ANDREA LATTUADA, PHD CANDIDATE @ ETH SYSTEMS GROUP

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❤️ NAIAD: A TIMELY DATAFLOW SYSTEM

DEREK G. MURRAY, FRANK MCSHERRY, REBECCA ISAACS, MICHAEL ISARD, PAUL BARHAM, MARTÍN ABADI

ABSTRACT

NAIAD IS A DISTRIBUTED SYSTEM FOR EXECUTING DATA PARALLEL, CYCLIC DATAFLOW PROGRAMS.

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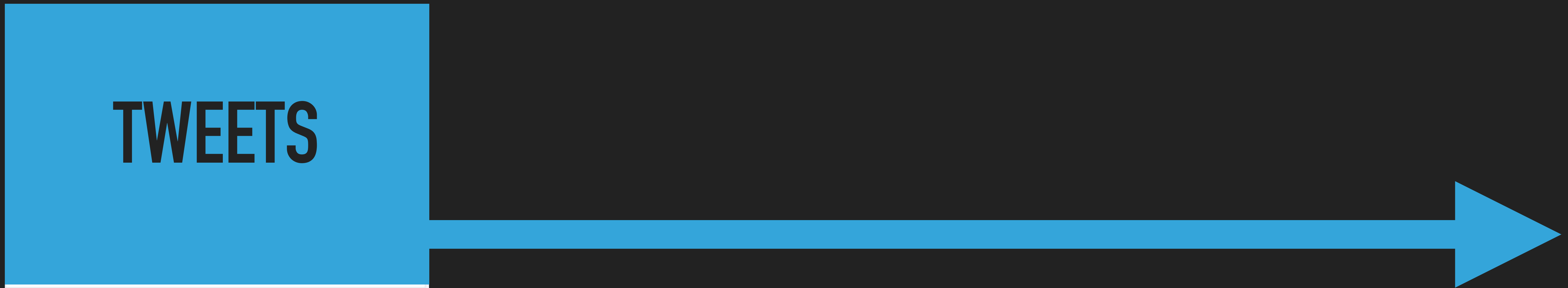

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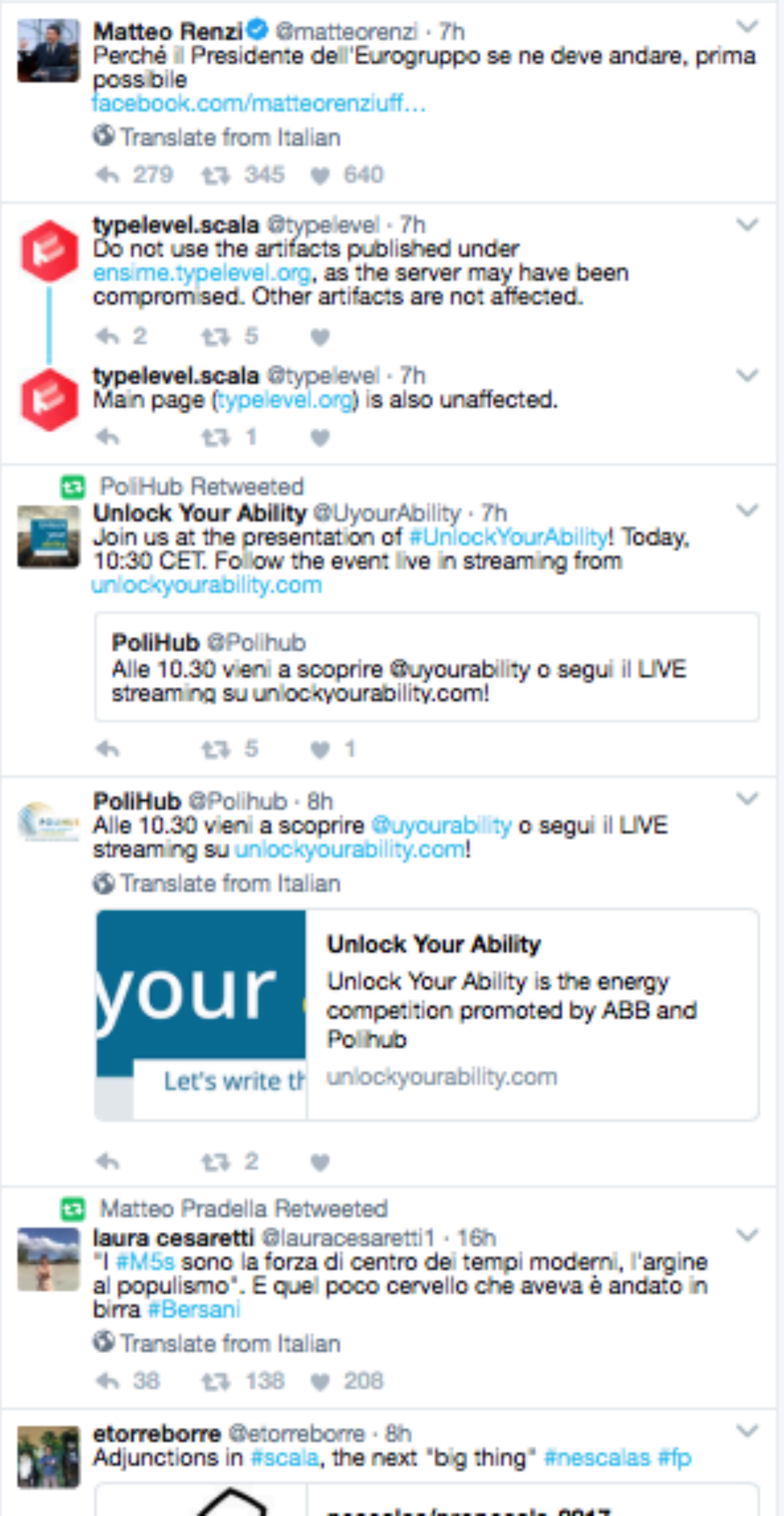


Matteo Renzi @matteorenzi · 7h
Perché il Presidente dell'Eurogruppo se ne deve andare, prima possibile
facebook.com/matteorenziuff…
Translate from Italian
279 345 640

typelevel.scala @typelevel · 7h
Do not use the artifacts published under ensime.typelevel.org, as the server may have been compromised. Other artifacts are not affected.
2 5

typelevel.scala @typelevel · 7h
Main page (typelevel.org) is also unaffected.
1

PoliHub Retweeted
Unlock Your Ability @UyourAbility · 7h
Join us at the presentation of #UnlockYourAbility! Today, 10:30 CET. Follow the event live in streaming from unlockyourability.com

PoliHub @Polihub
Alle 10.30 vieni a scoprire @uyourability o segui il LIVE streaming su unlockyourability.com!

5 1

PoliHub @Polihub · 8h
Alle 10.30 vieni a scoprire @uyourability o segui il LIVE streaming su unlockyourability.com!
Translate from Italian

your
Let's write th

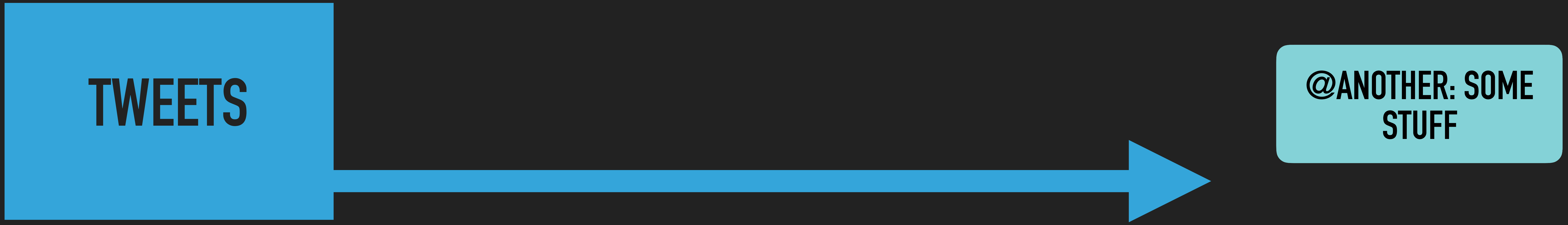
Unlock Your Ability
Unlock Your Ability is the energy competition promoted by ABB and Polihub
unlockyourability.com

2

Matteo Pradella Retweeted
laura cesaretti @lauracesaretti1 · 16h
"I #M5s sono la forza di centro dei tempi moderni, l'argine al populismo". E quel poco cervello che aveva è andato in birra #Bersani
Translate from Italian
38 138 208

etorreborre @etorreborre · 8h
Adjunctions in #scala, the next "big thing" #nescalas #fp

CONTINUOUS INPUT



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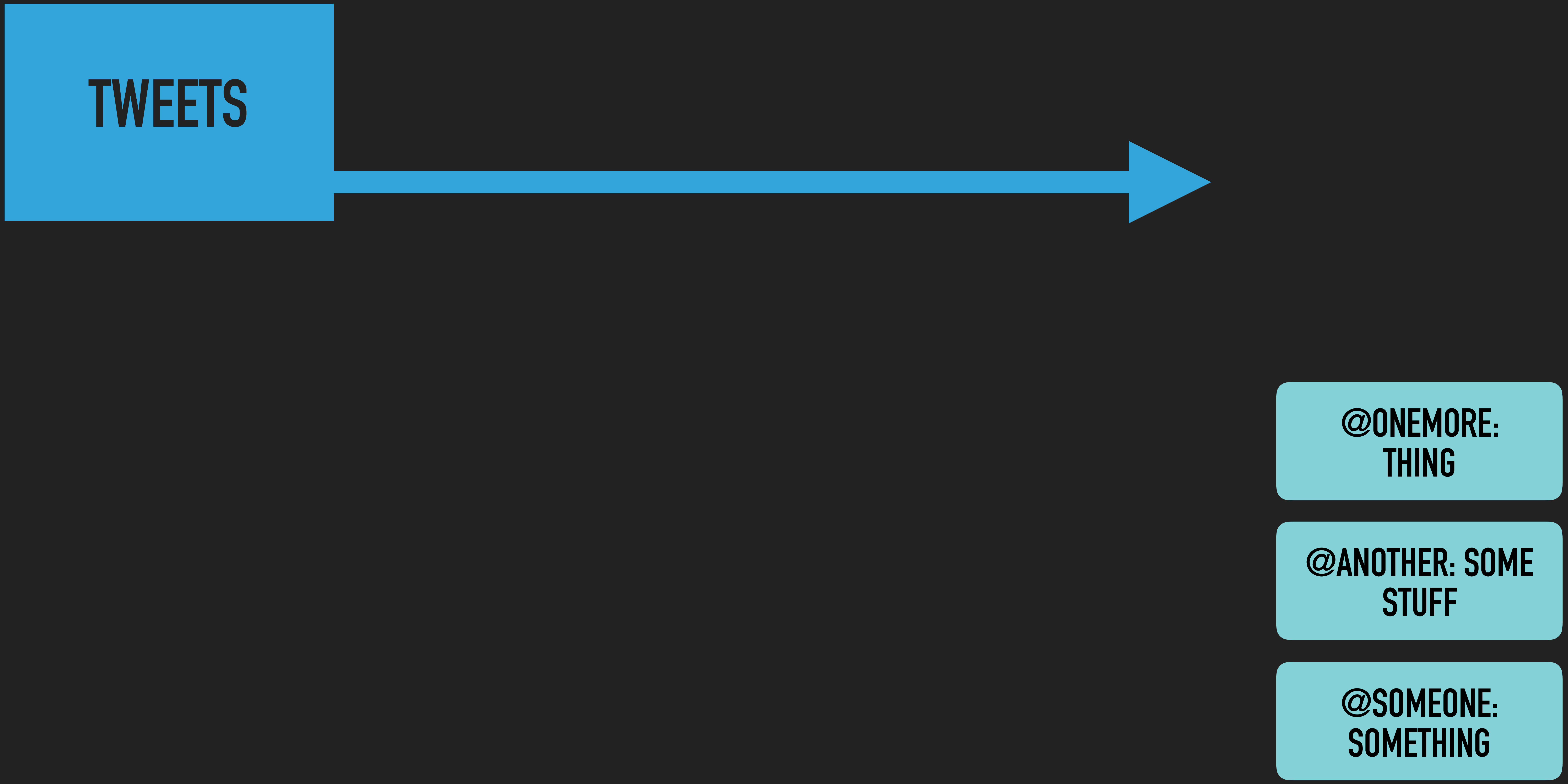
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@ANOTHER: SOME STUFF

@SOMEONE: SOMETHING

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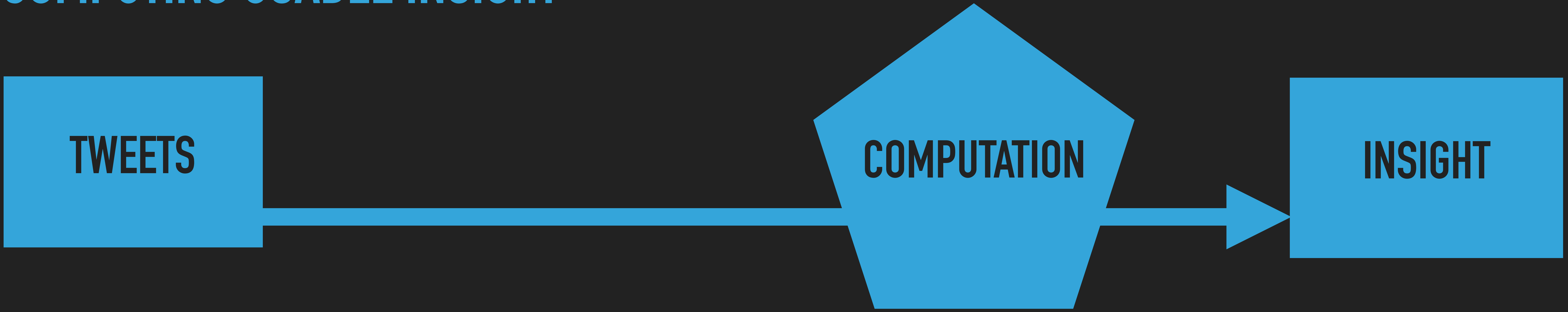

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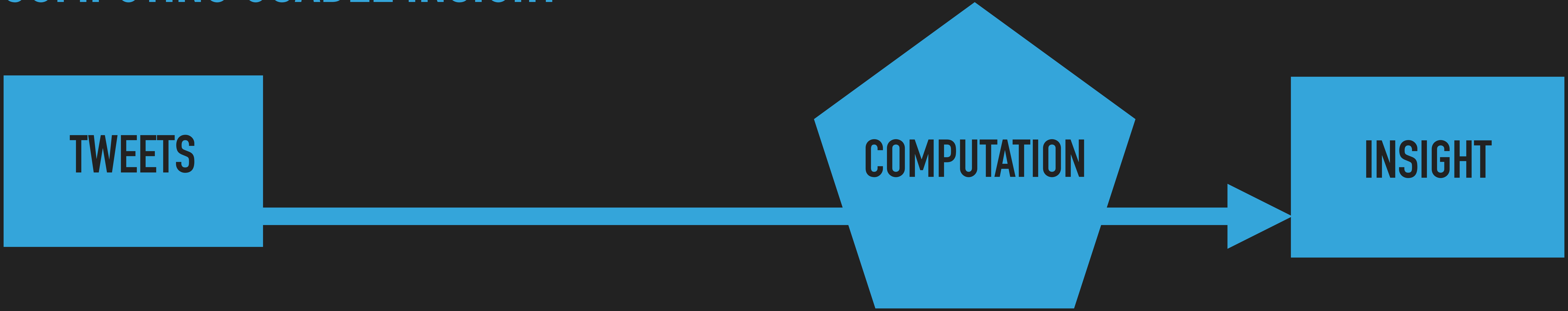

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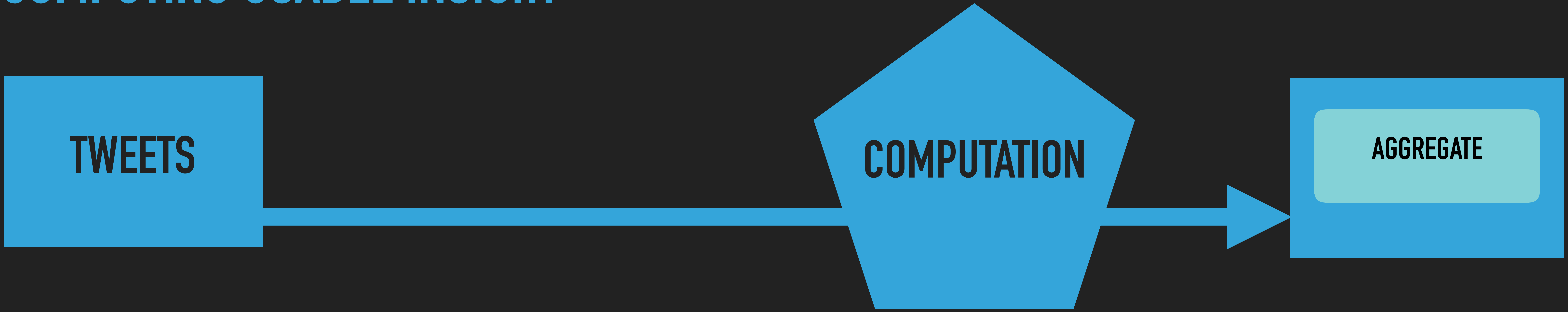

CONTEXT: AGGREGATION

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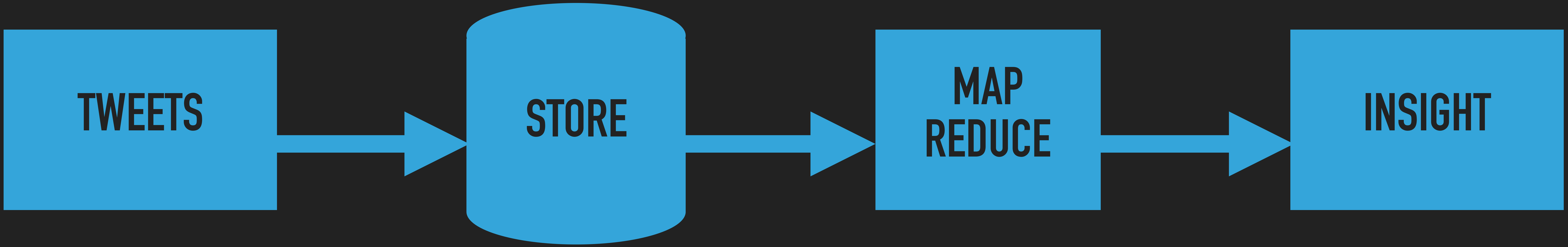

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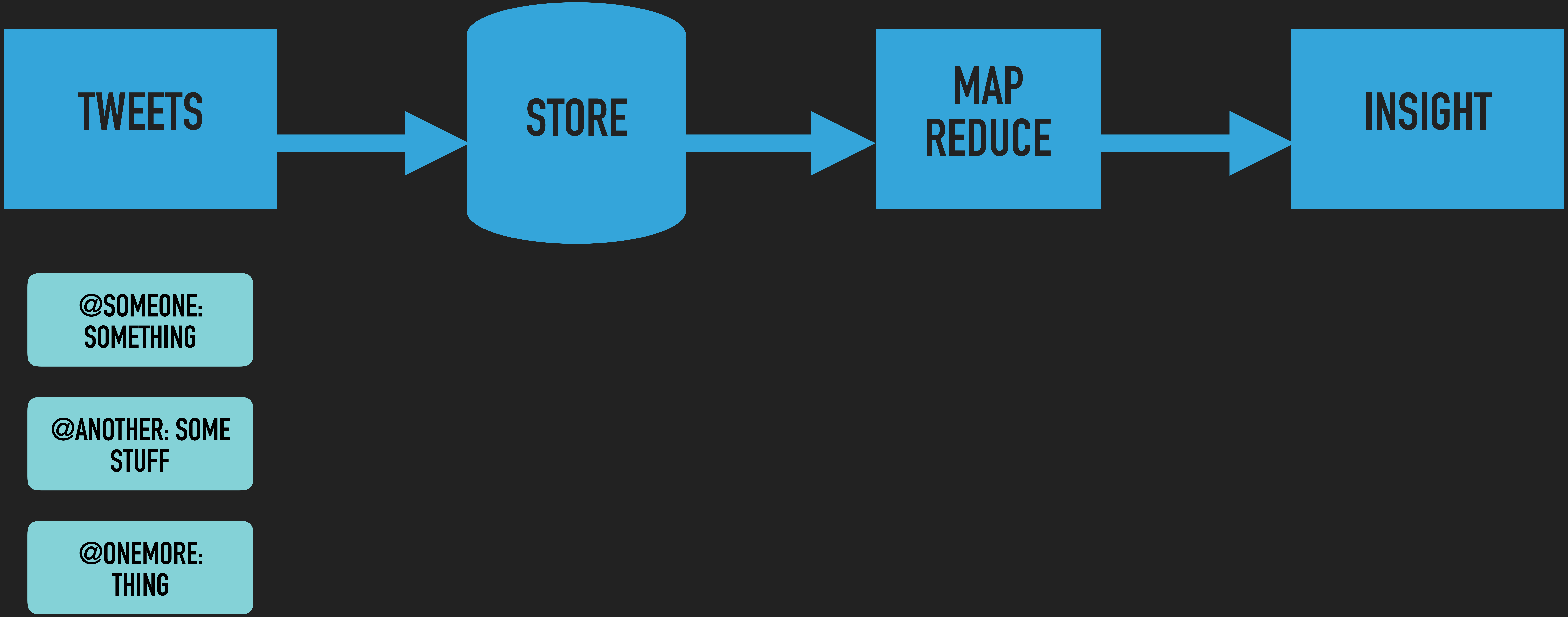

