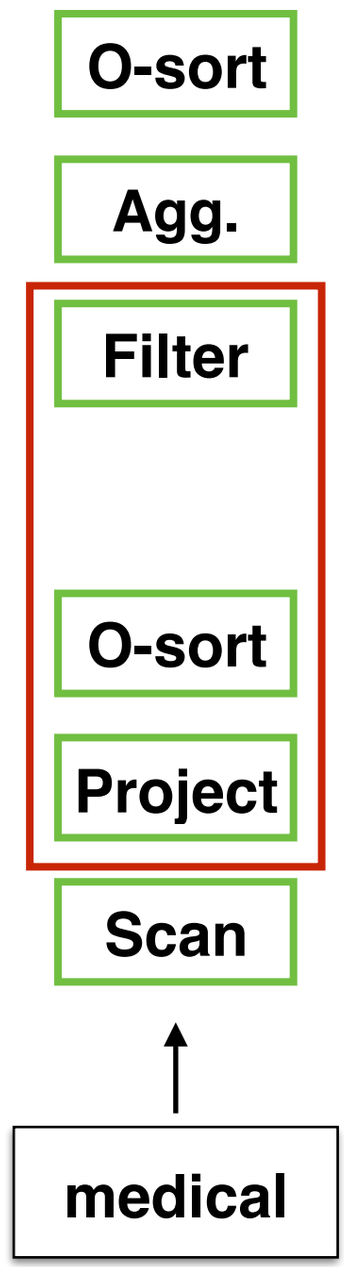

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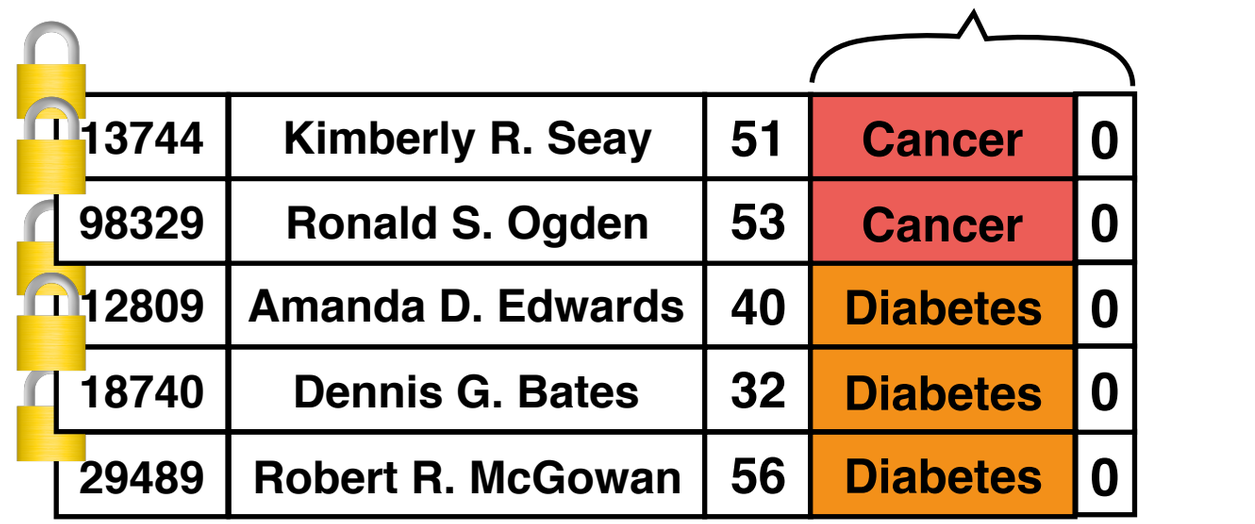

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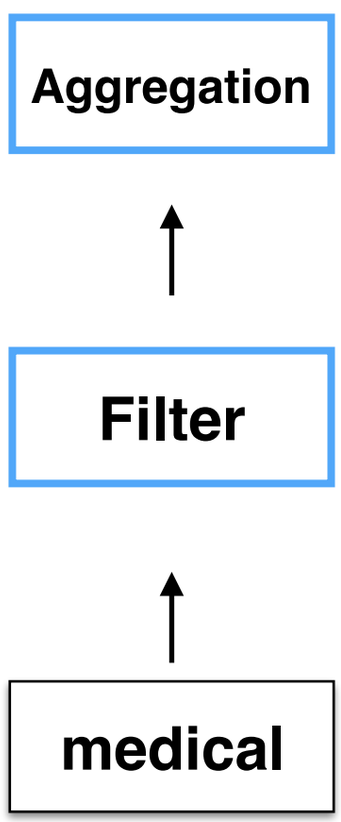
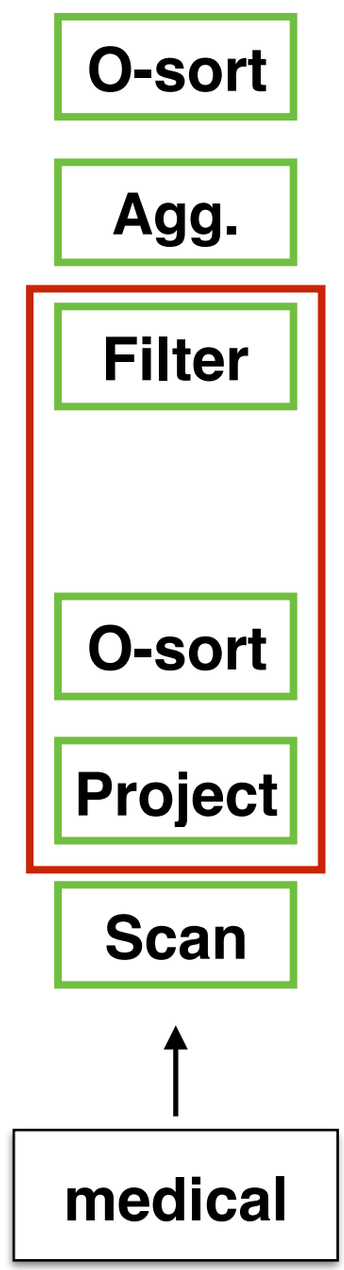
Rule-based optimization

Logical op.



Opaque op.



multi-column sort

13744	Kimberly R. Seay	51	Cancer	0
98329	Ronald S. Ogden	53	Cancer	0
12809	Amanda D. Edwards	40	Diabetes	0
18740	Dennis G. Bates	32	Diabetes	0
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Eliminated one oblivious sort!

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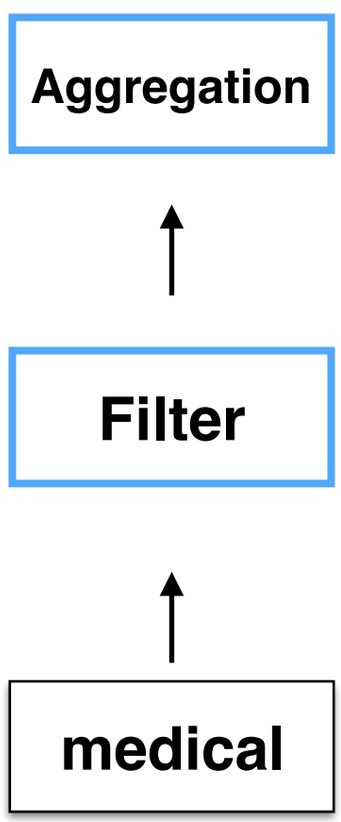

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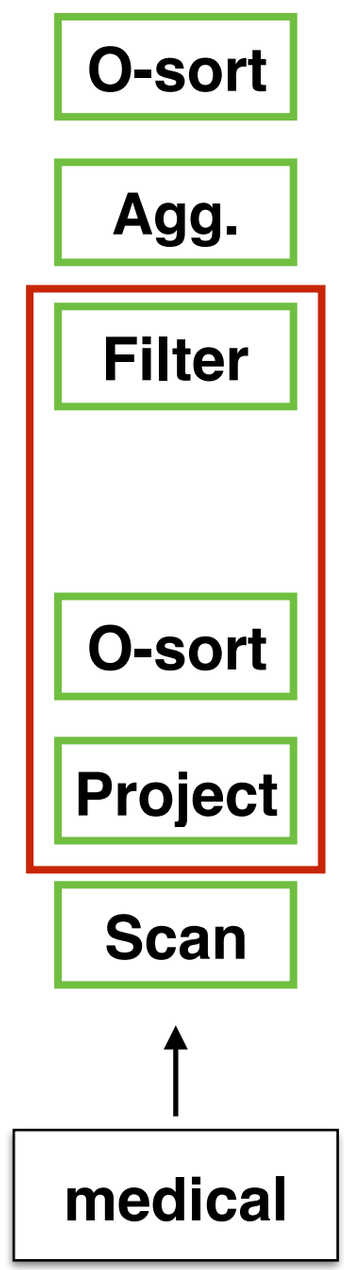