TWEETS

STORE

MAP REDUCE

INSIGHT

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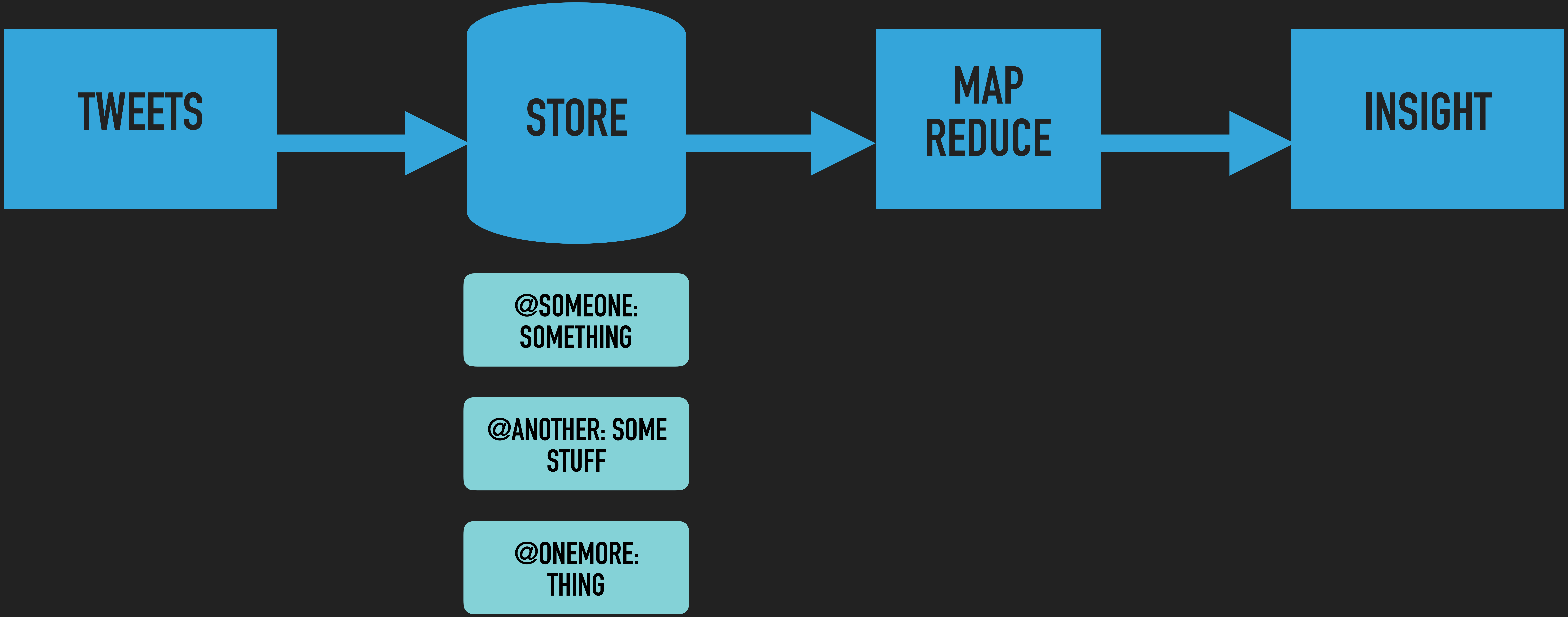
MAP REDUCE



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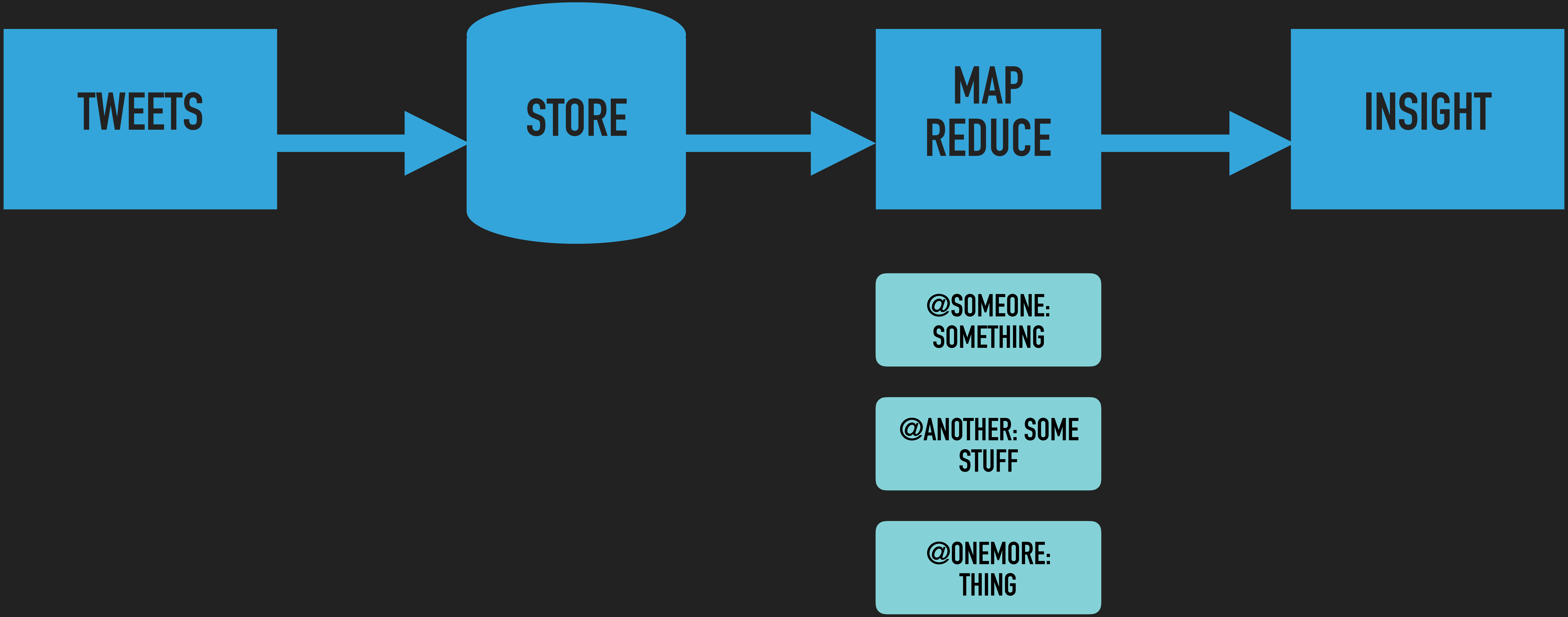
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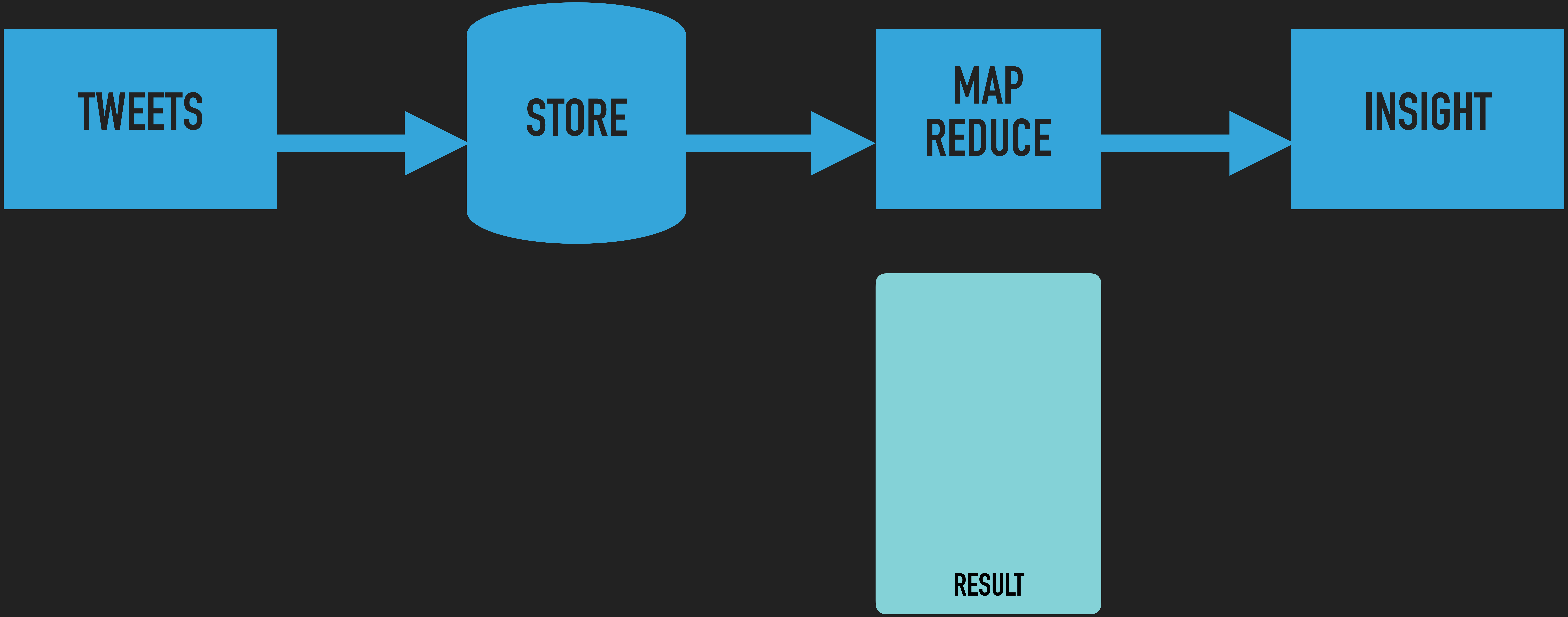

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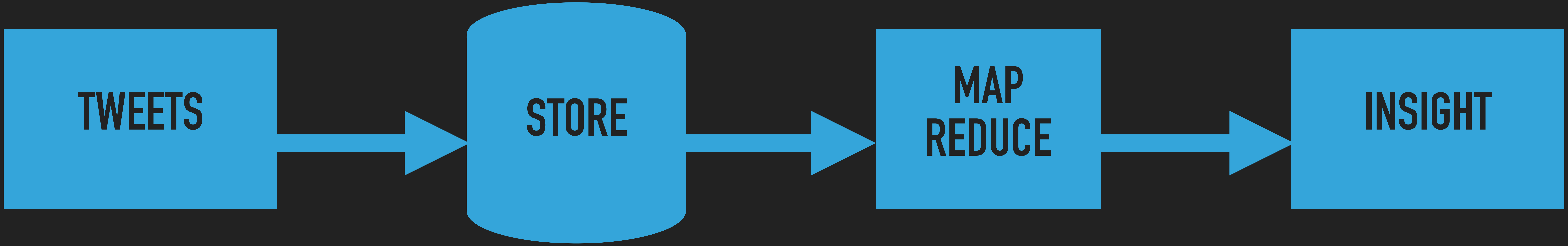

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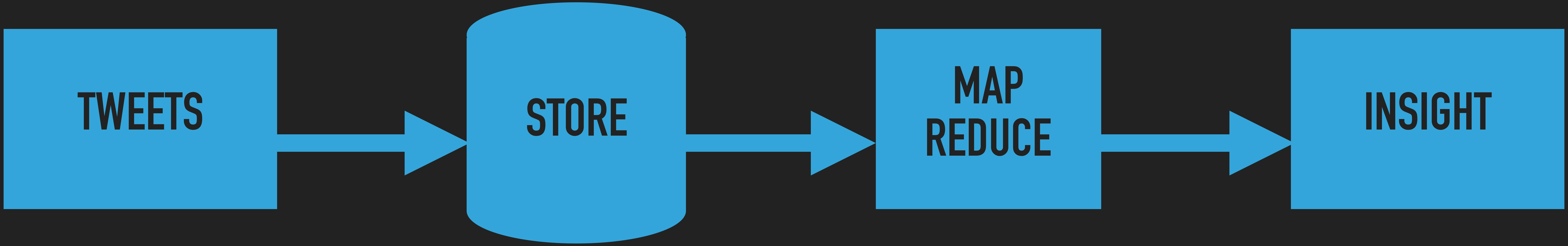

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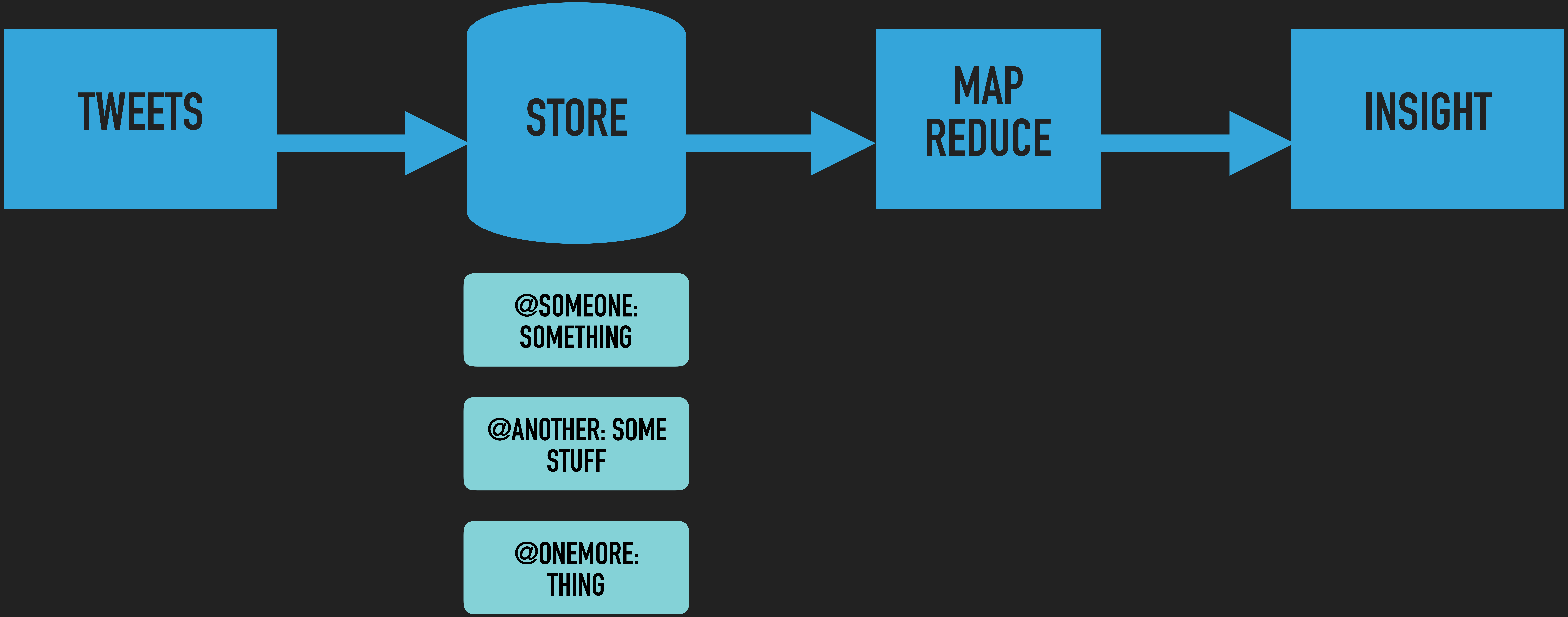
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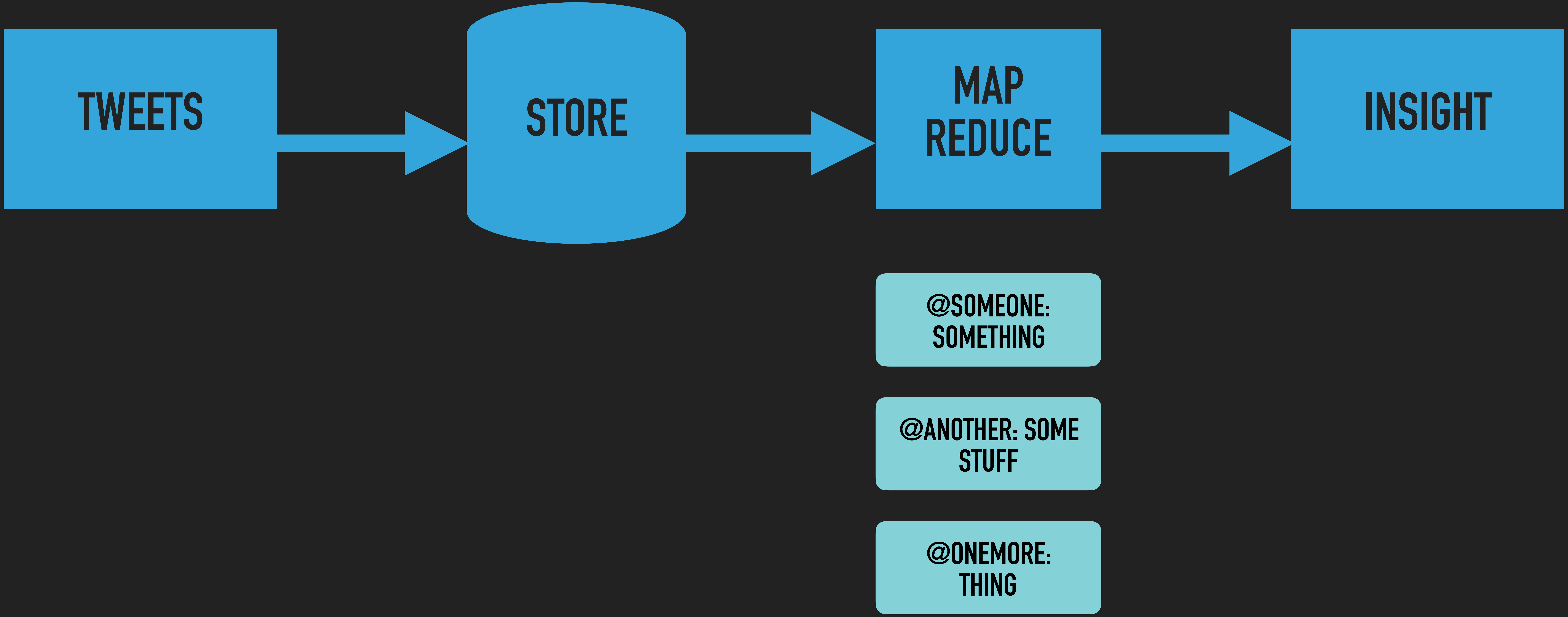
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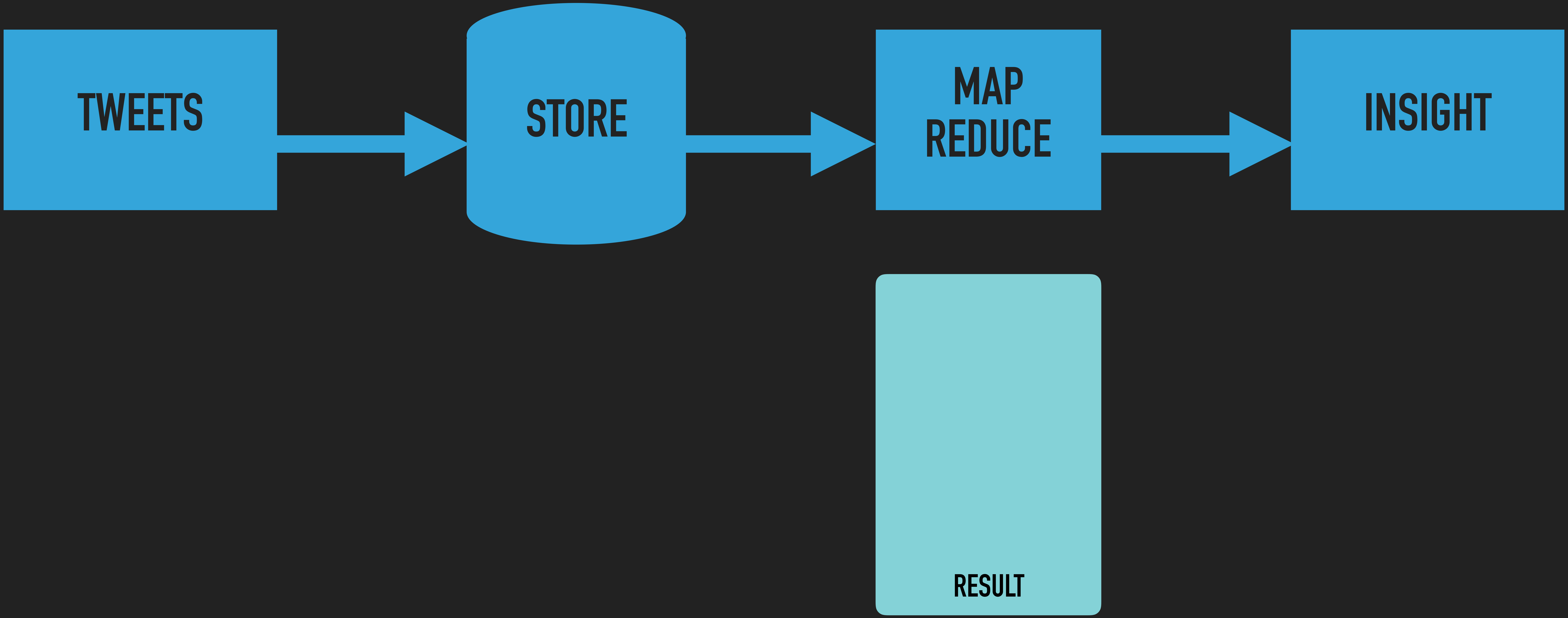

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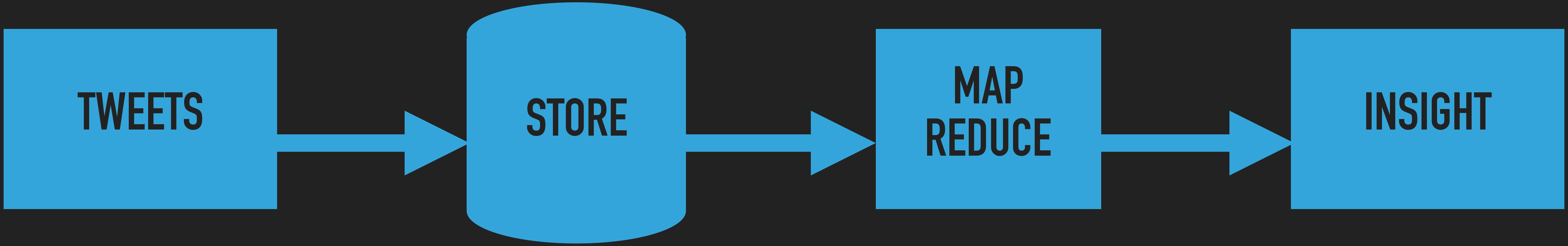

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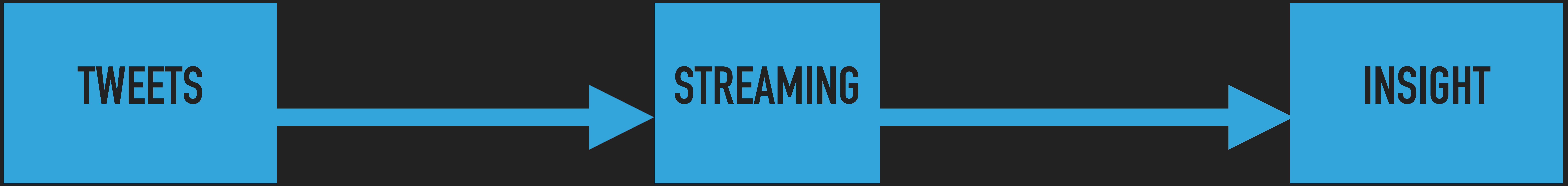

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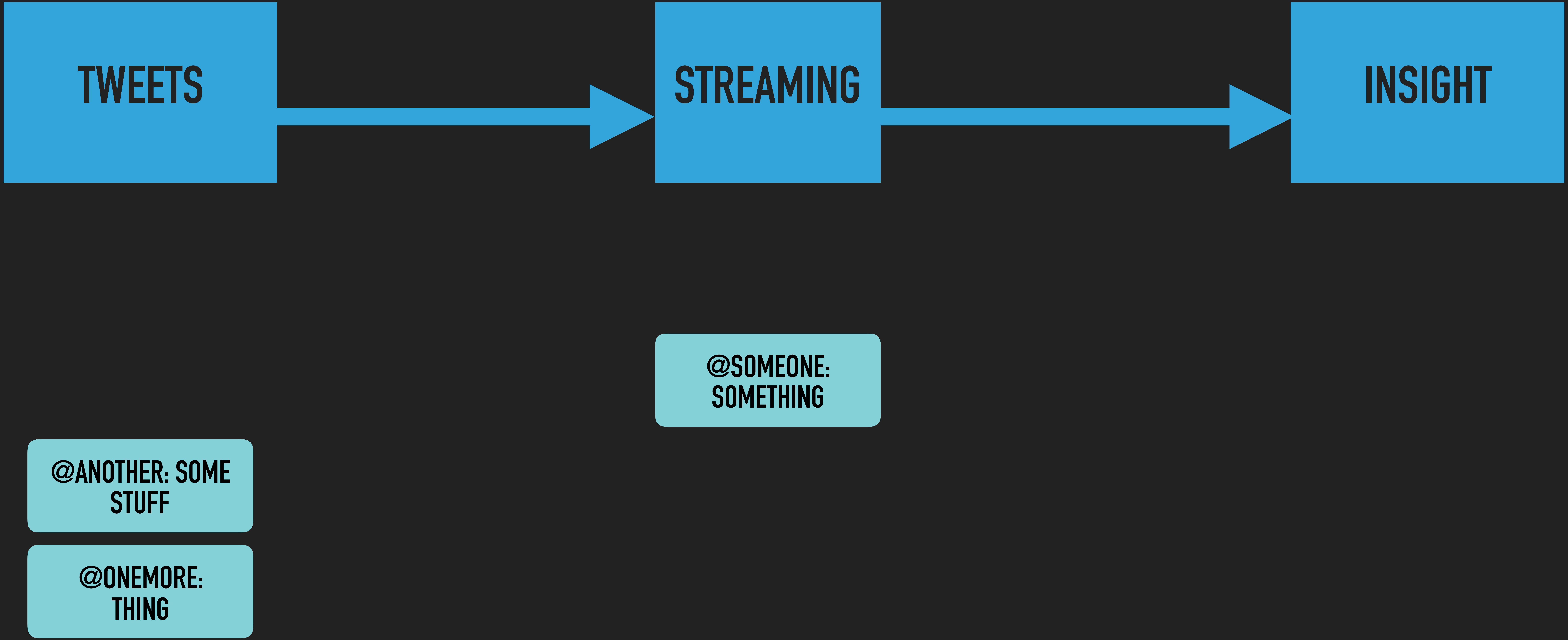

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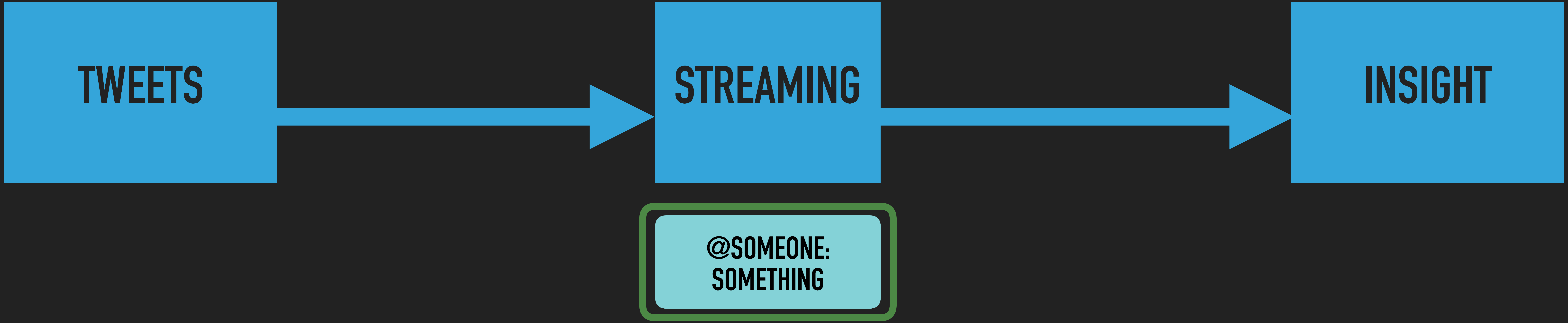

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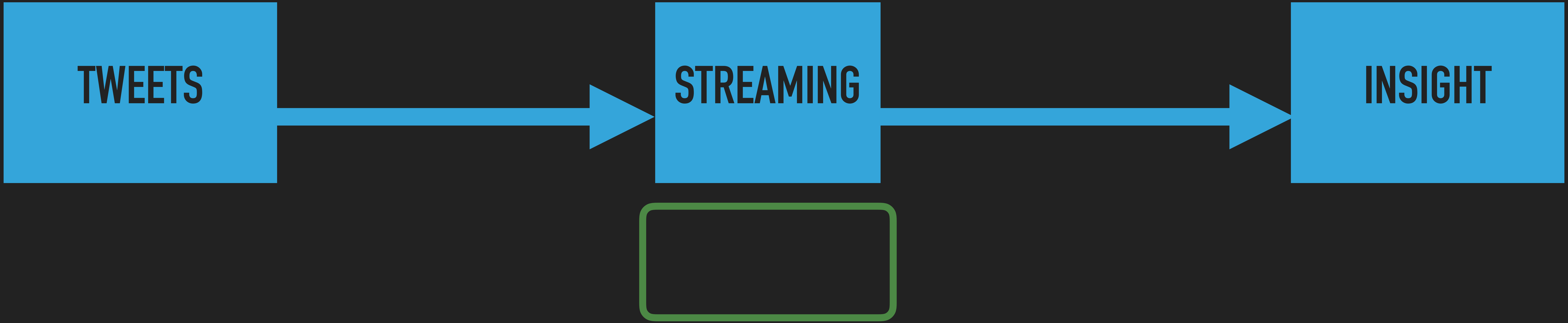
CONTEXT: AGGREGATION

STREAMING



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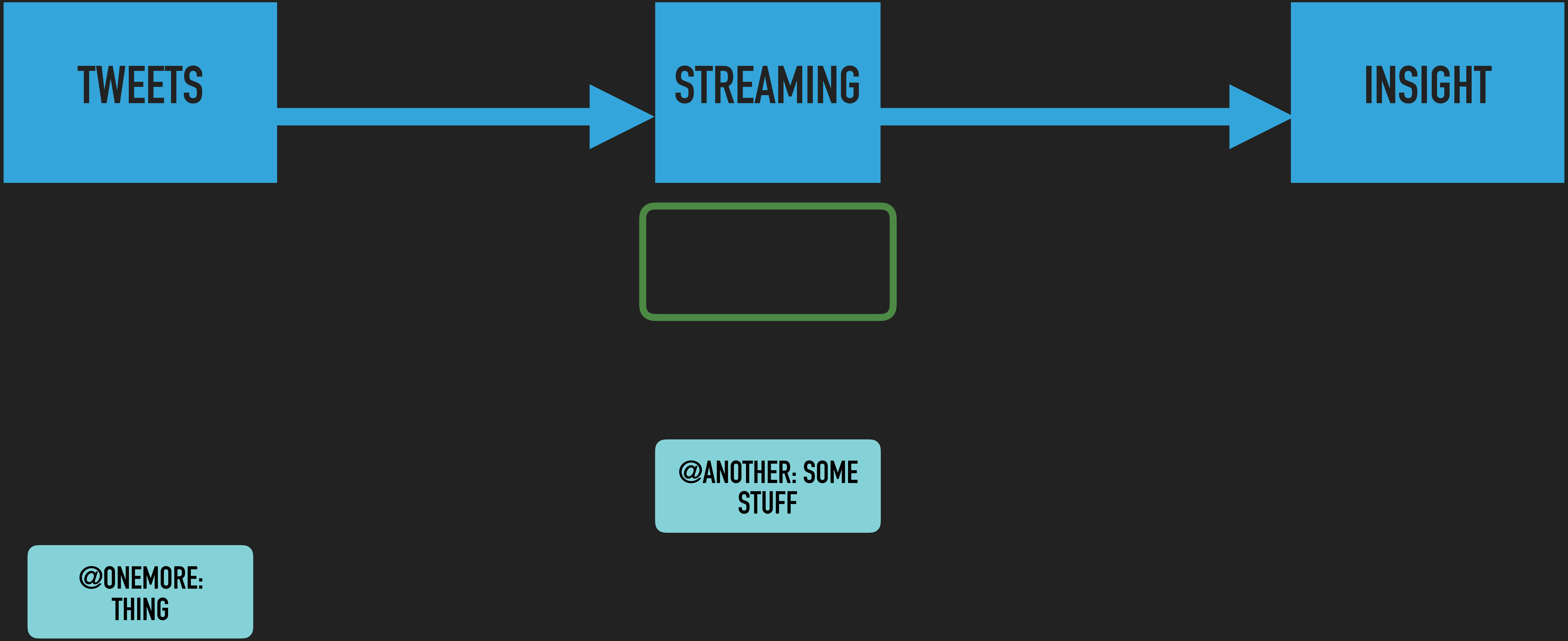

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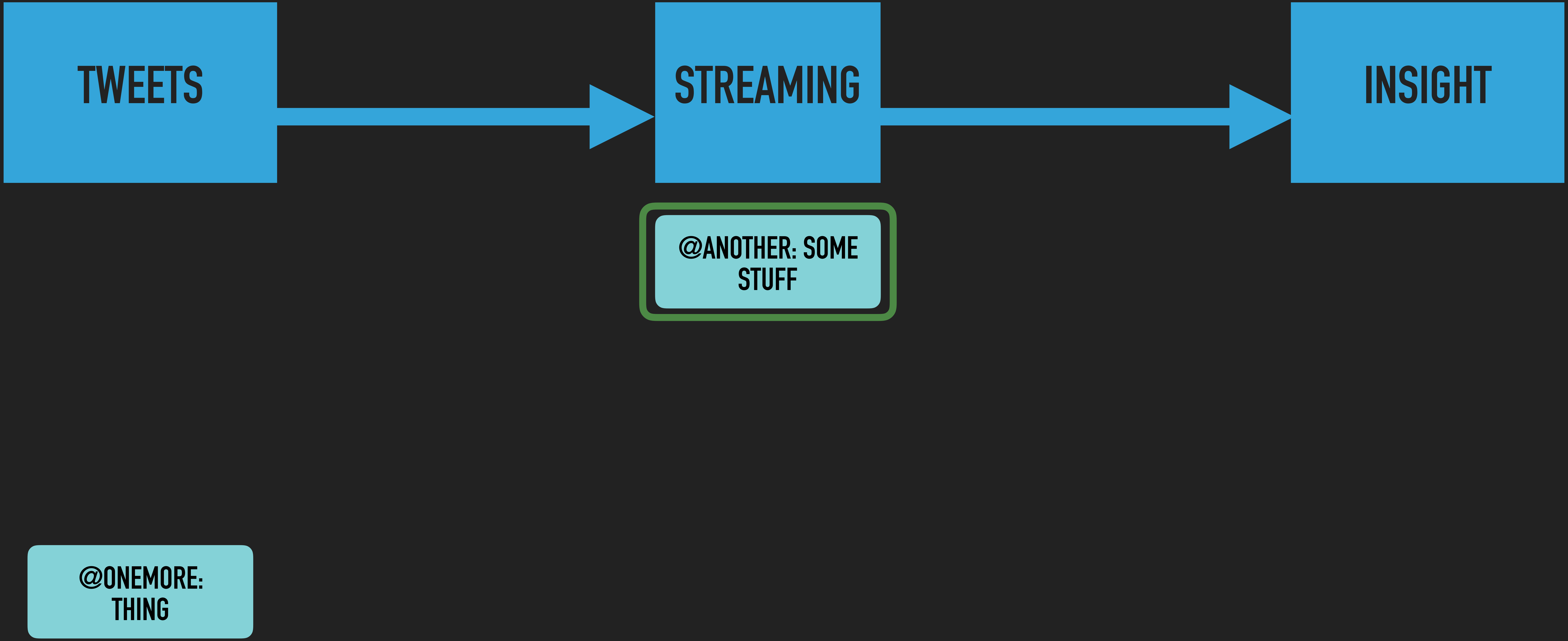
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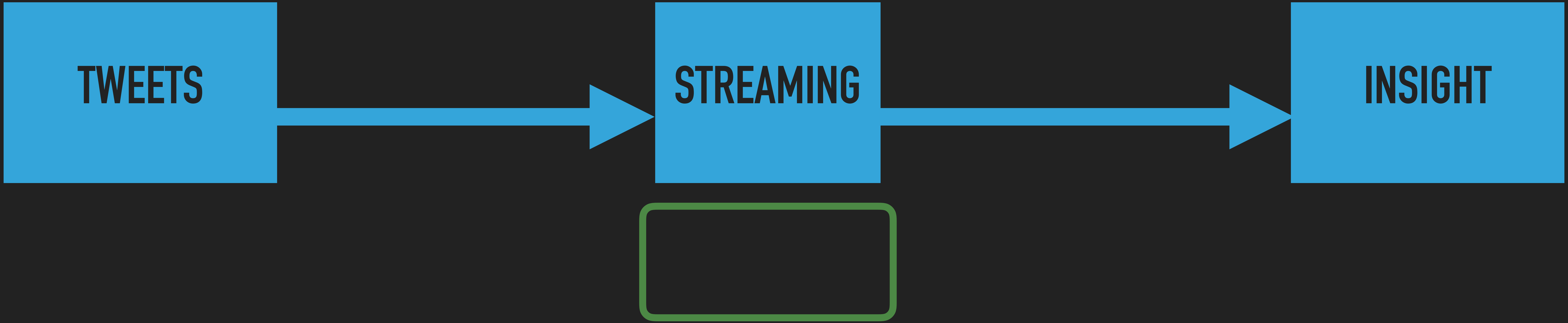

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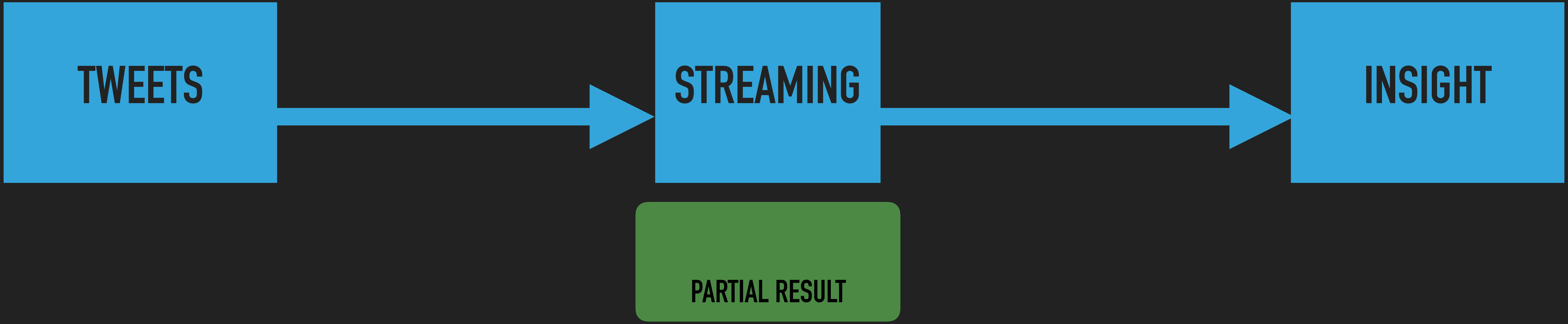

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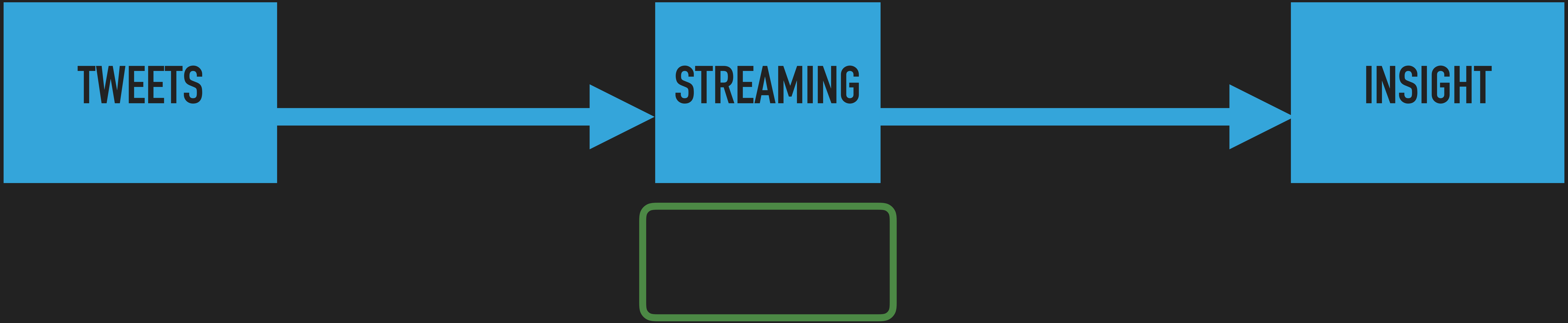

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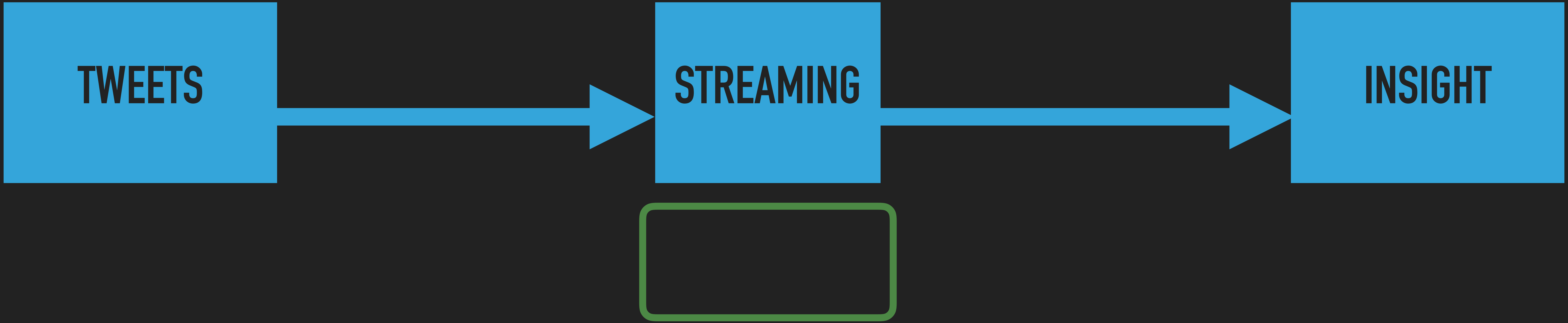

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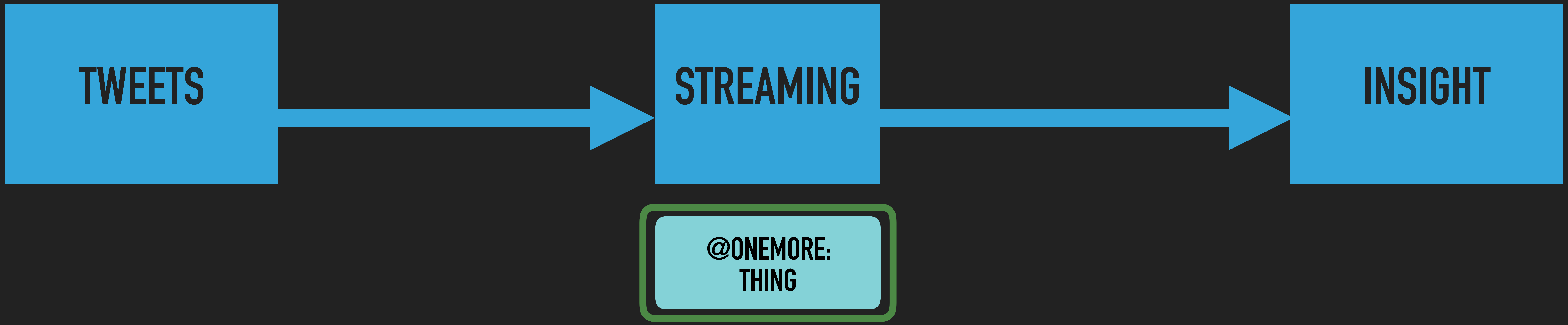