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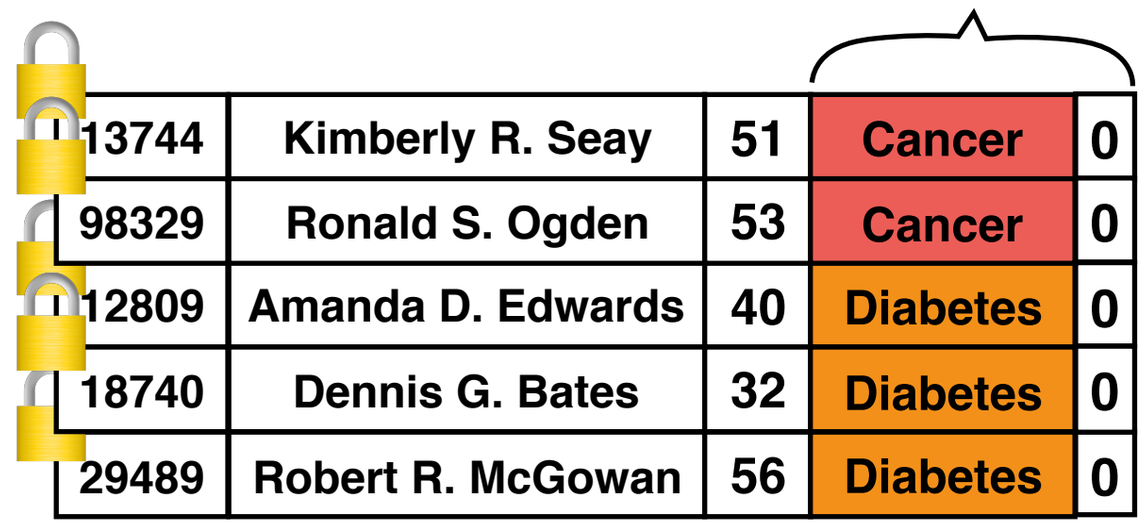

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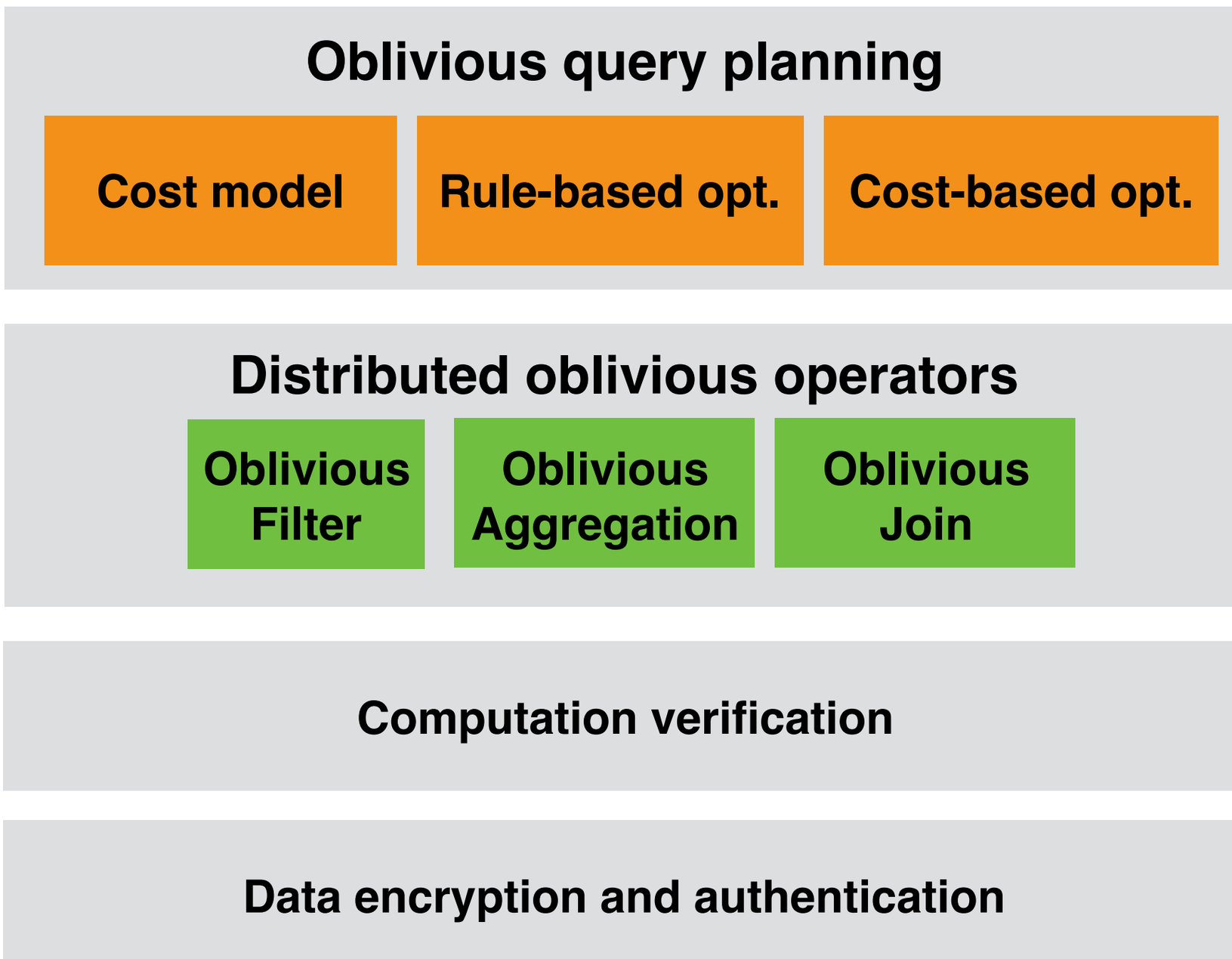
No change to the Spark SQL planner!

More in the paper..



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- Distributed experiments
  - A cluster of 5 SGX machines

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Data encryption, authentication, computation verification