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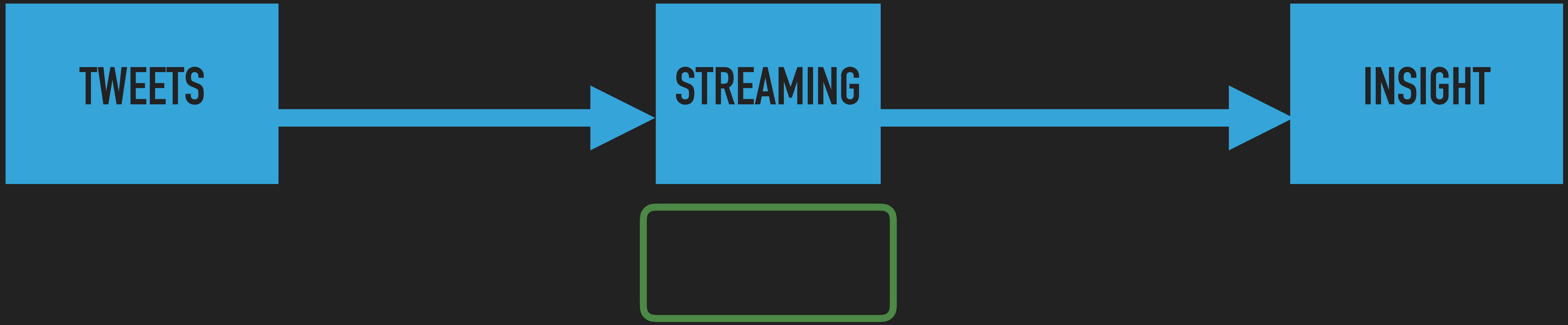

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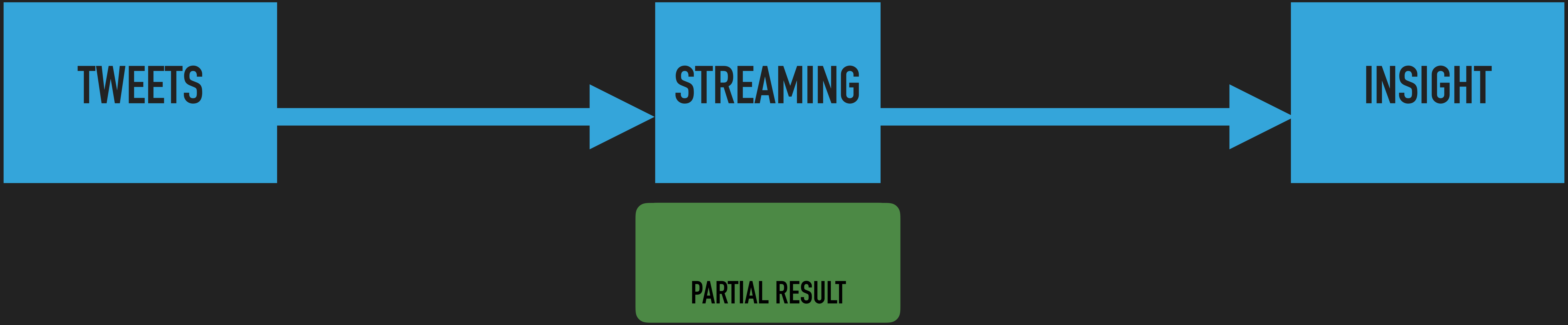

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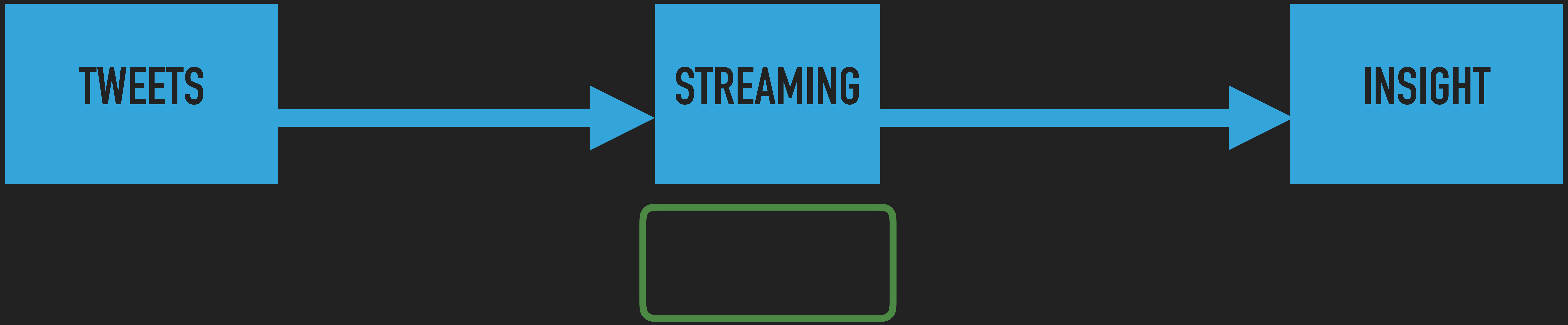
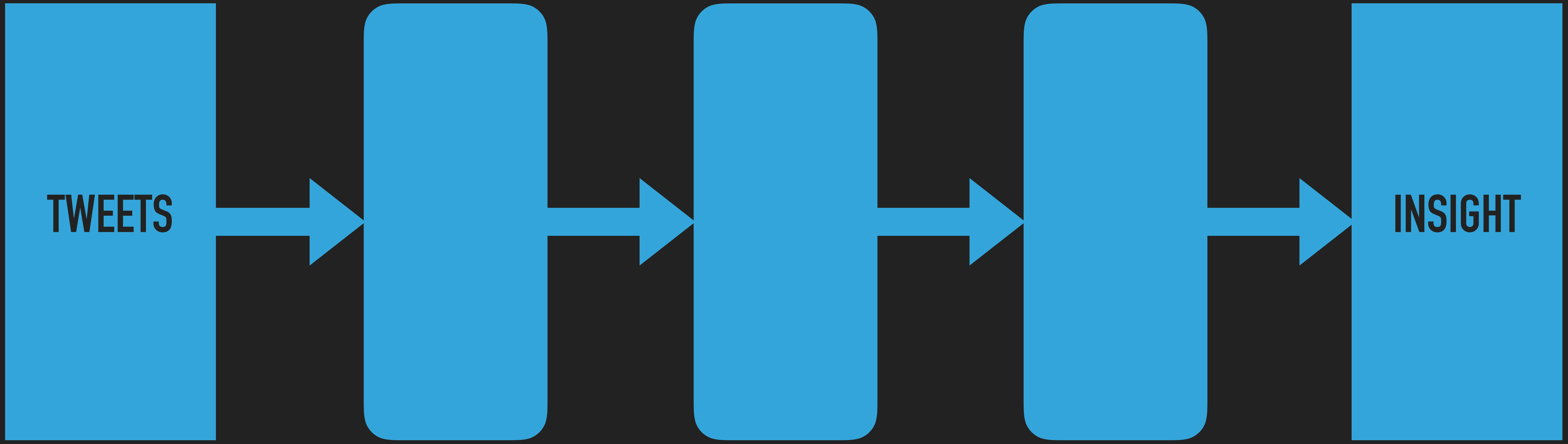


DATAFLOW



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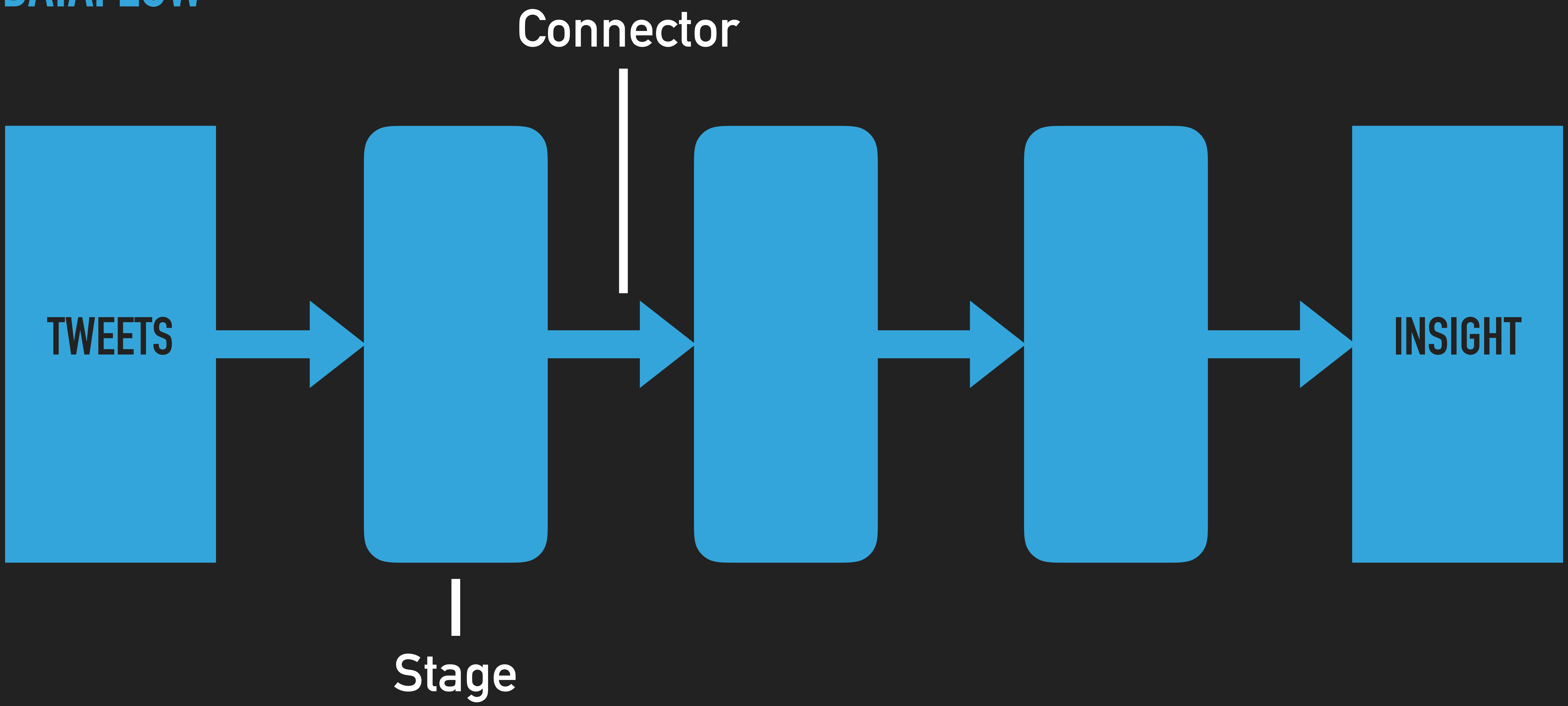
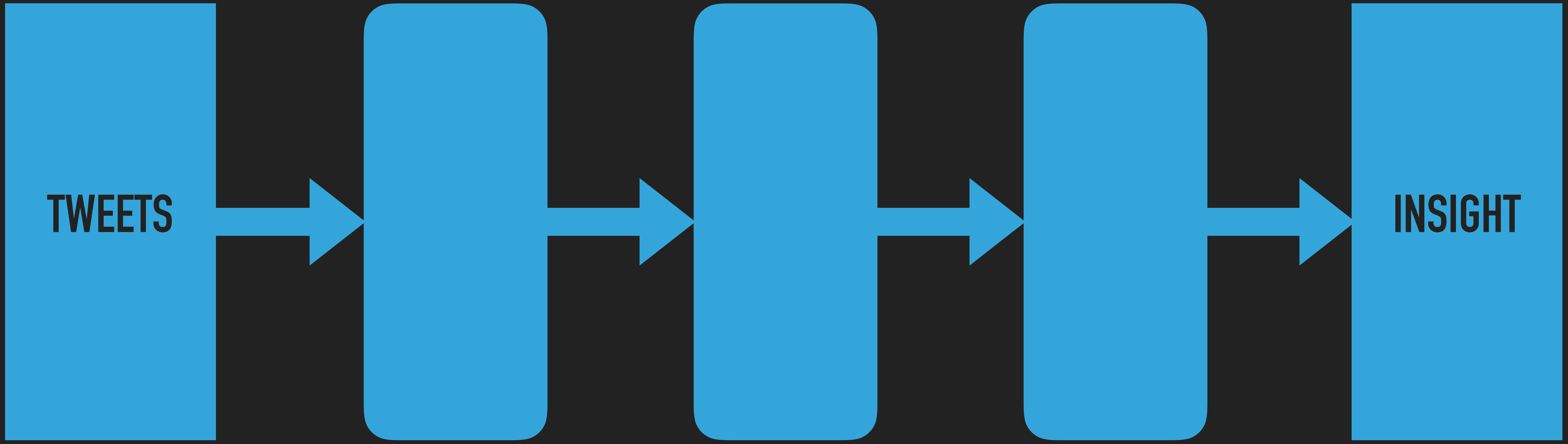


DATAFLOW: PARALLELISM



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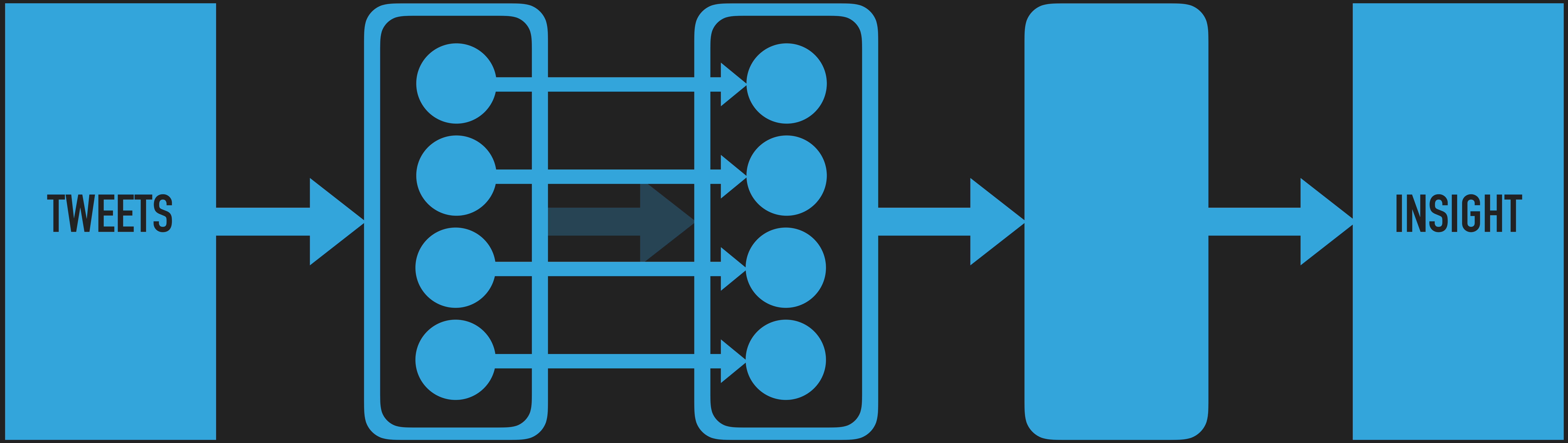

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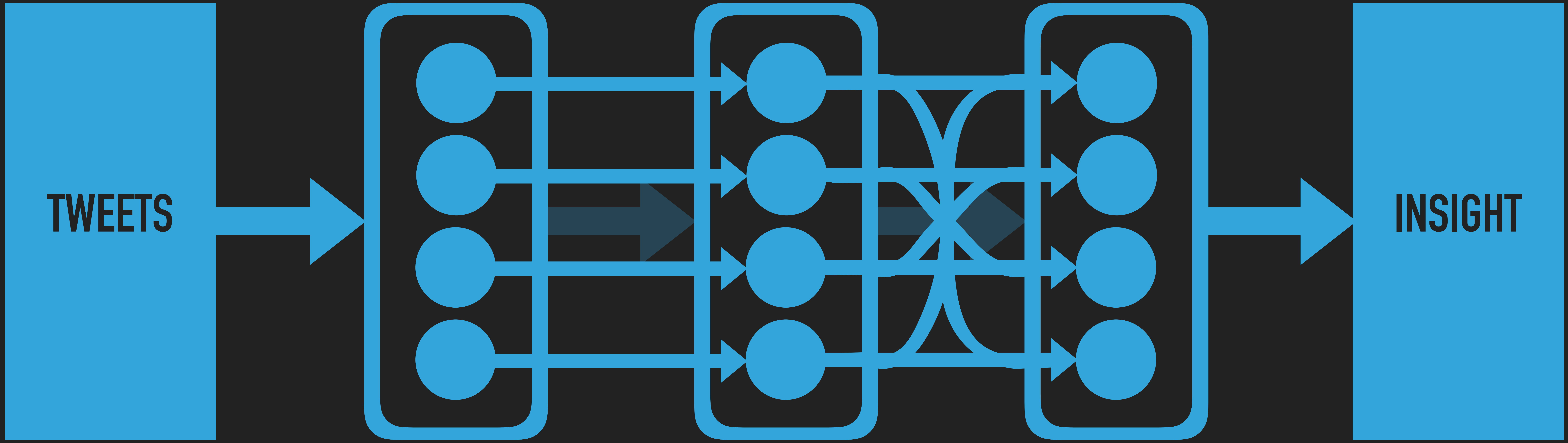

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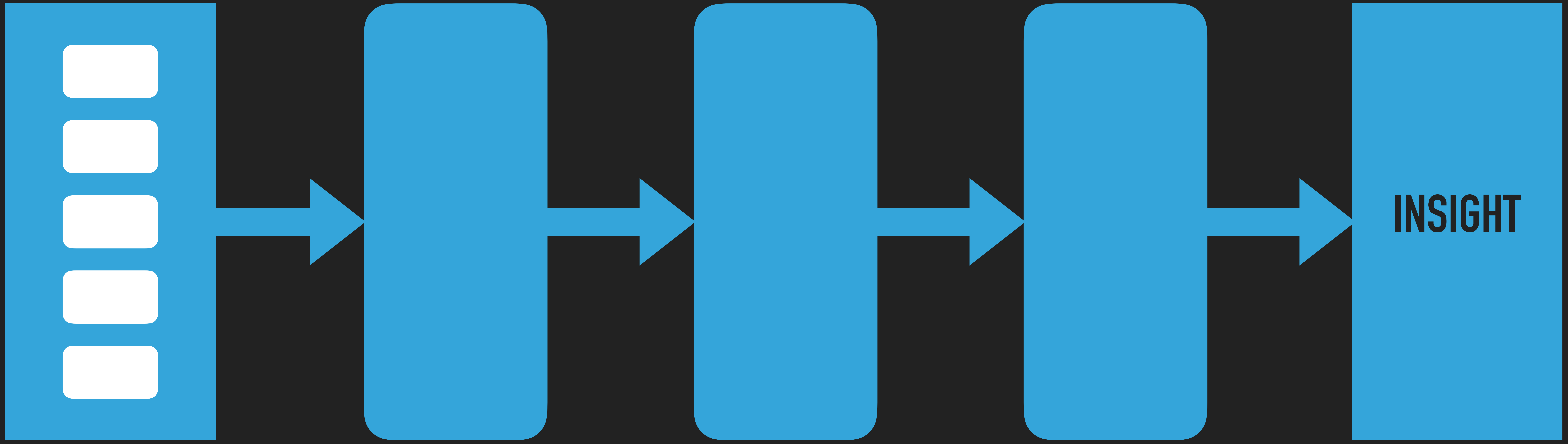

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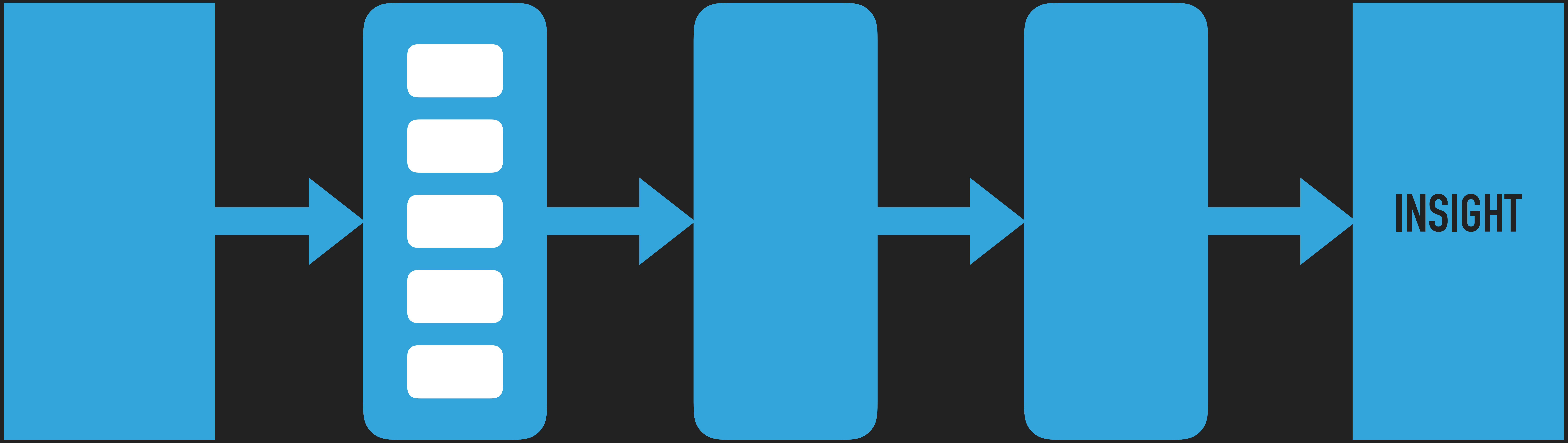

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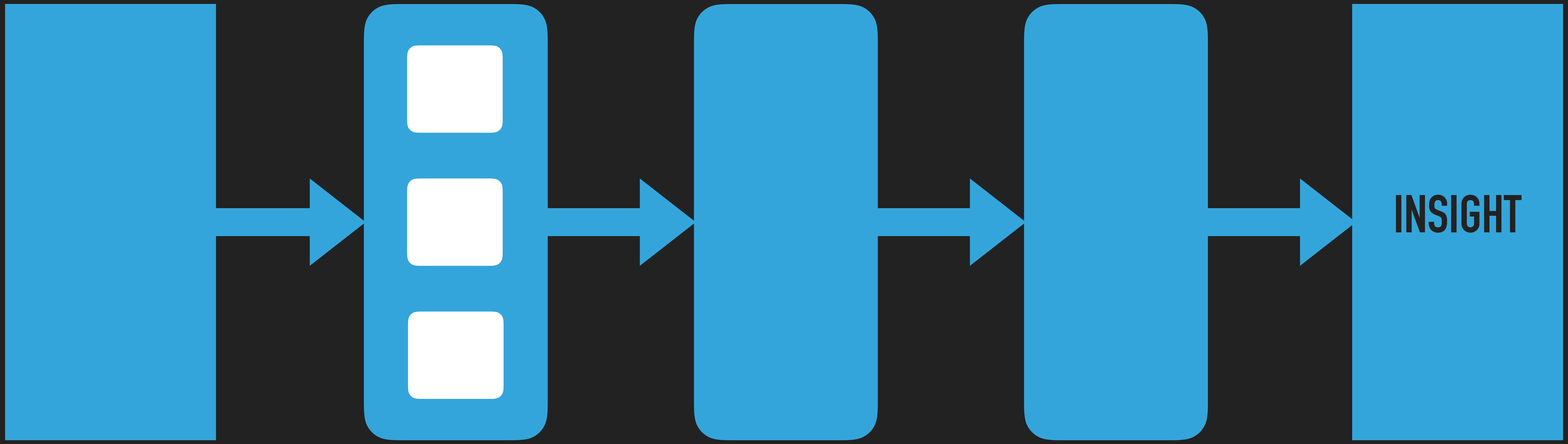

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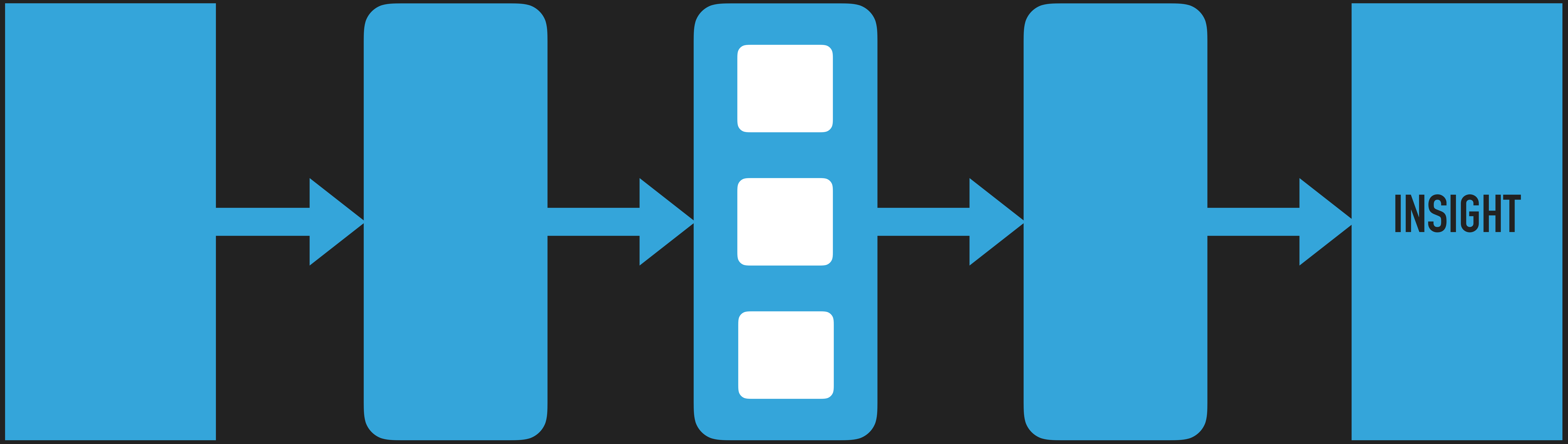
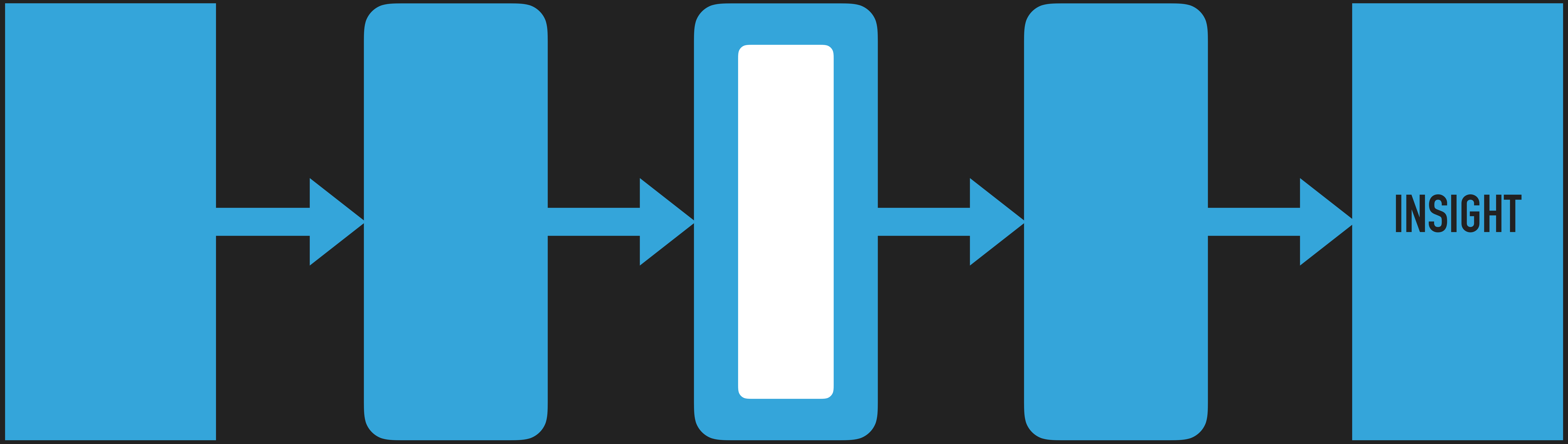
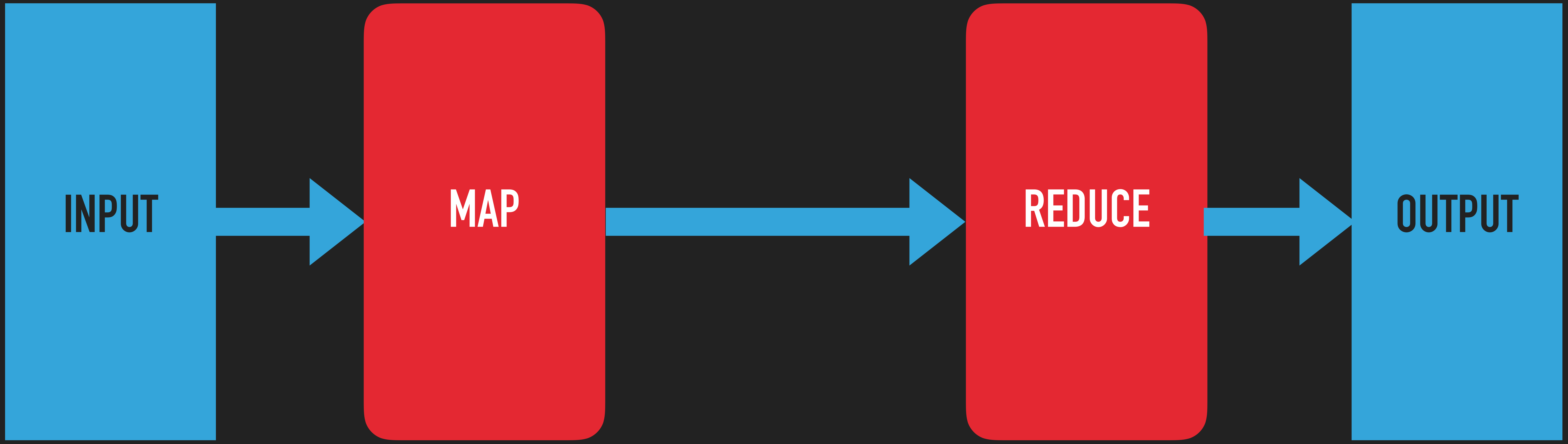


CONTEXT: PROGRAMMING MODEL

DATAFLOW: BATCH



DATAFLOW: BATCH ➡ MAP/REDUCE



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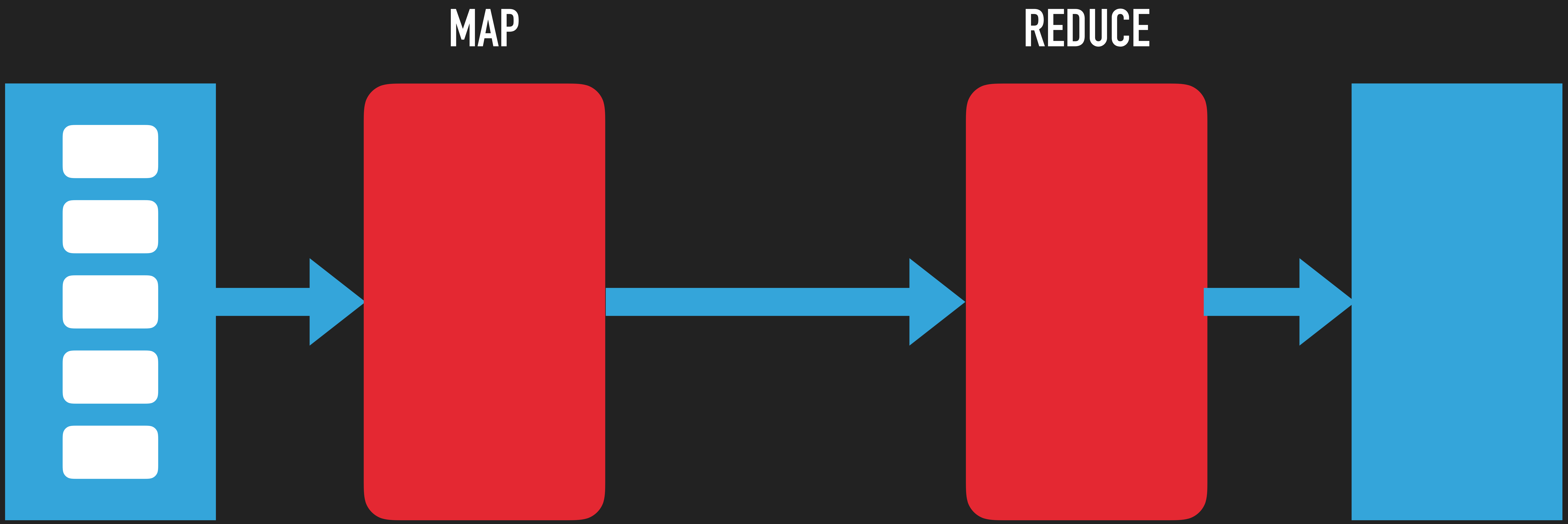

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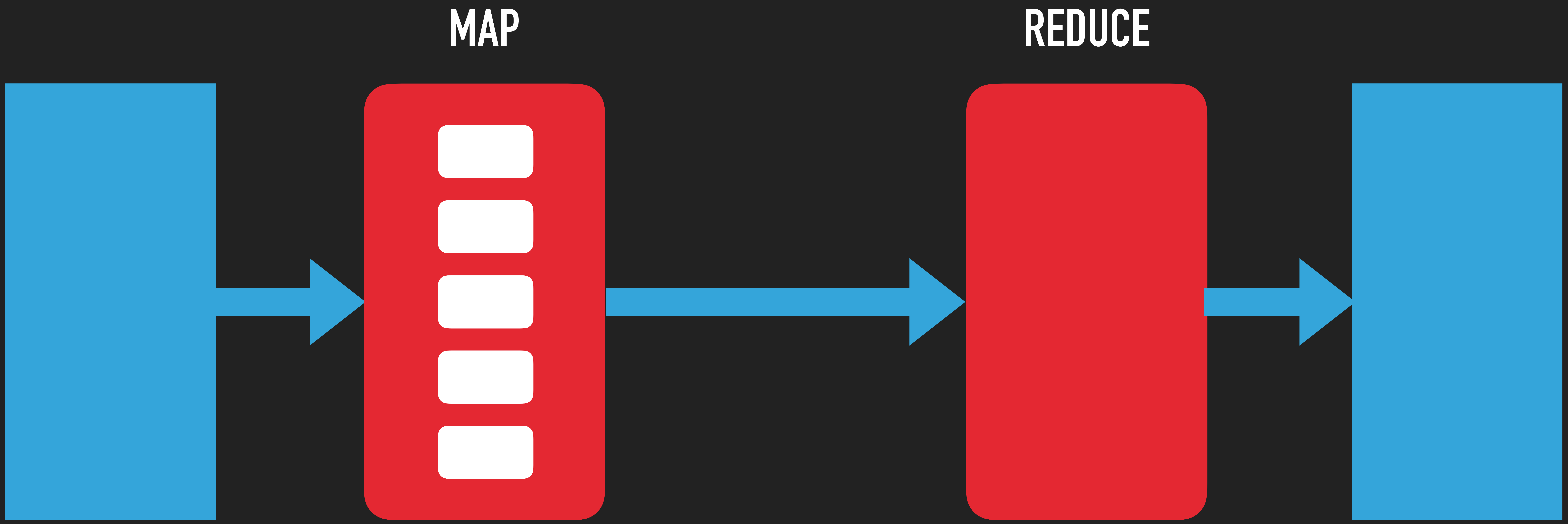

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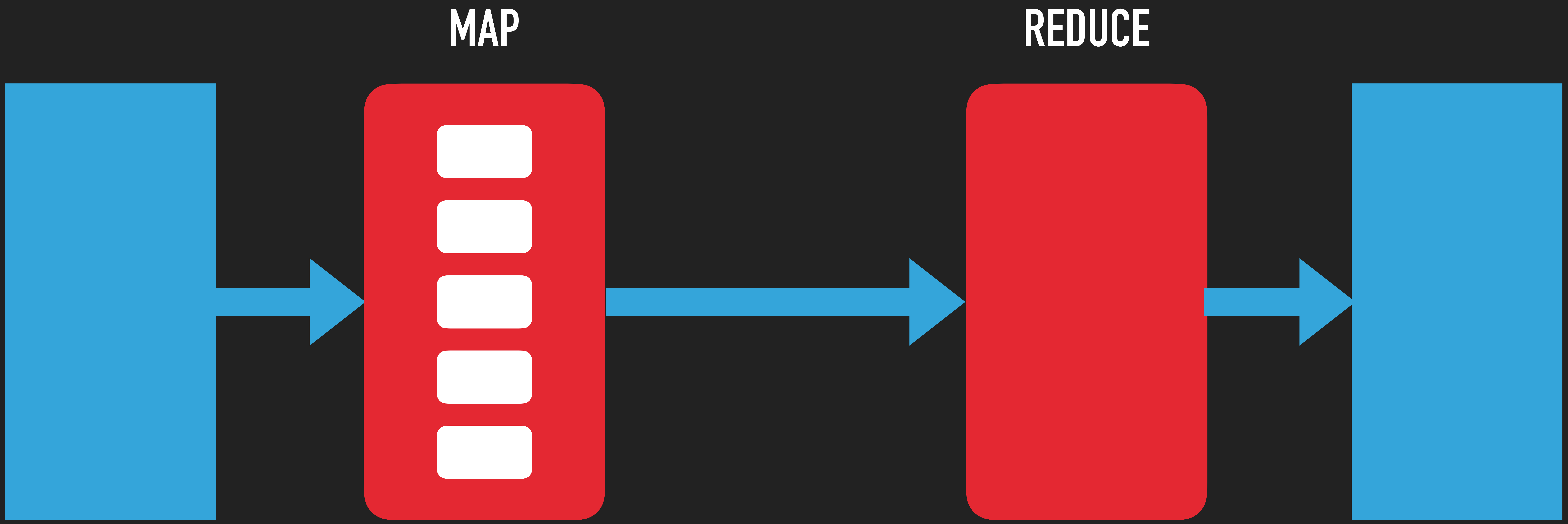

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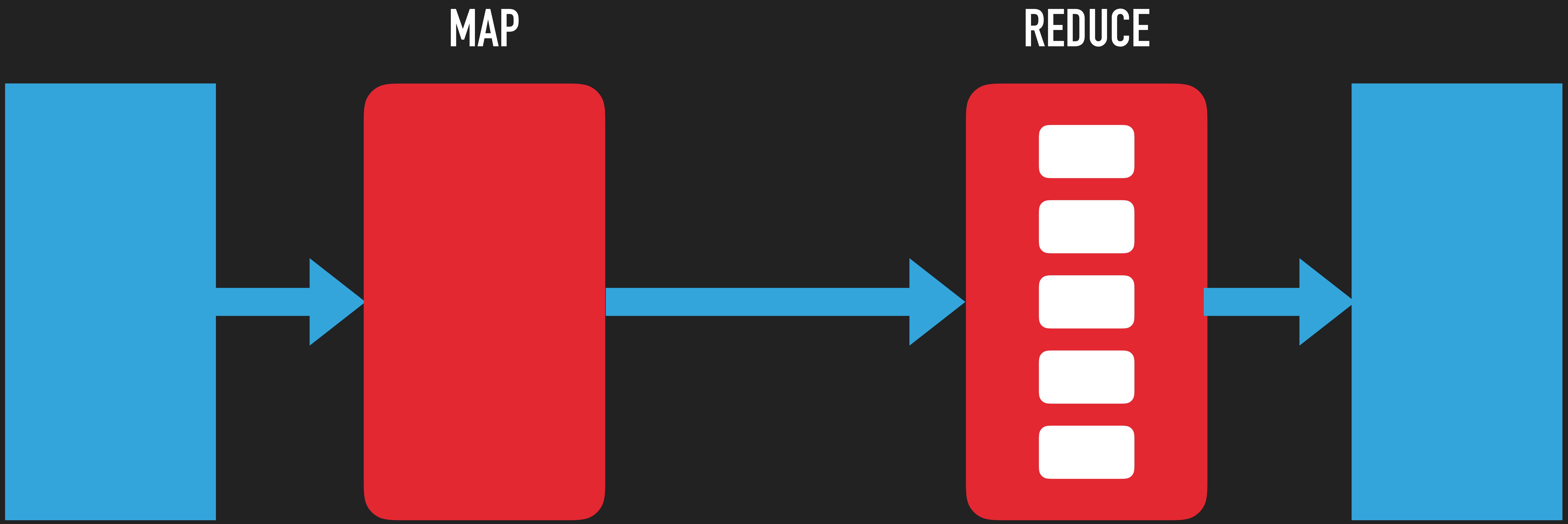

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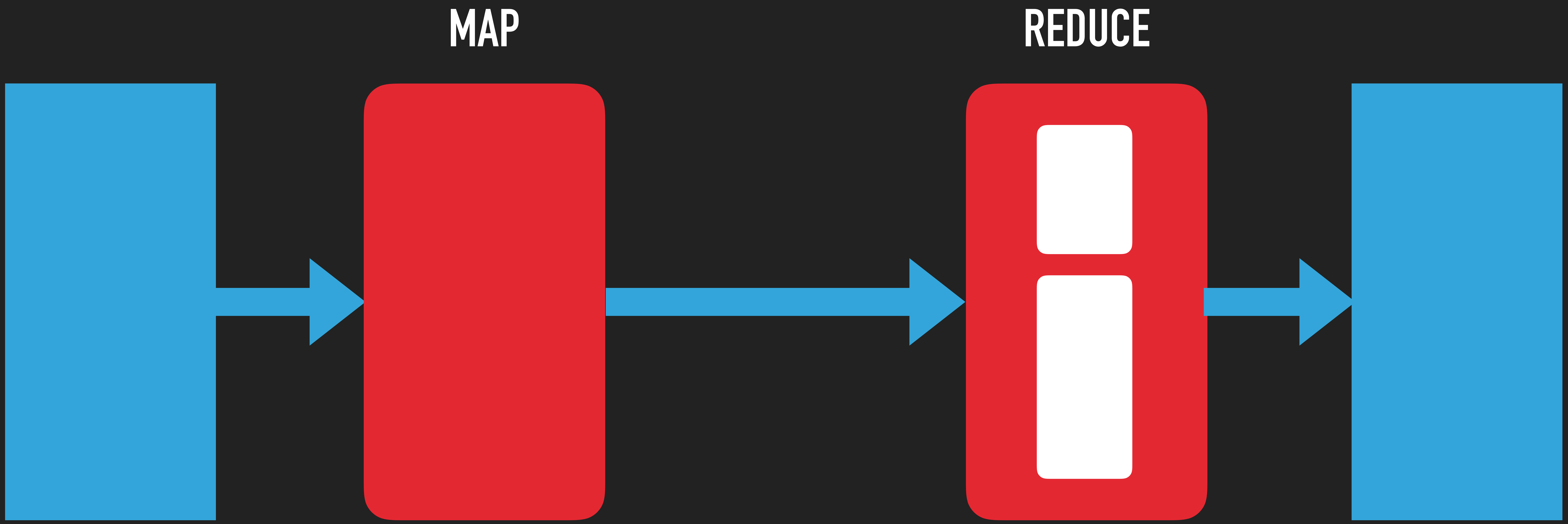