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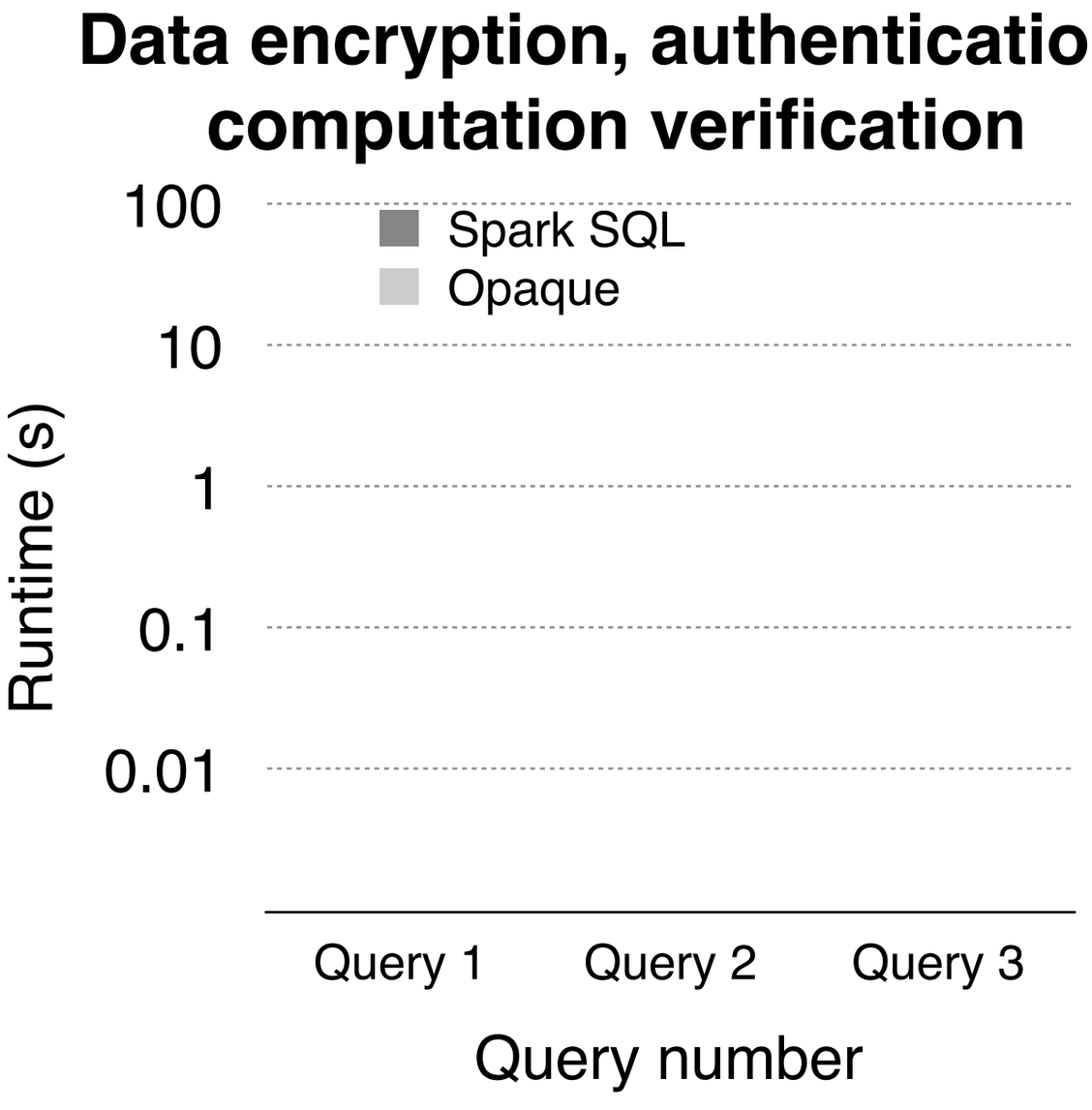
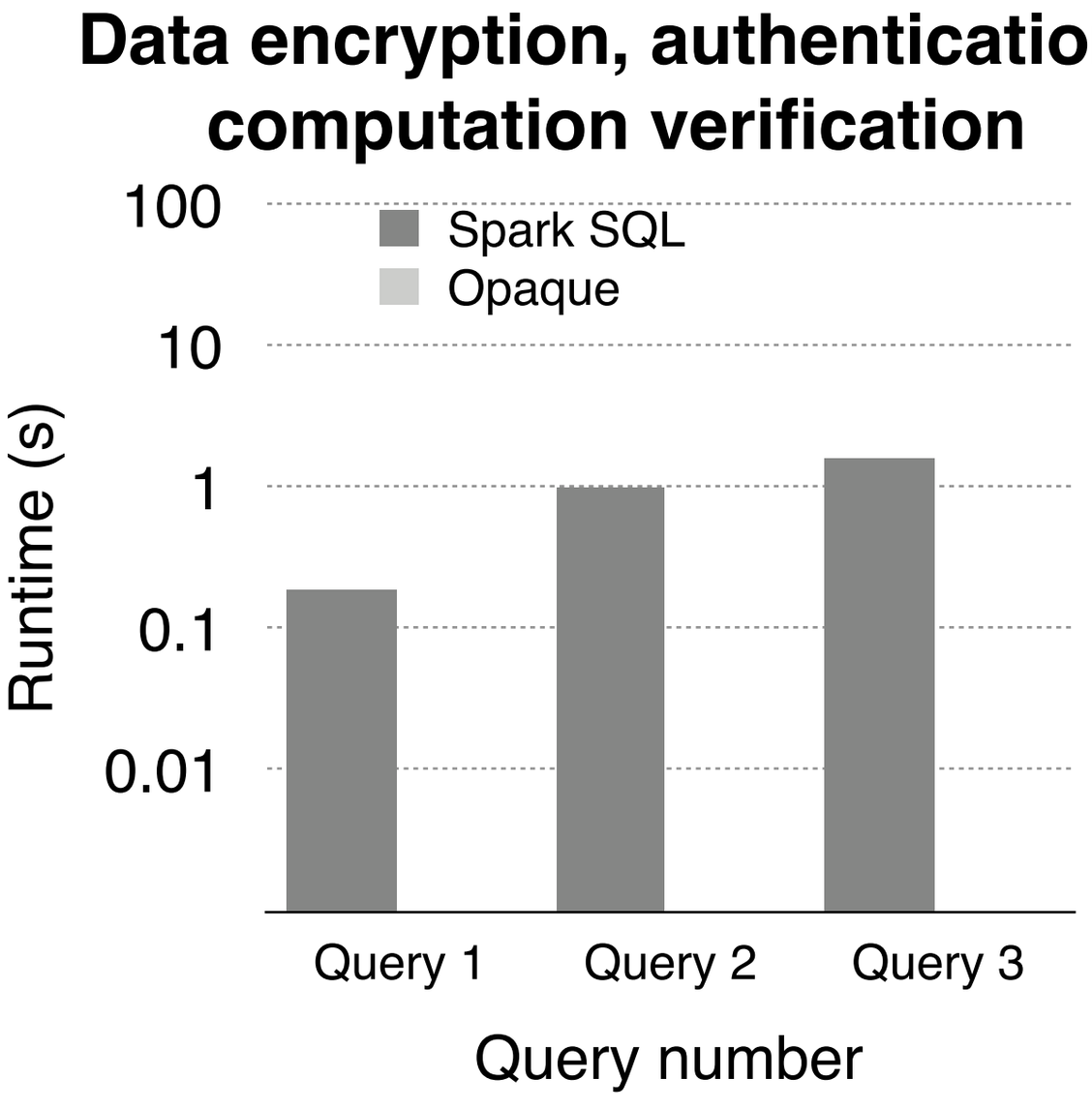


Big Data Benchmark (distributed)



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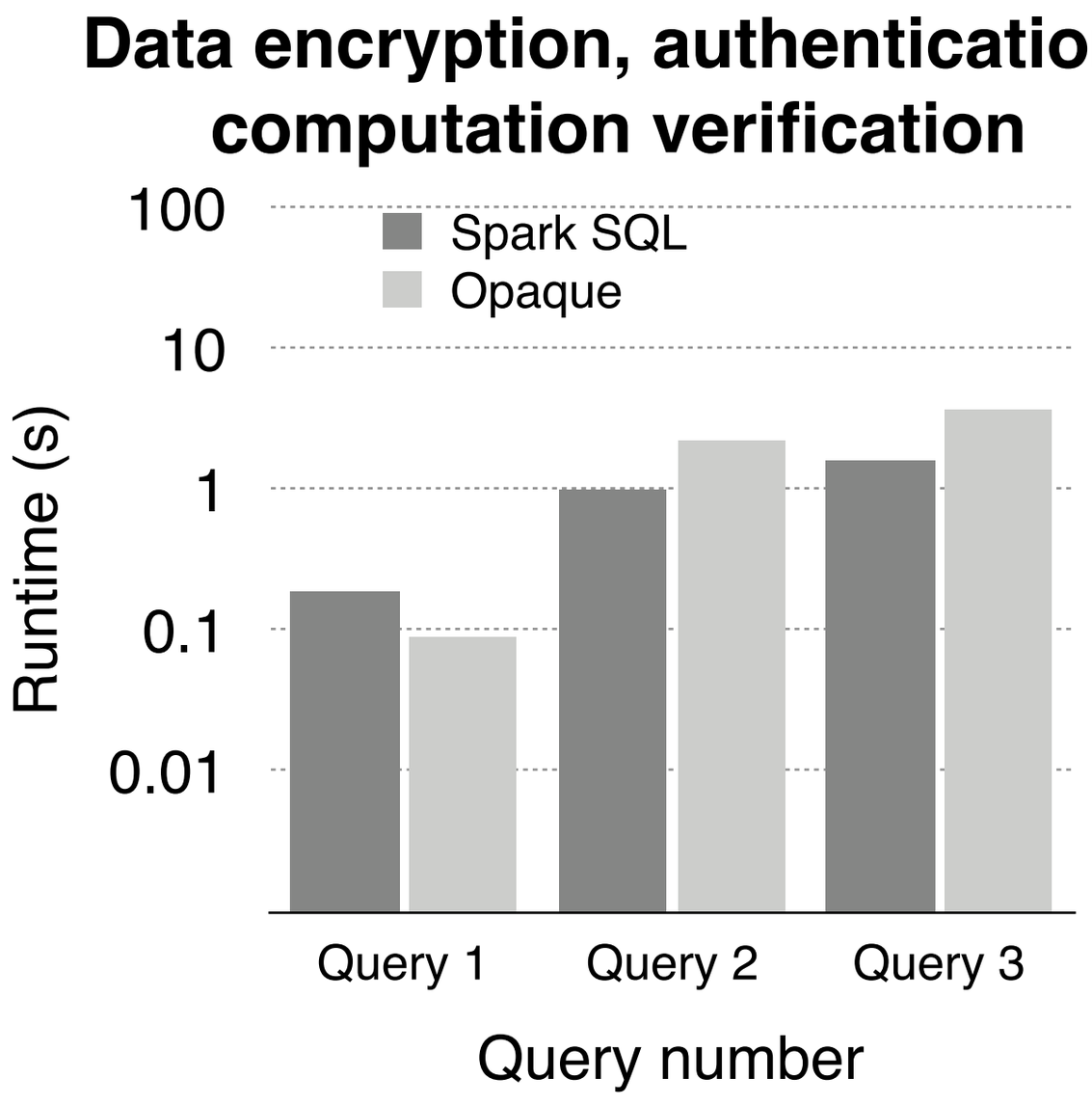