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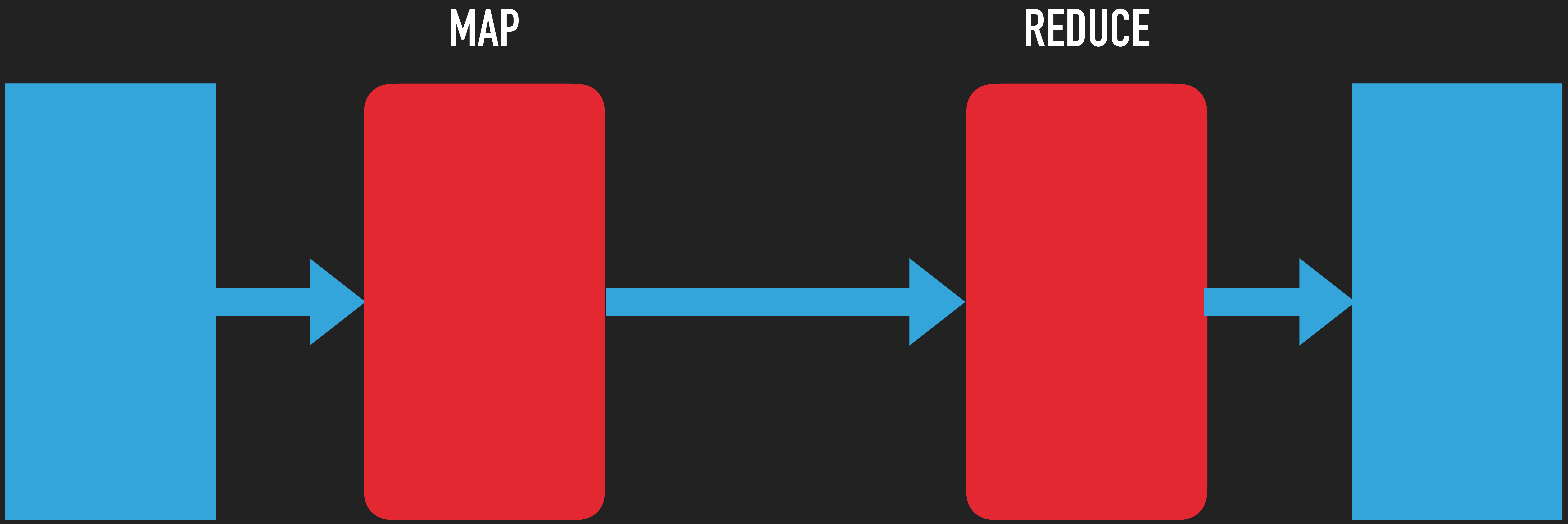

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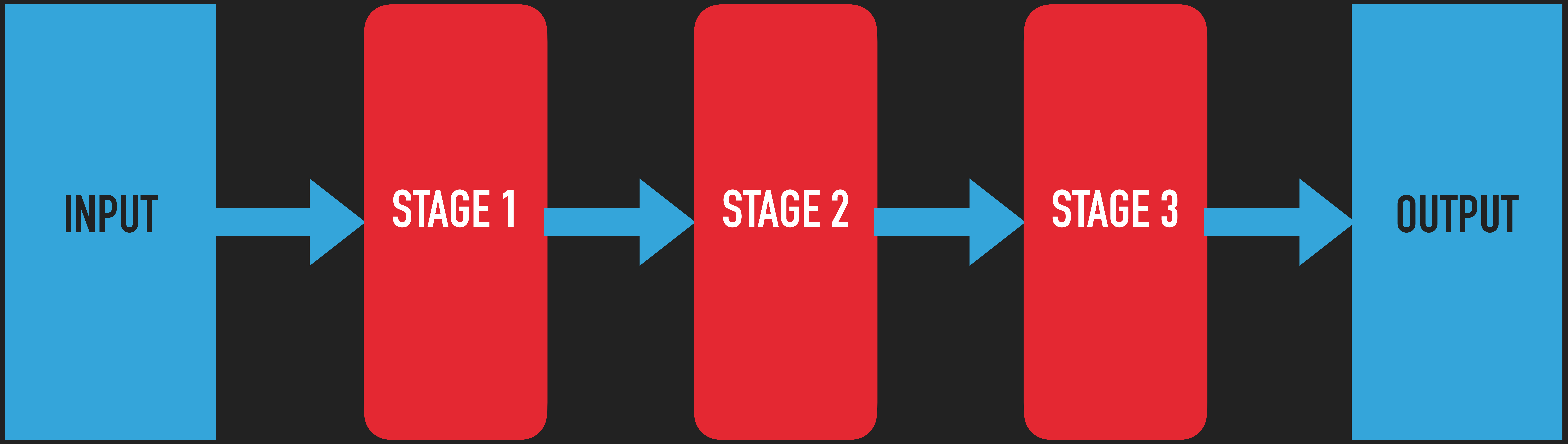

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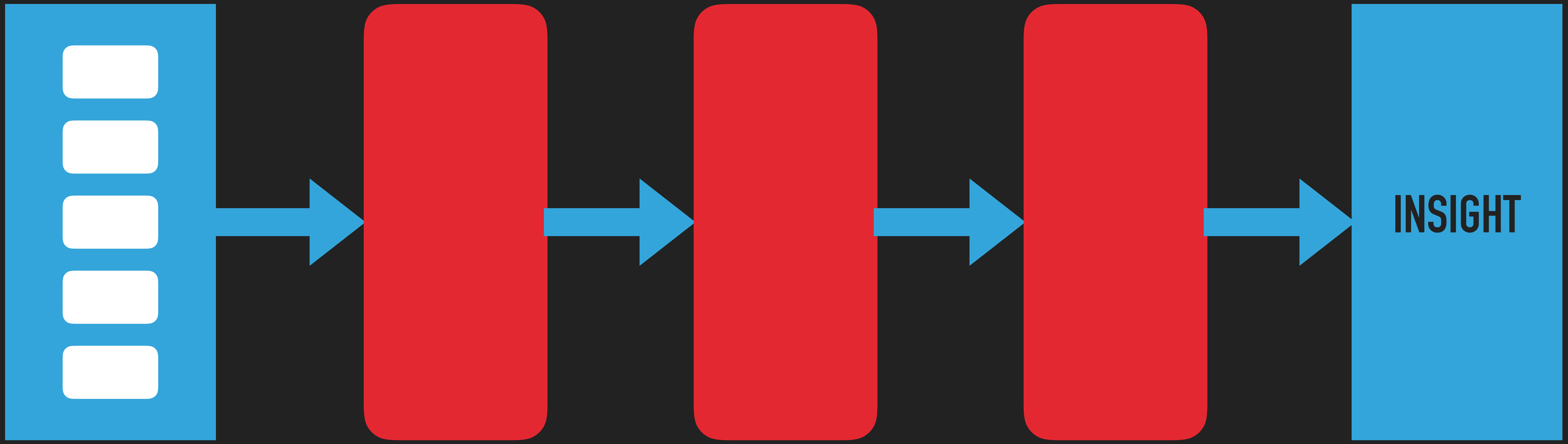

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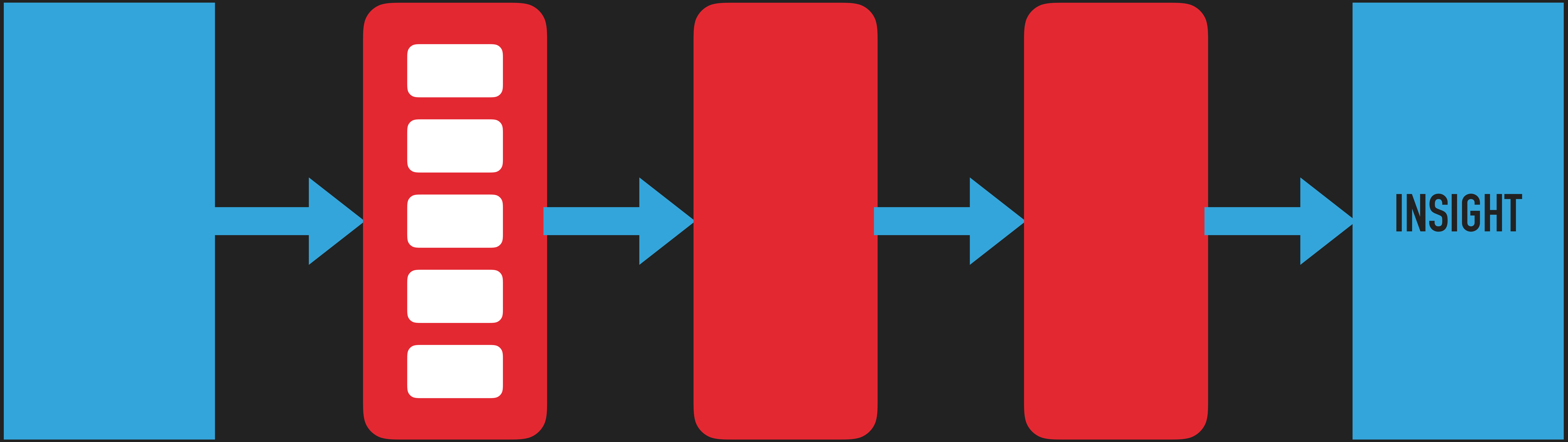
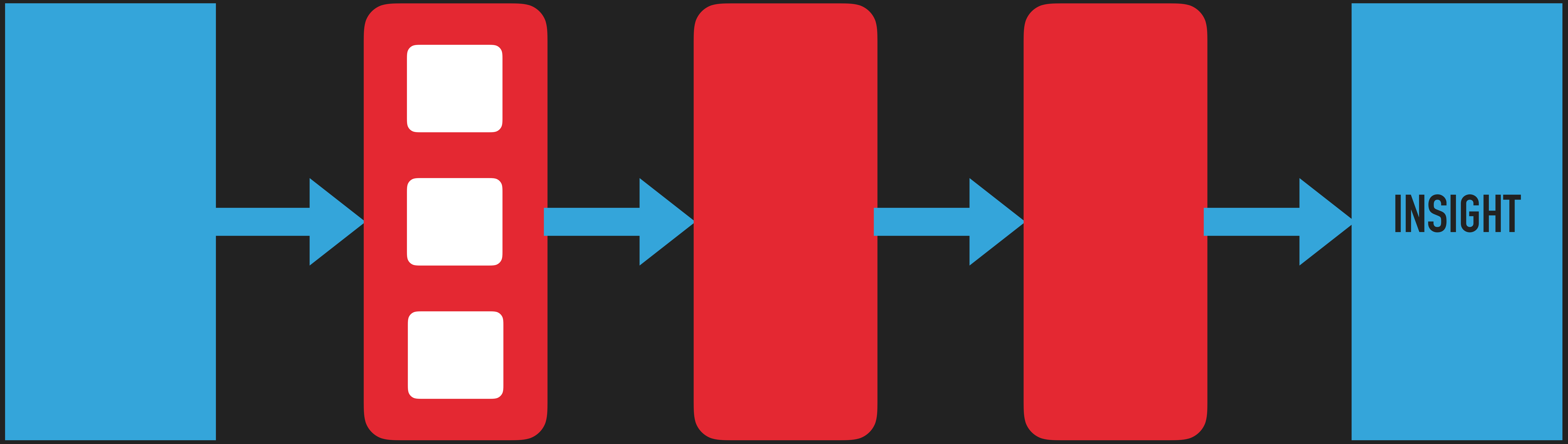


DATAFLOW: BATCH → SPARK



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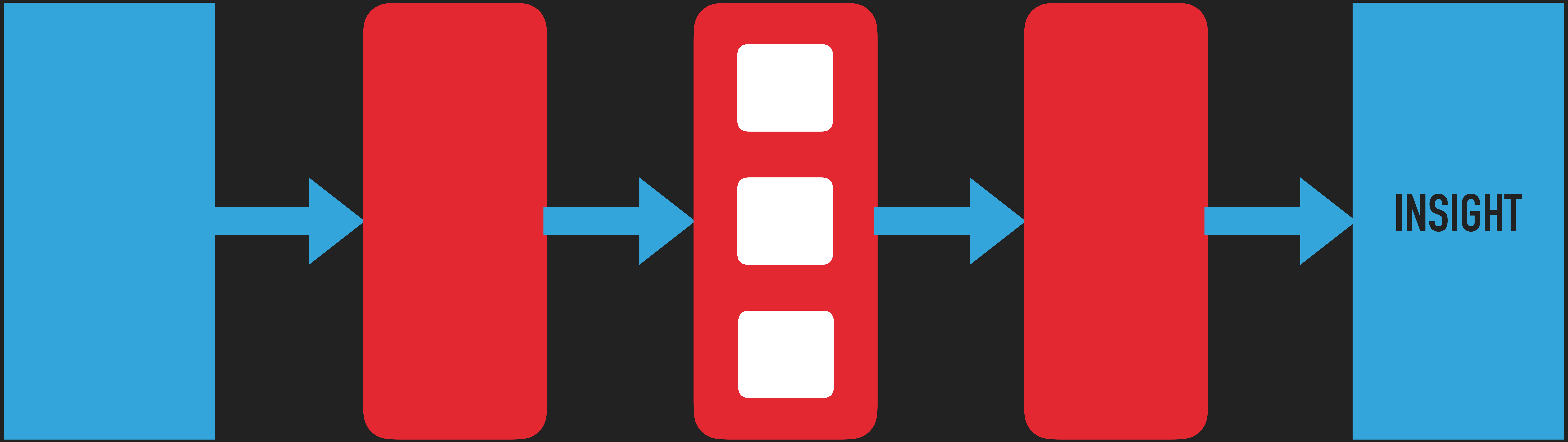

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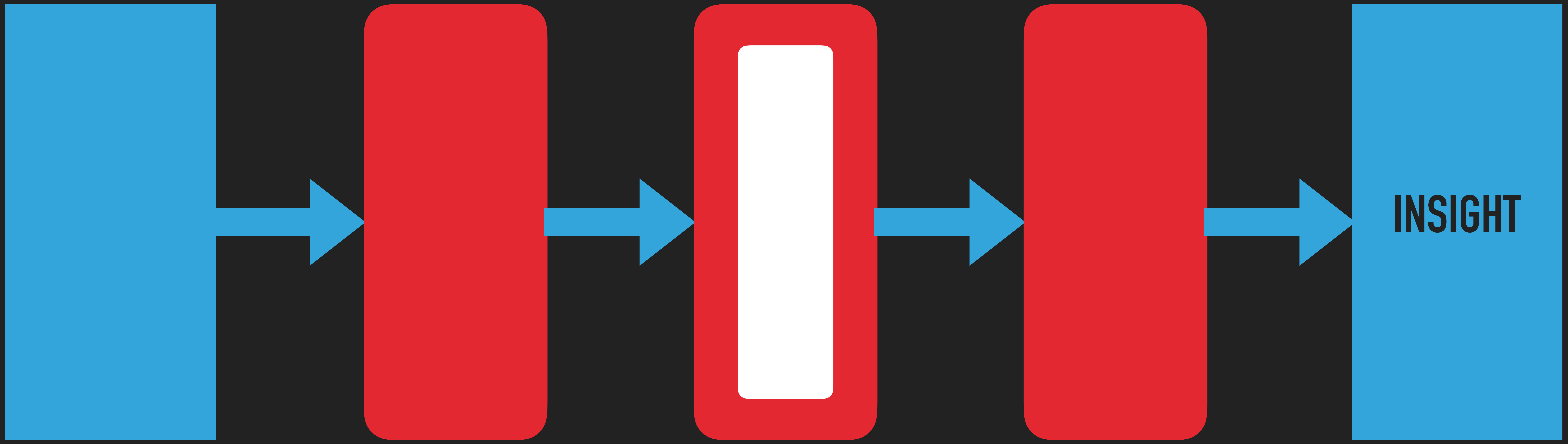

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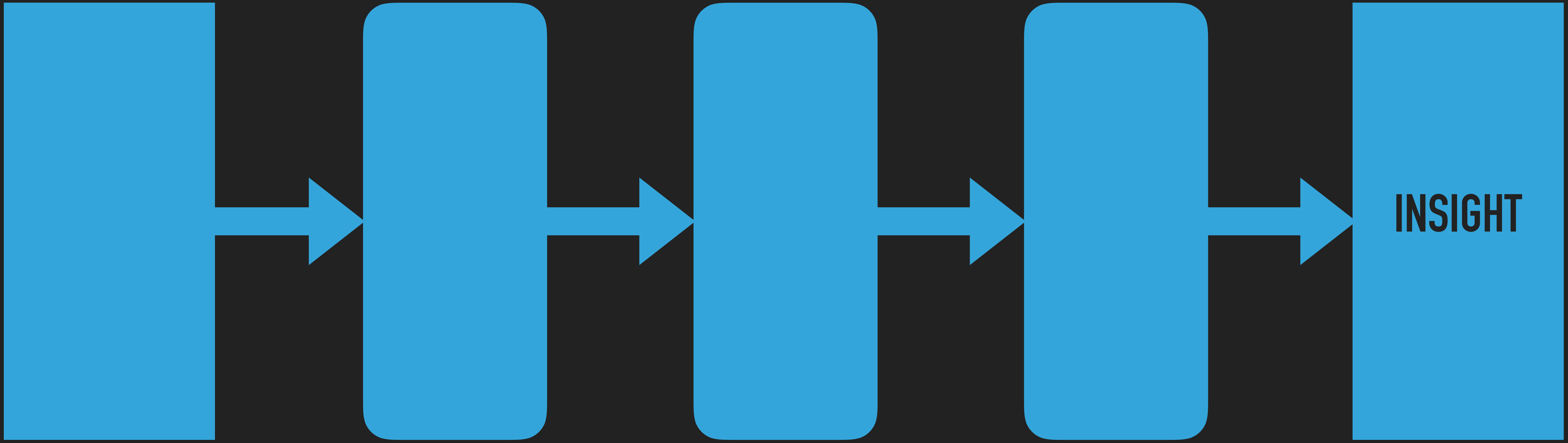

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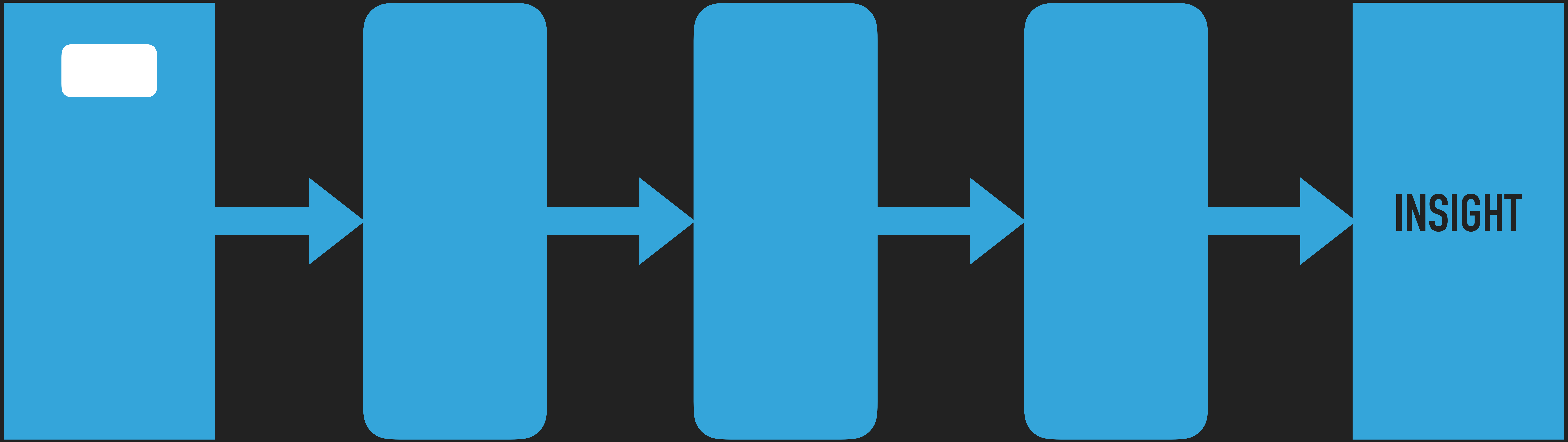

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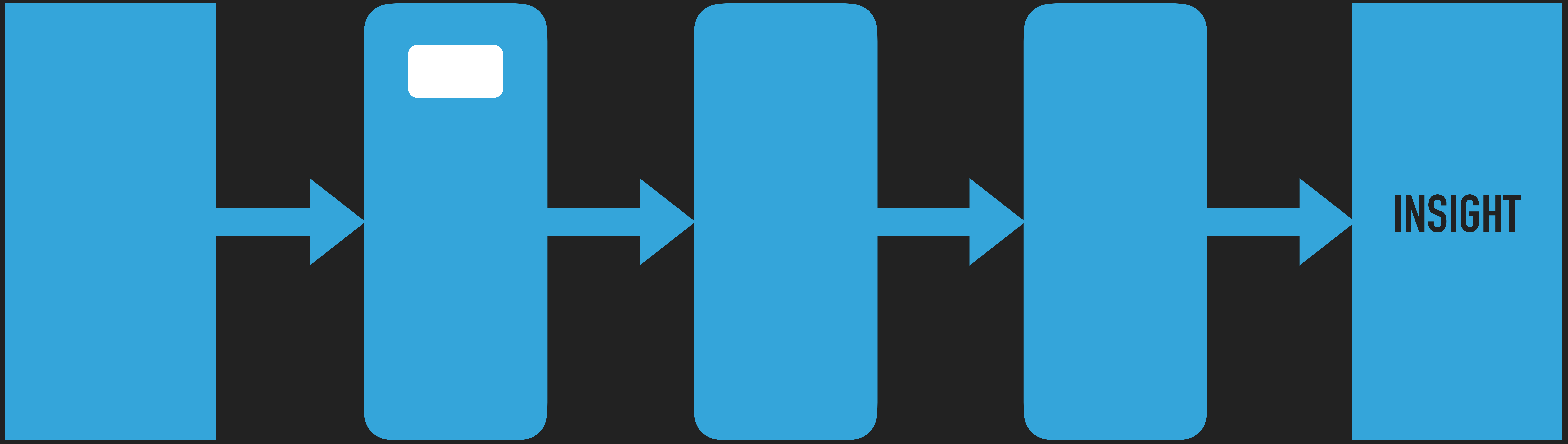