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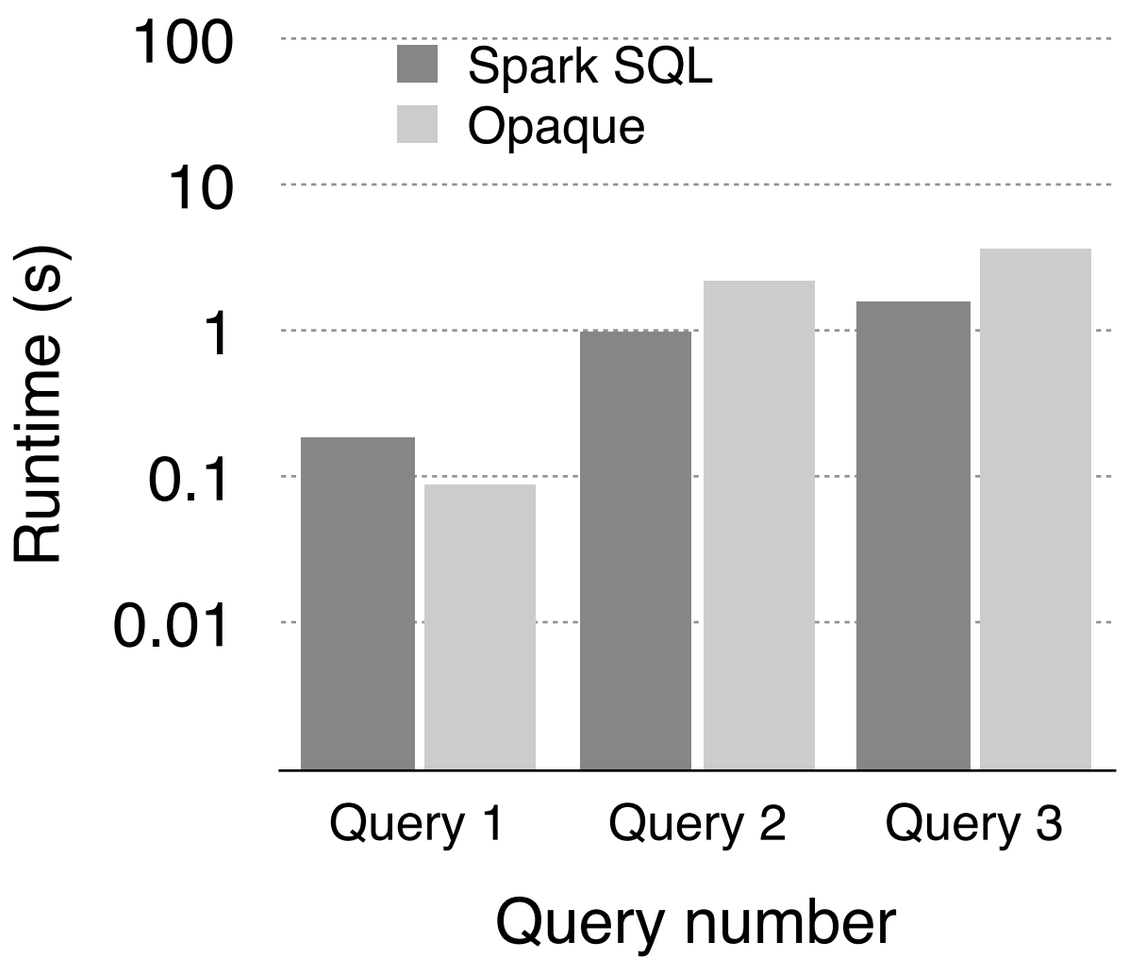

Overhead: -0.47x to 2.3x

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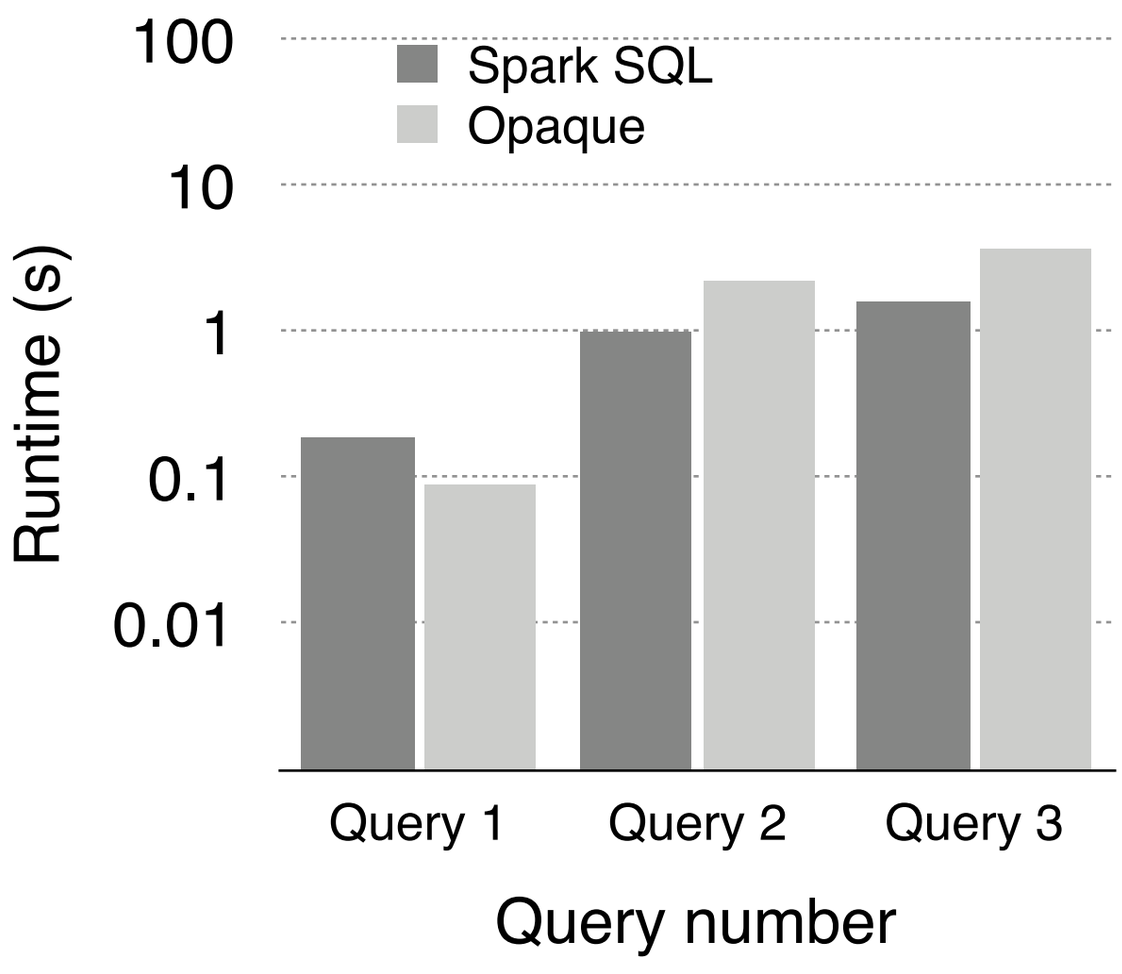

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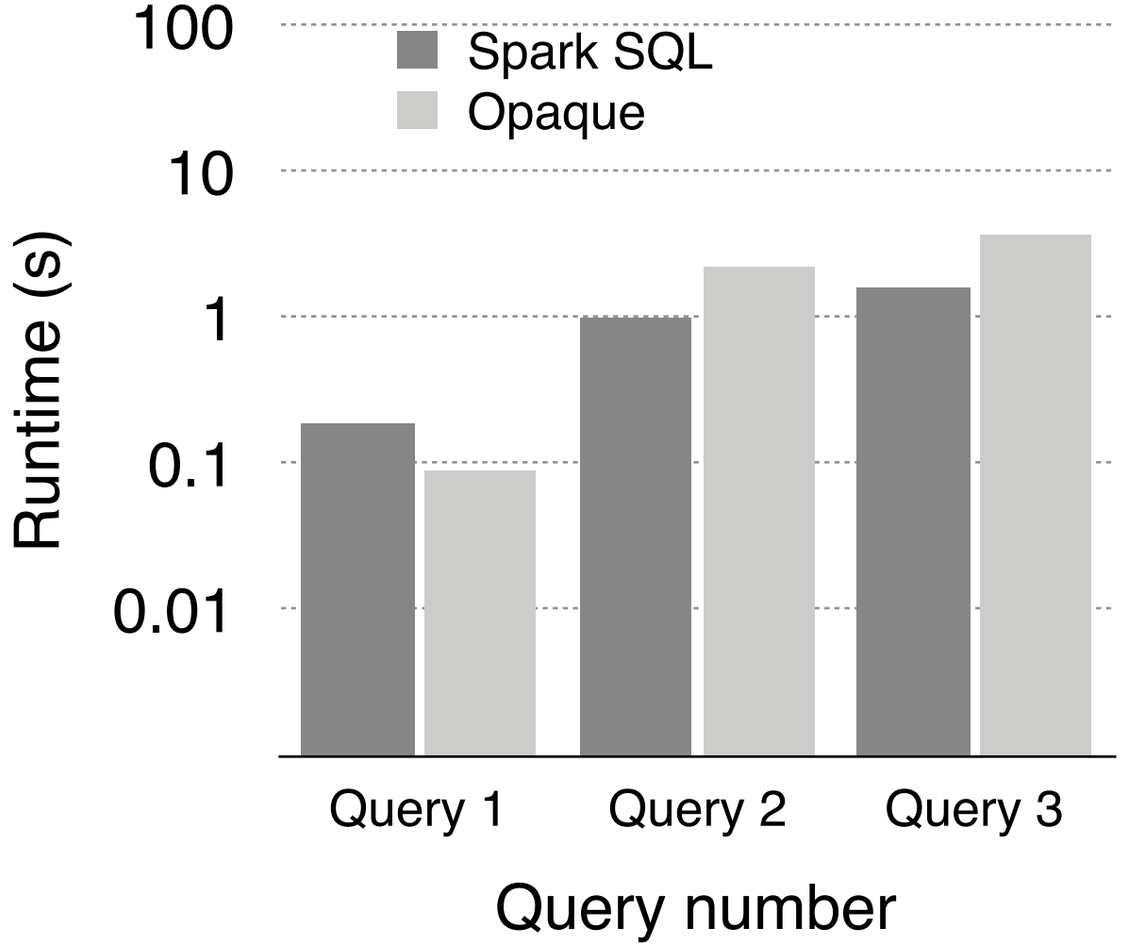

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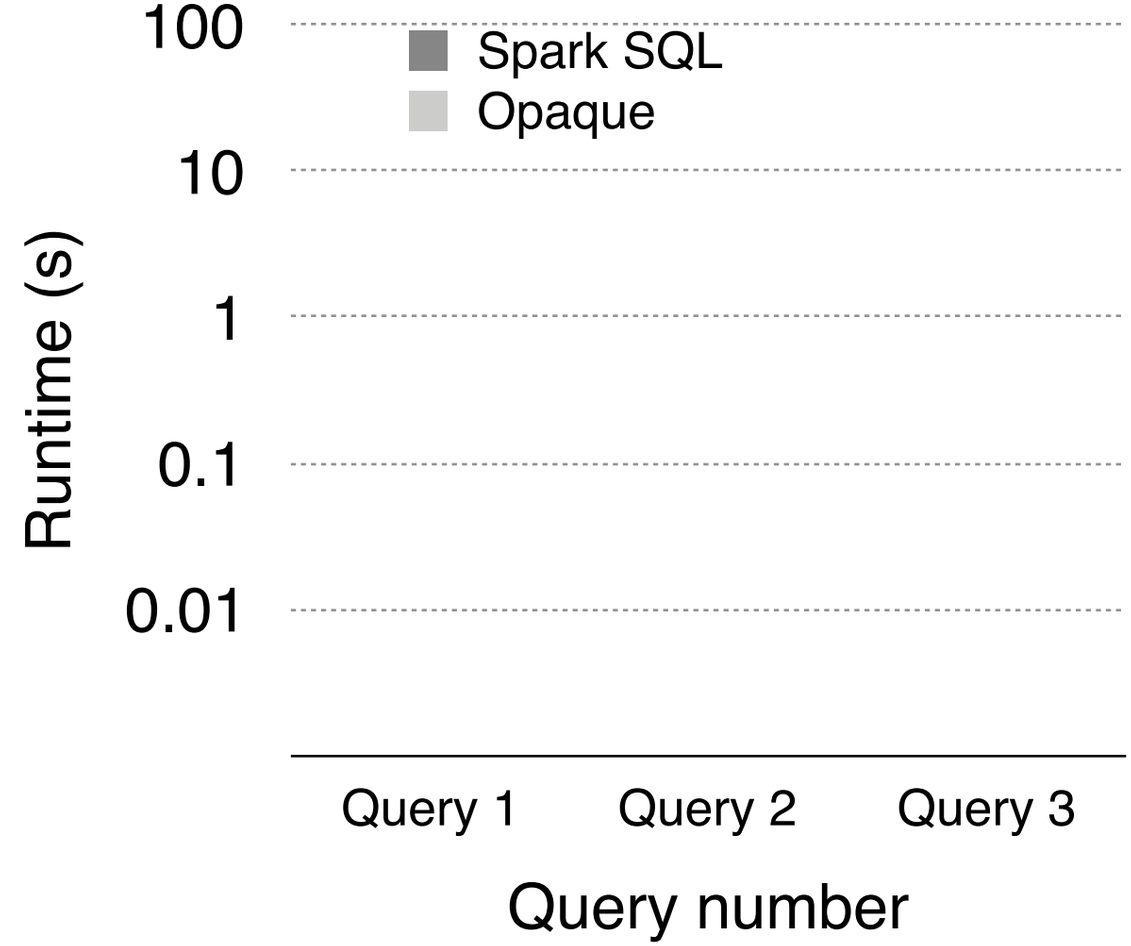

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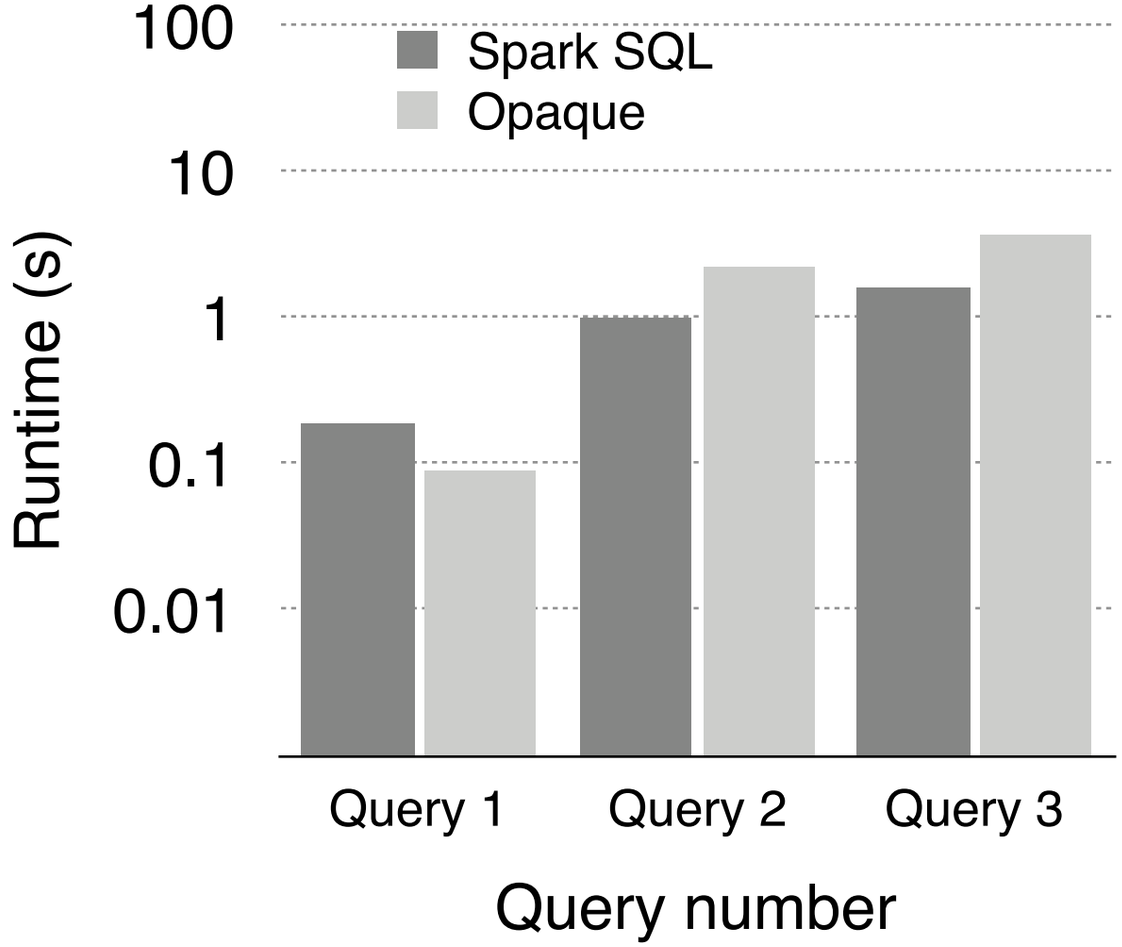