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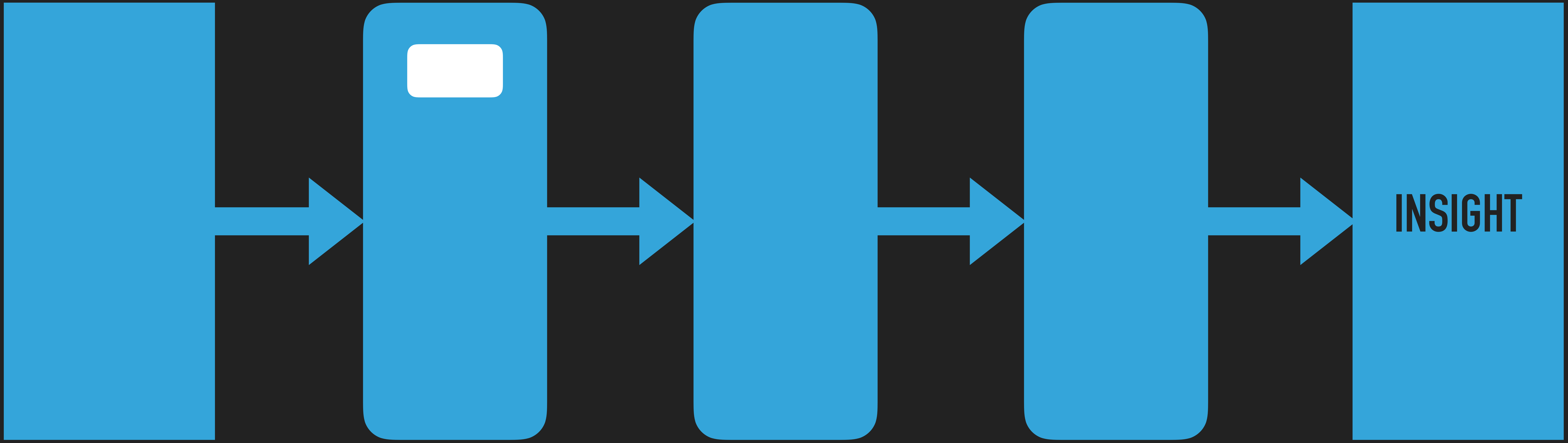

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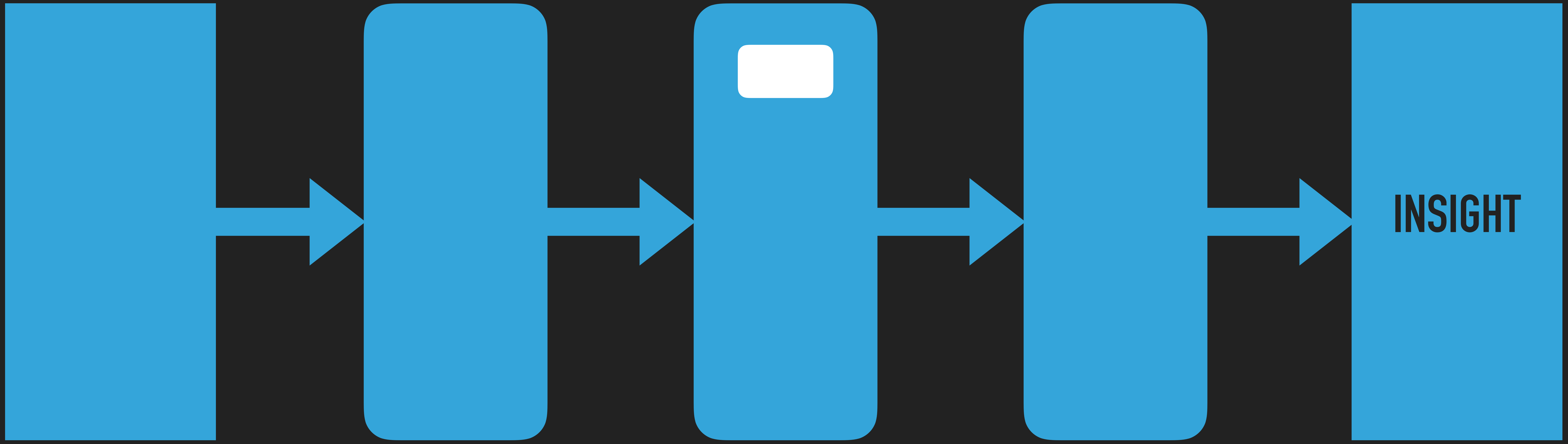

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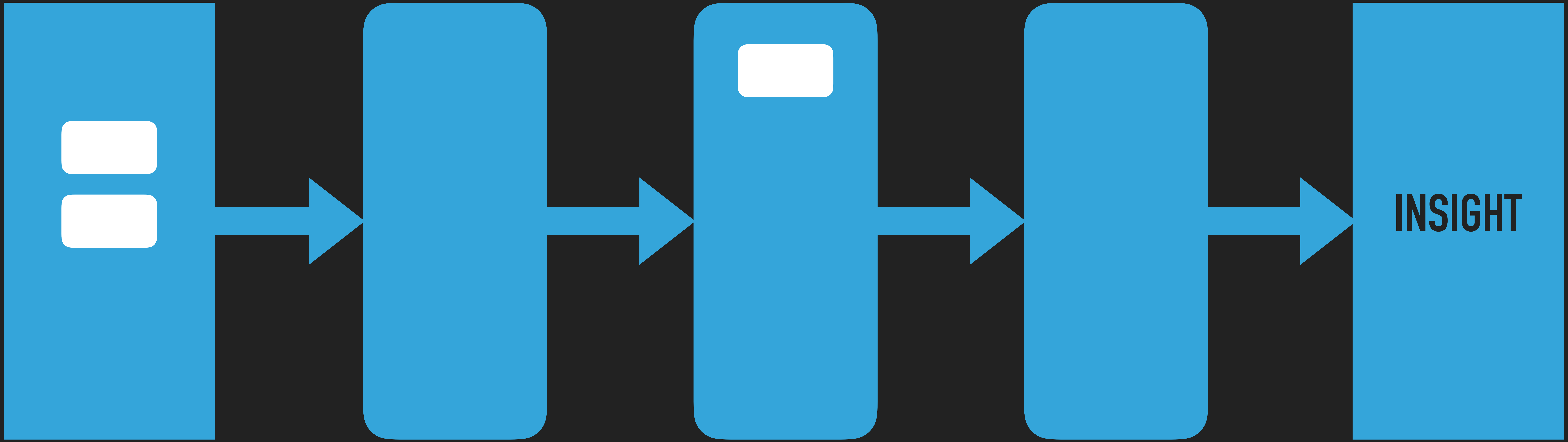

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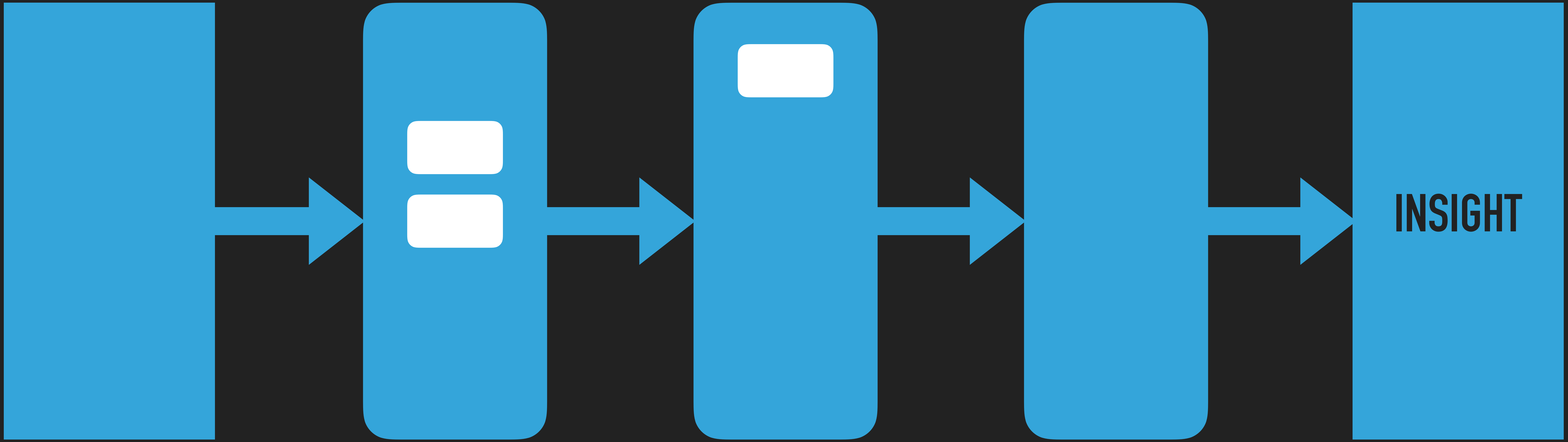

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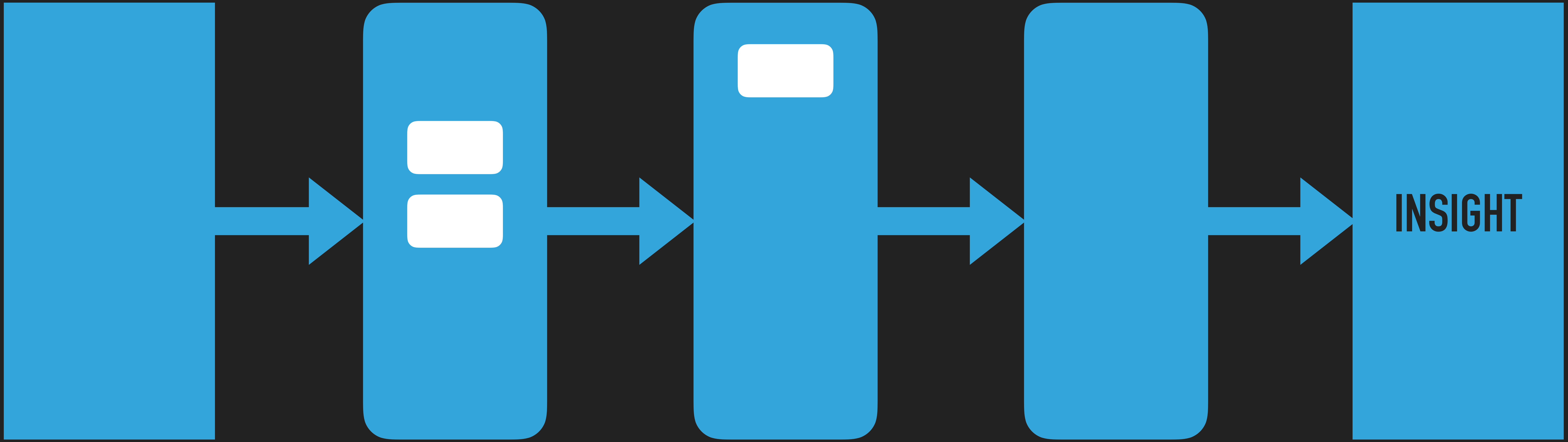

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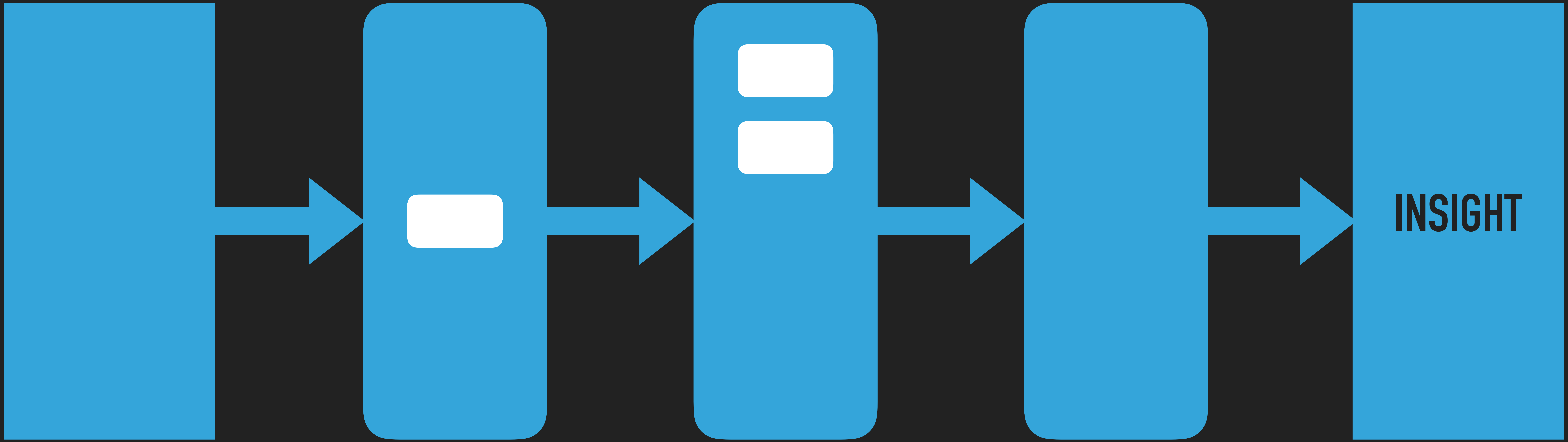

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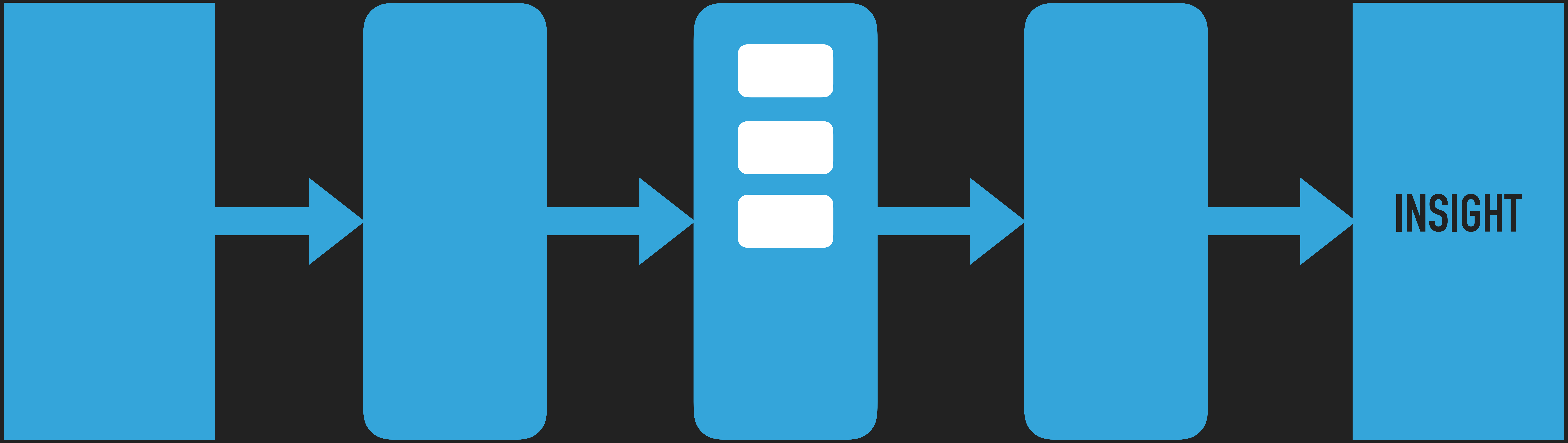

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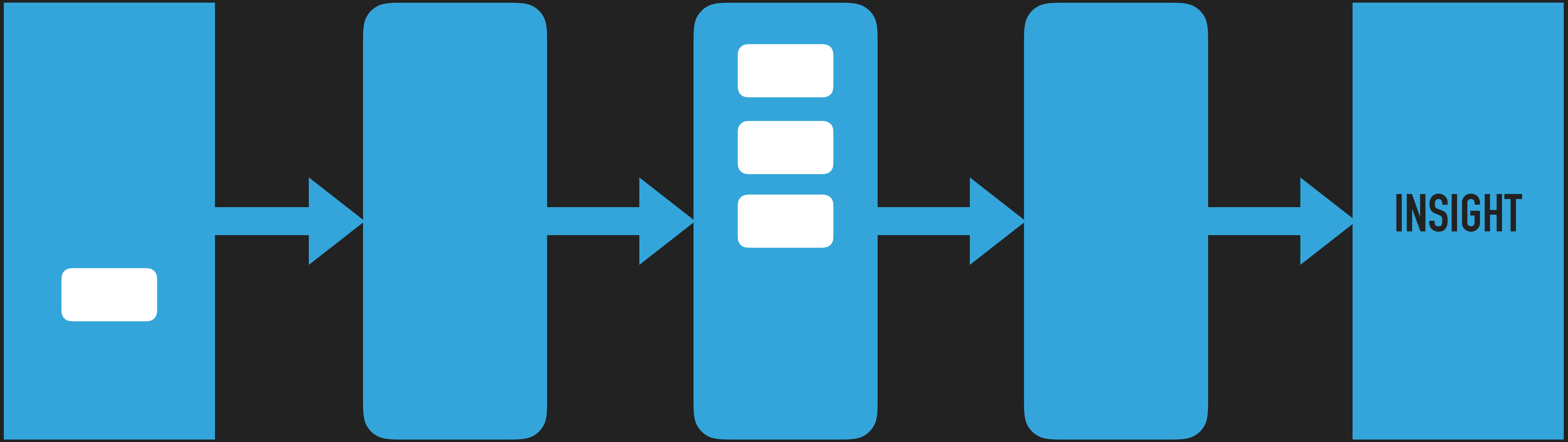

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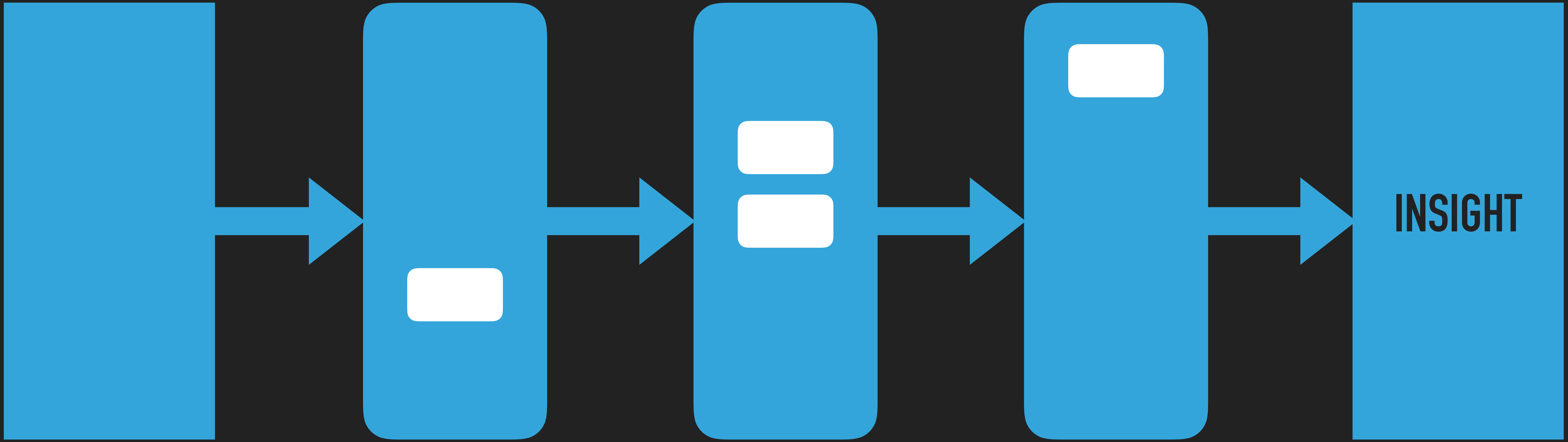

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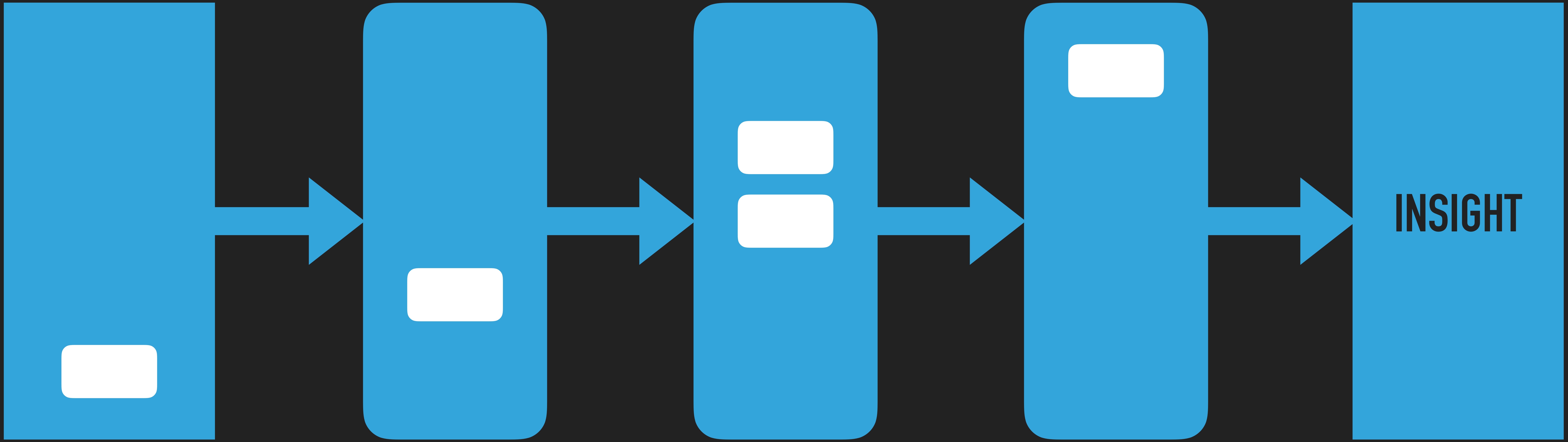