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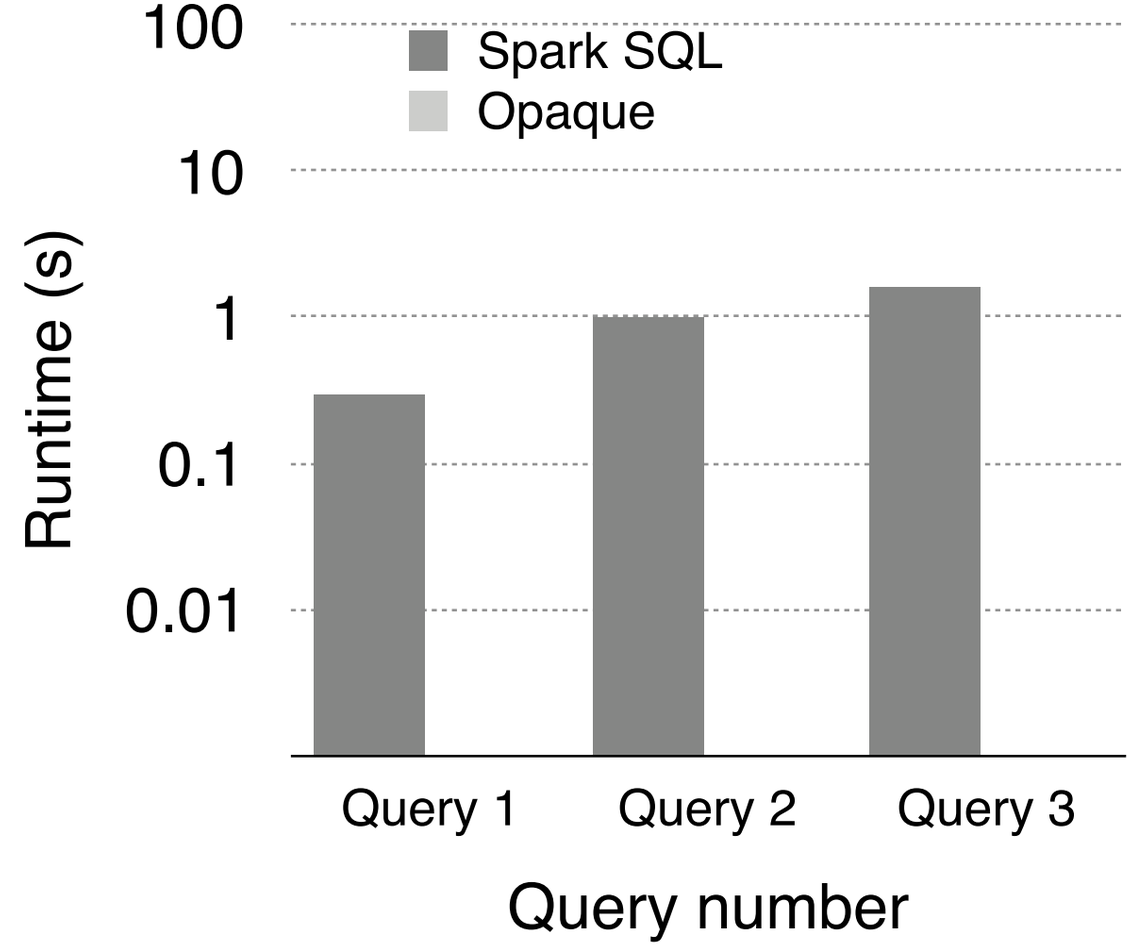

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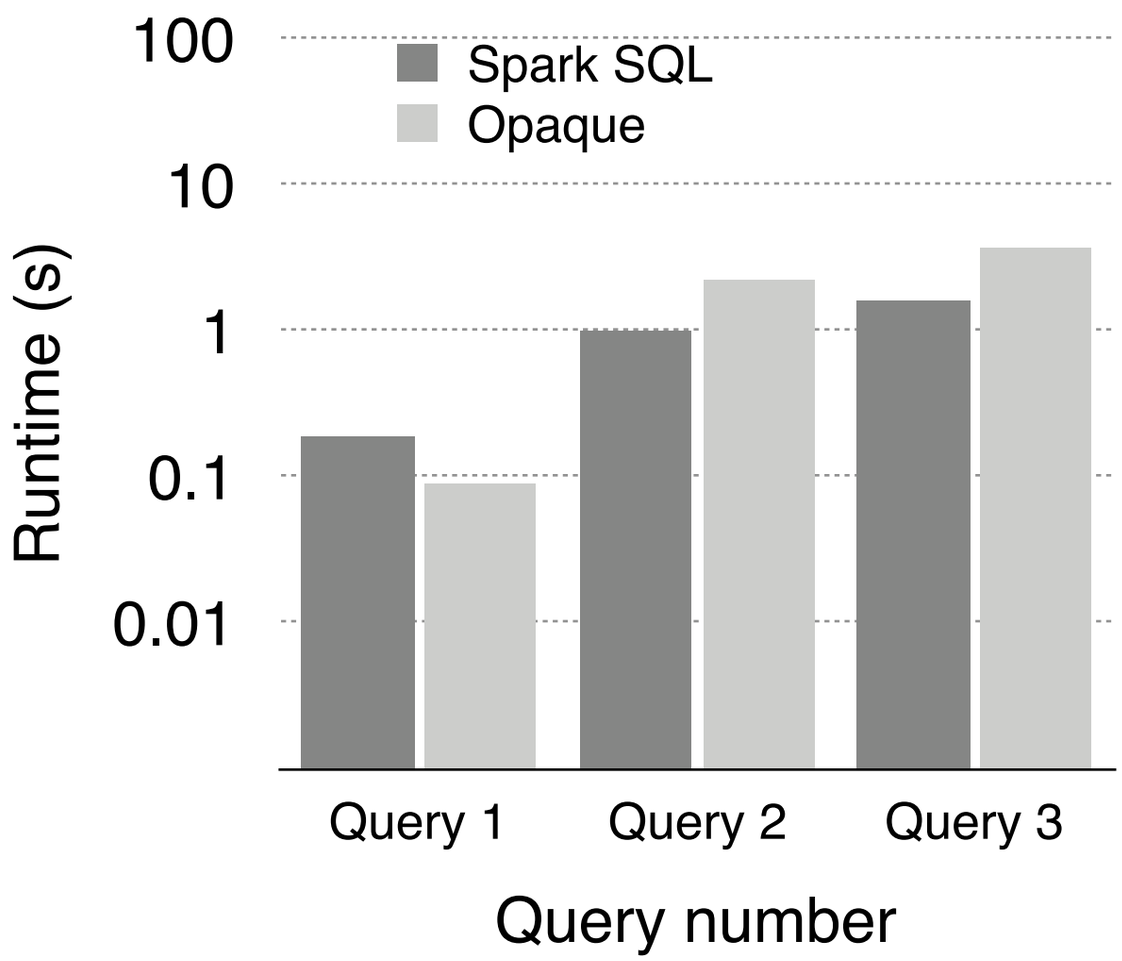

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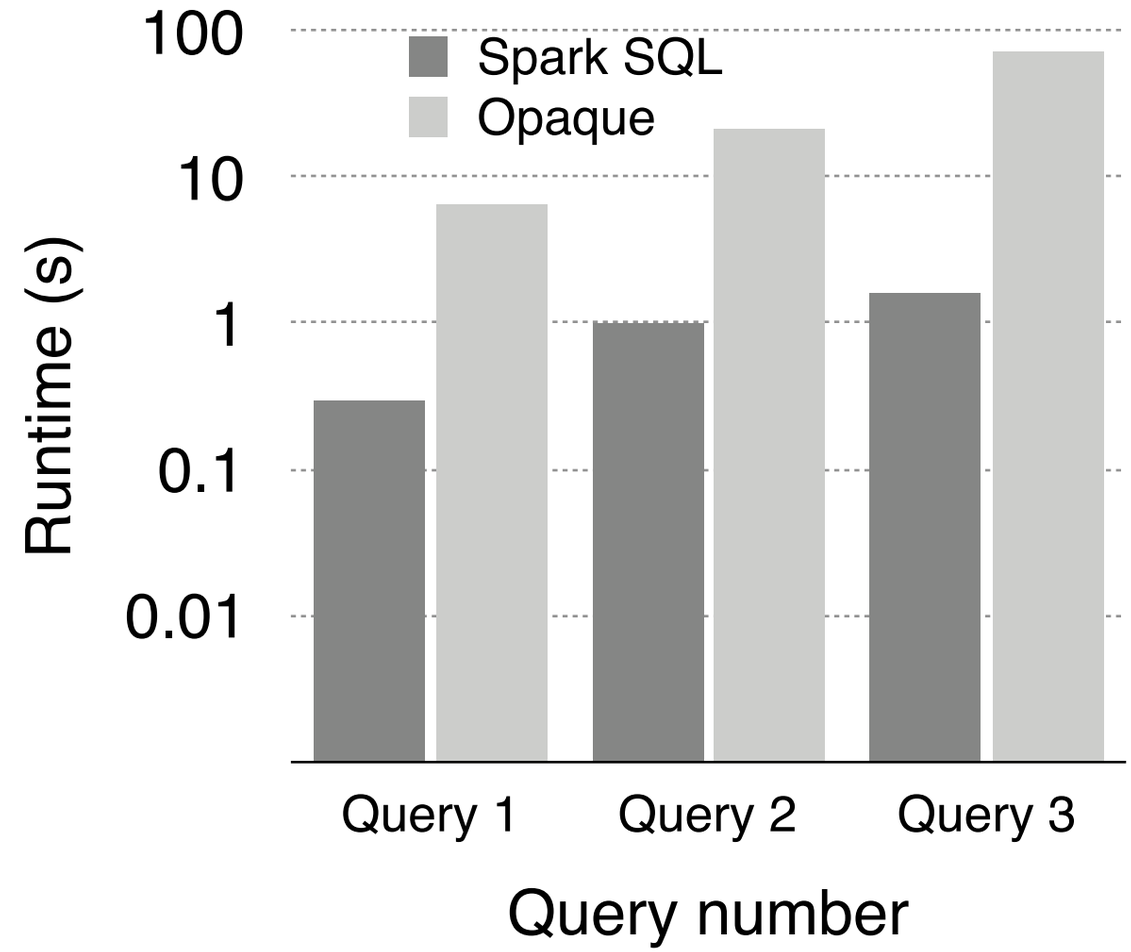

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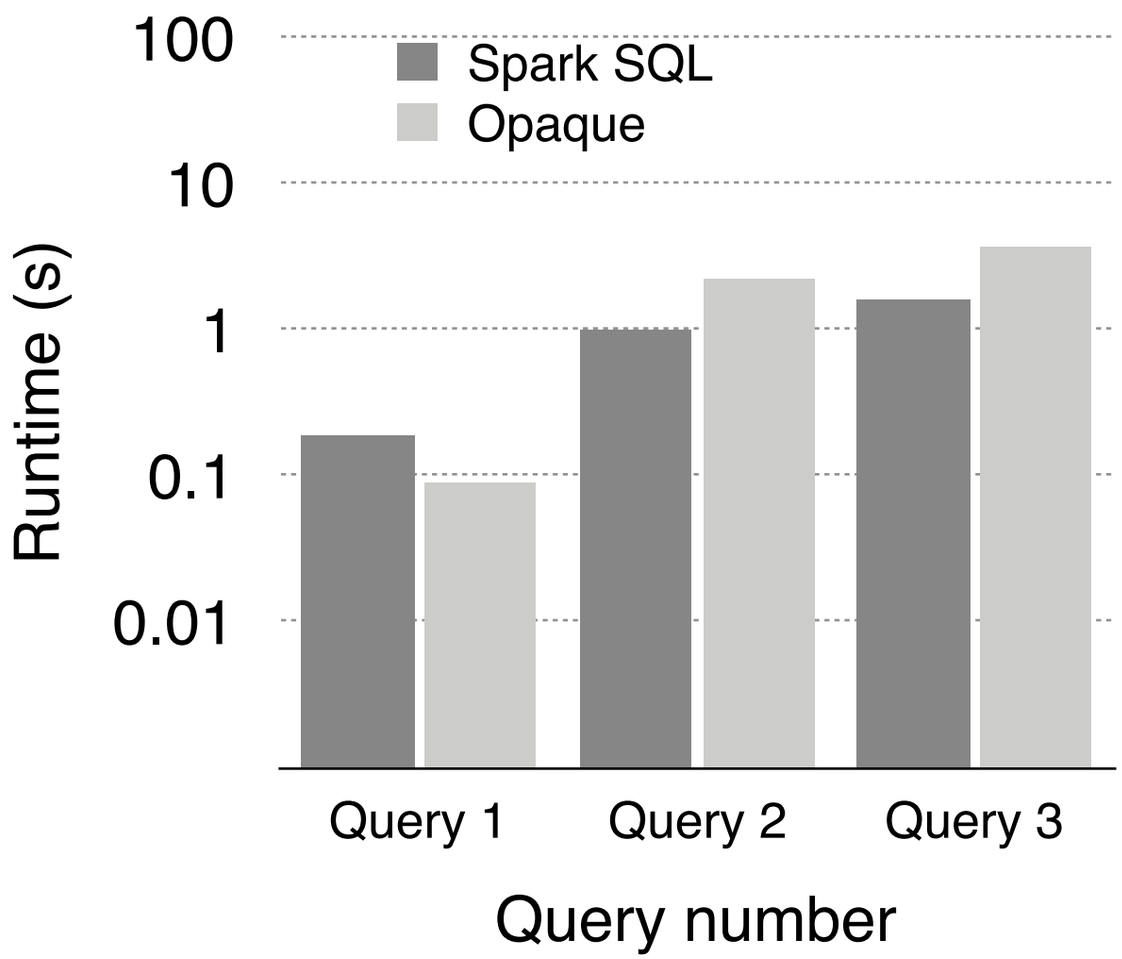

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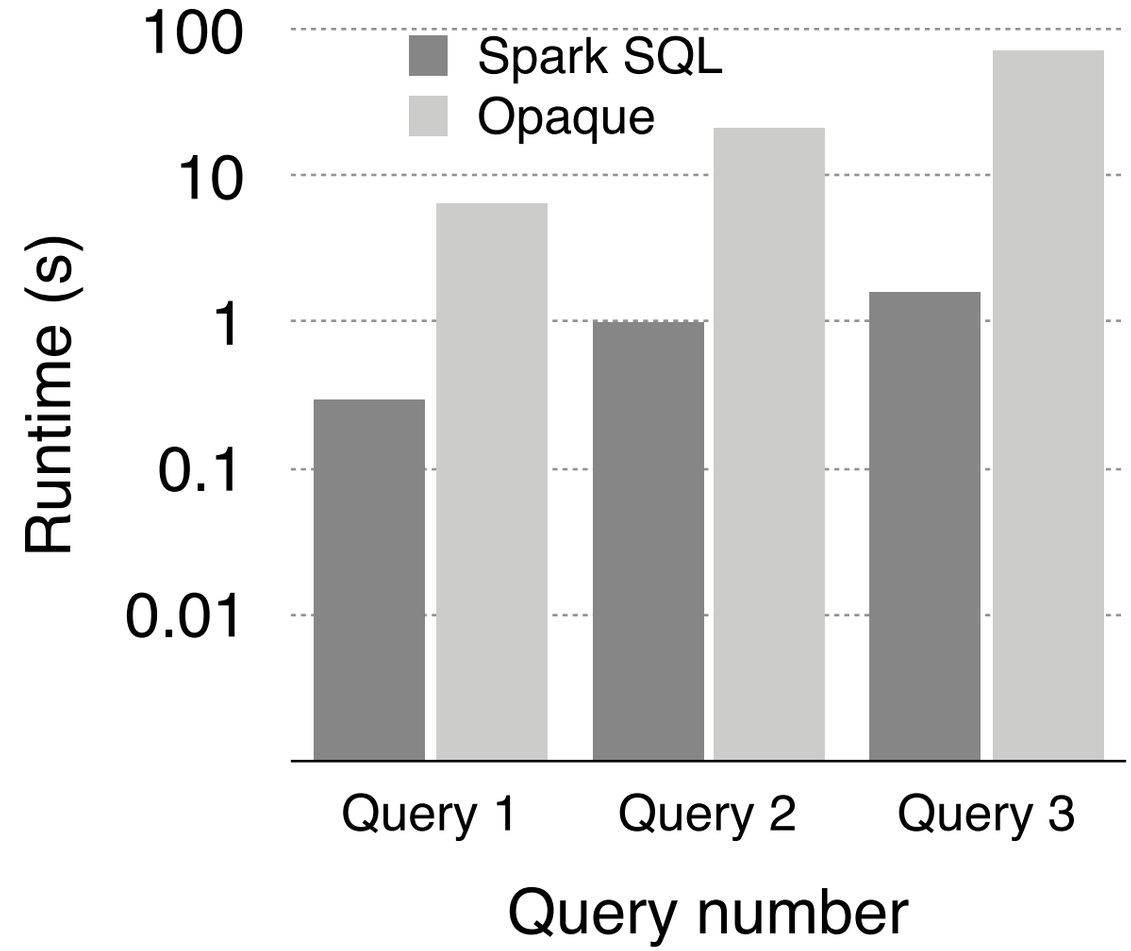
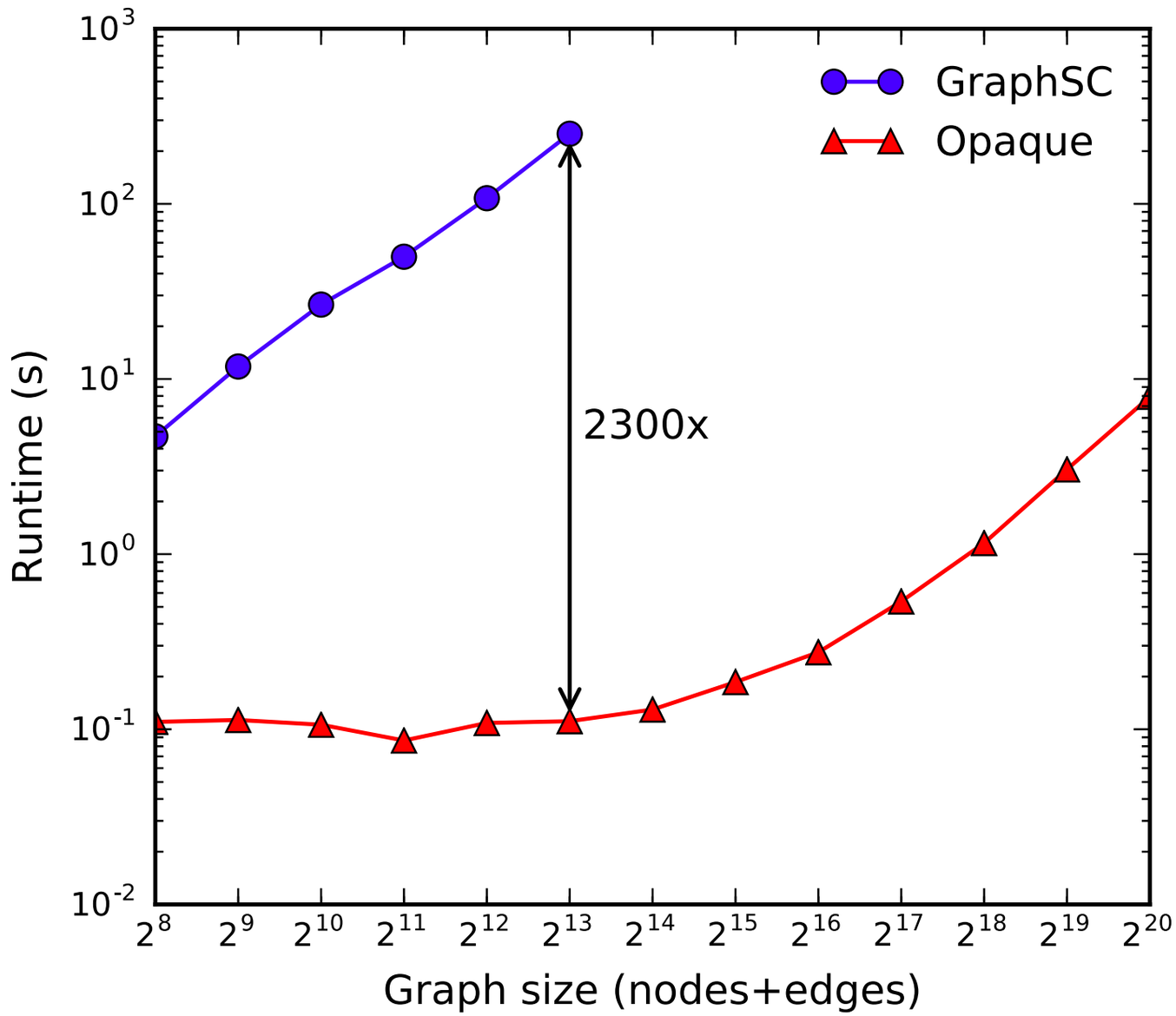


Overhead: -0.47x to 2.3x

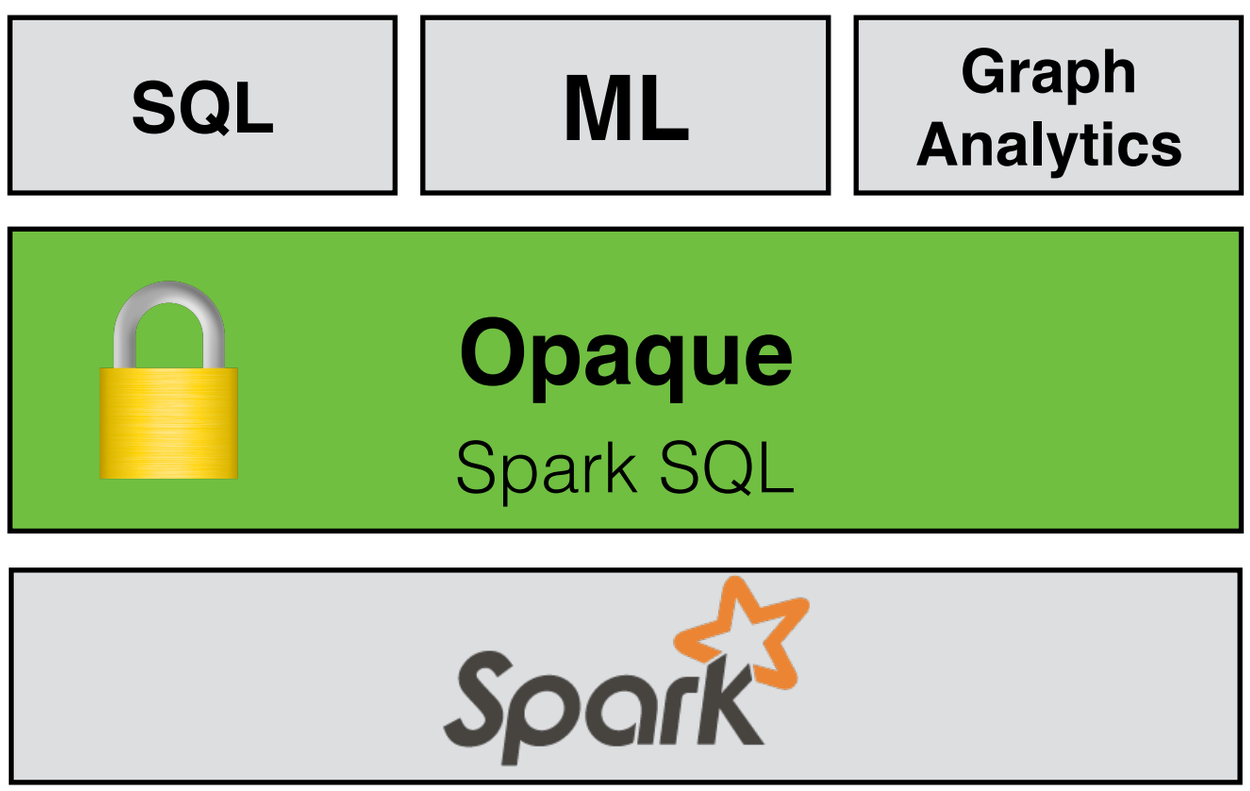
Overhead: 21x to 45x

PageRank: comparison with GraphSC (single machine)



Conclusion

Opaque is an oblivious and encrypted distributed analytics platform



WIP open source: github.com/ucbrise/opaque