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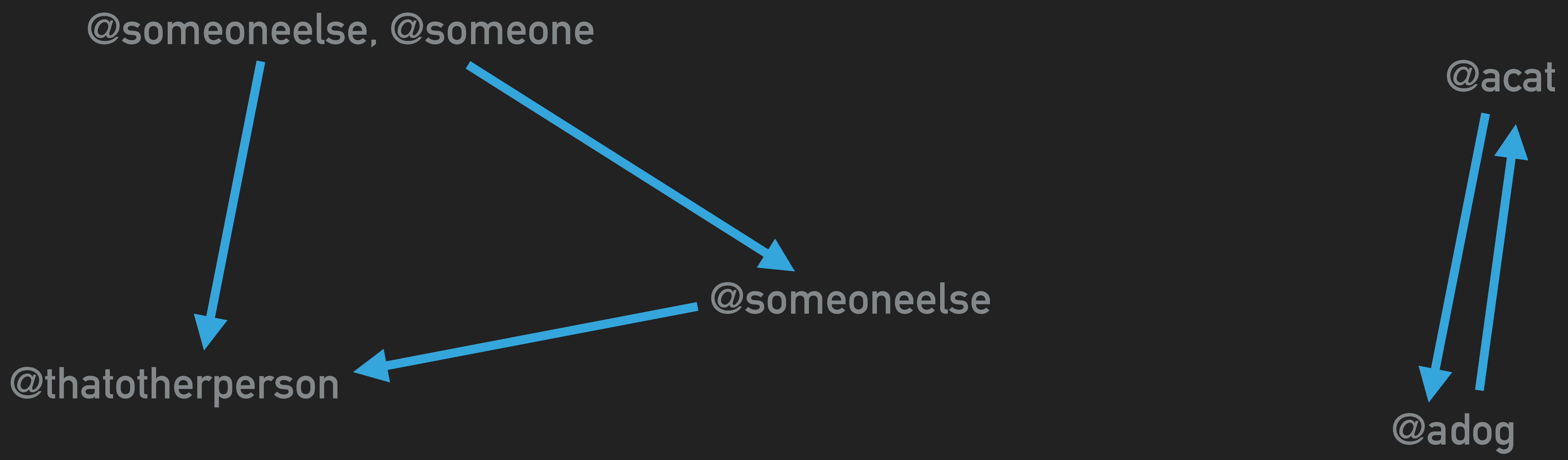
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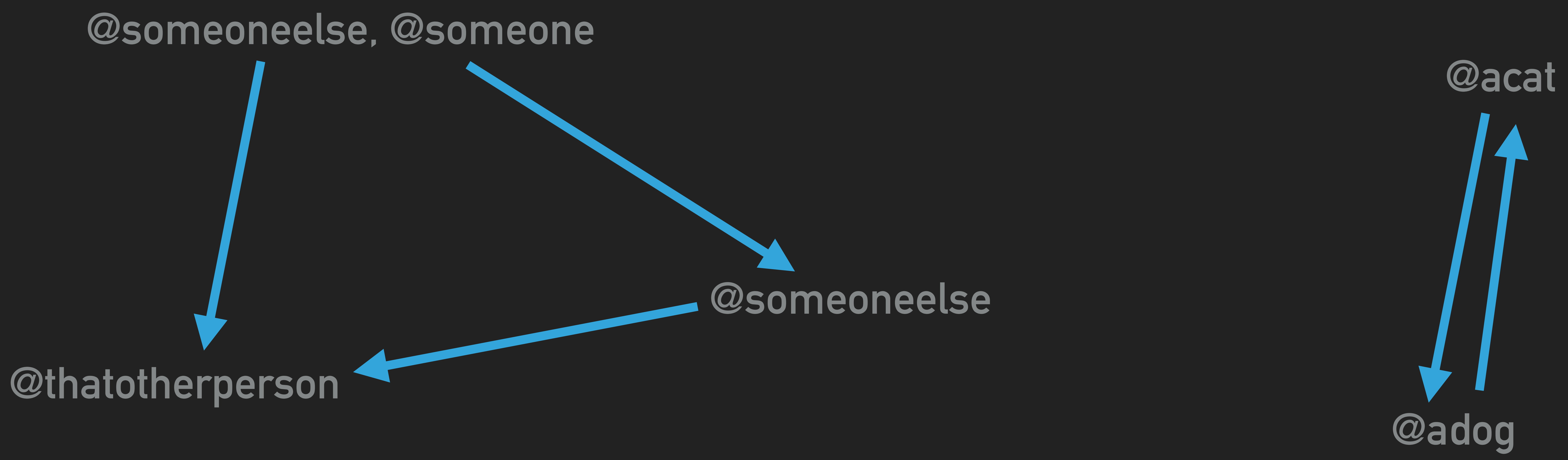
GRAPH



CONNECTED COMPONENTS

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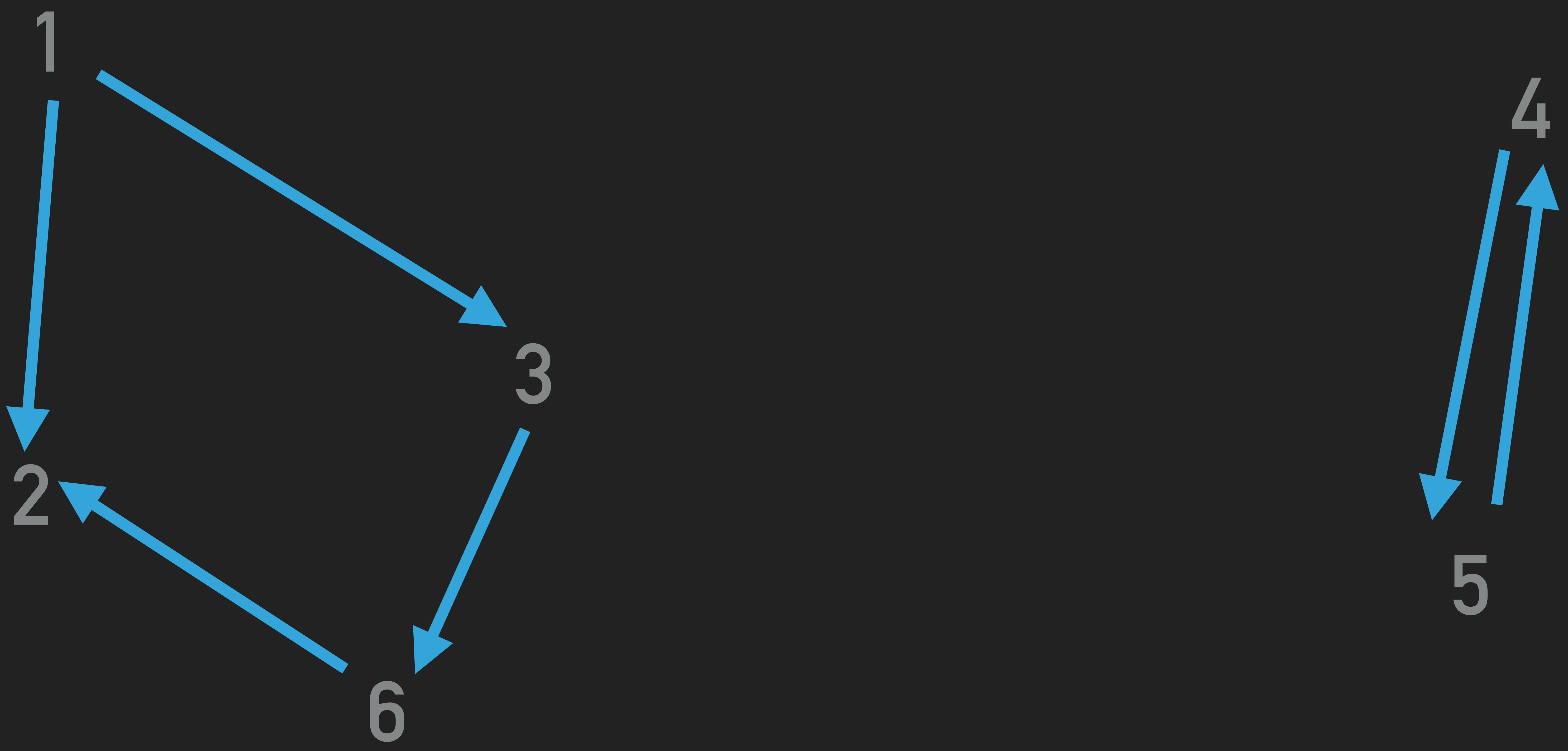

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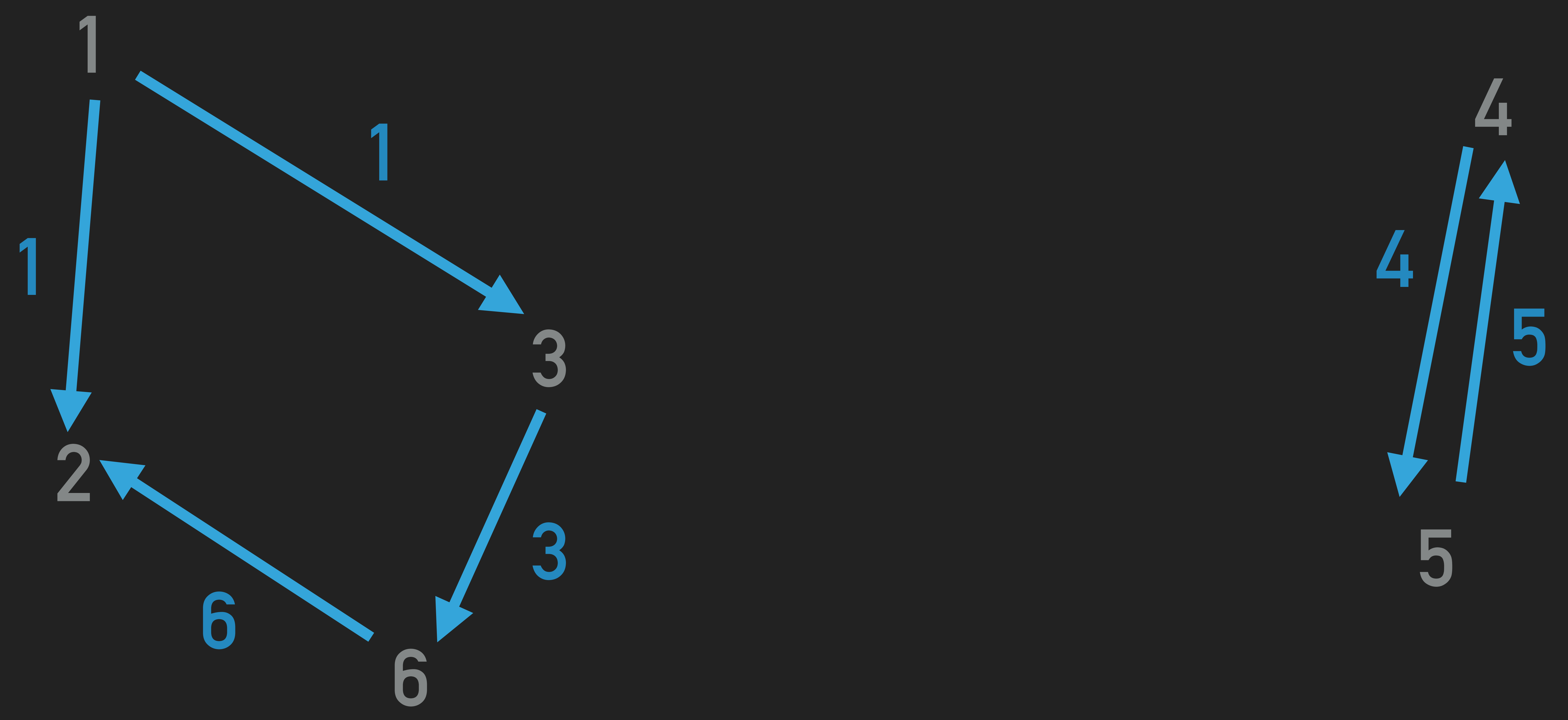

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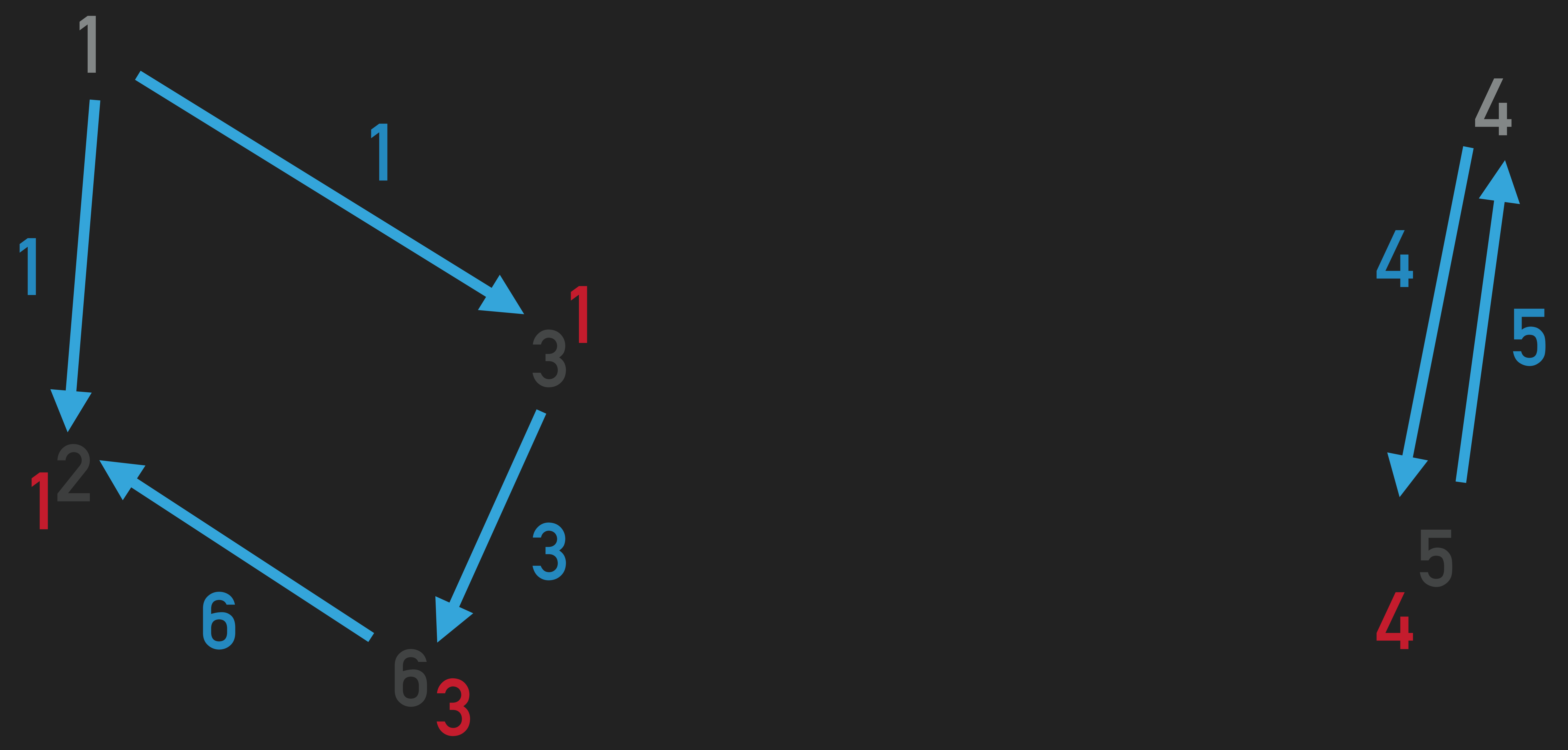

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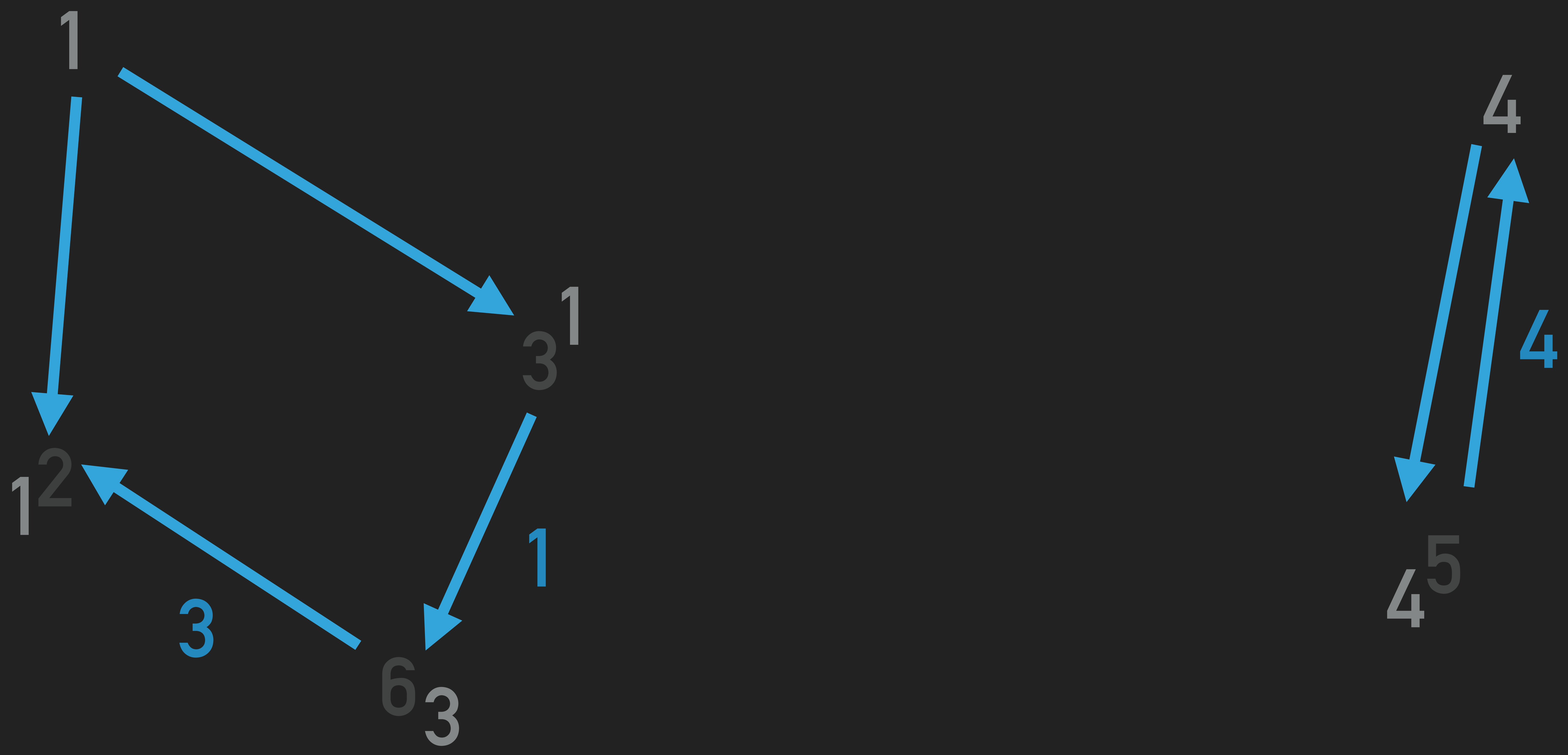

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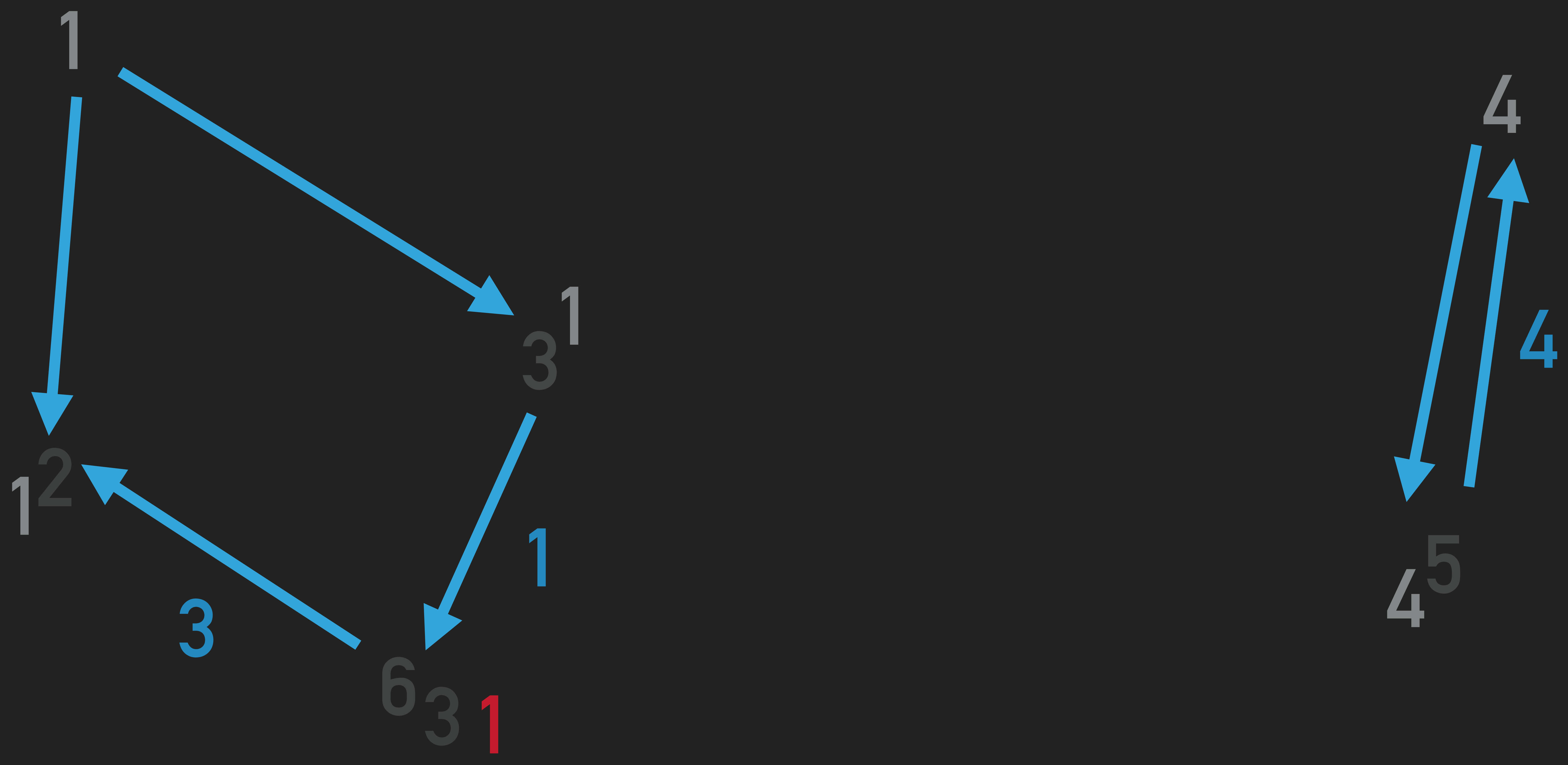

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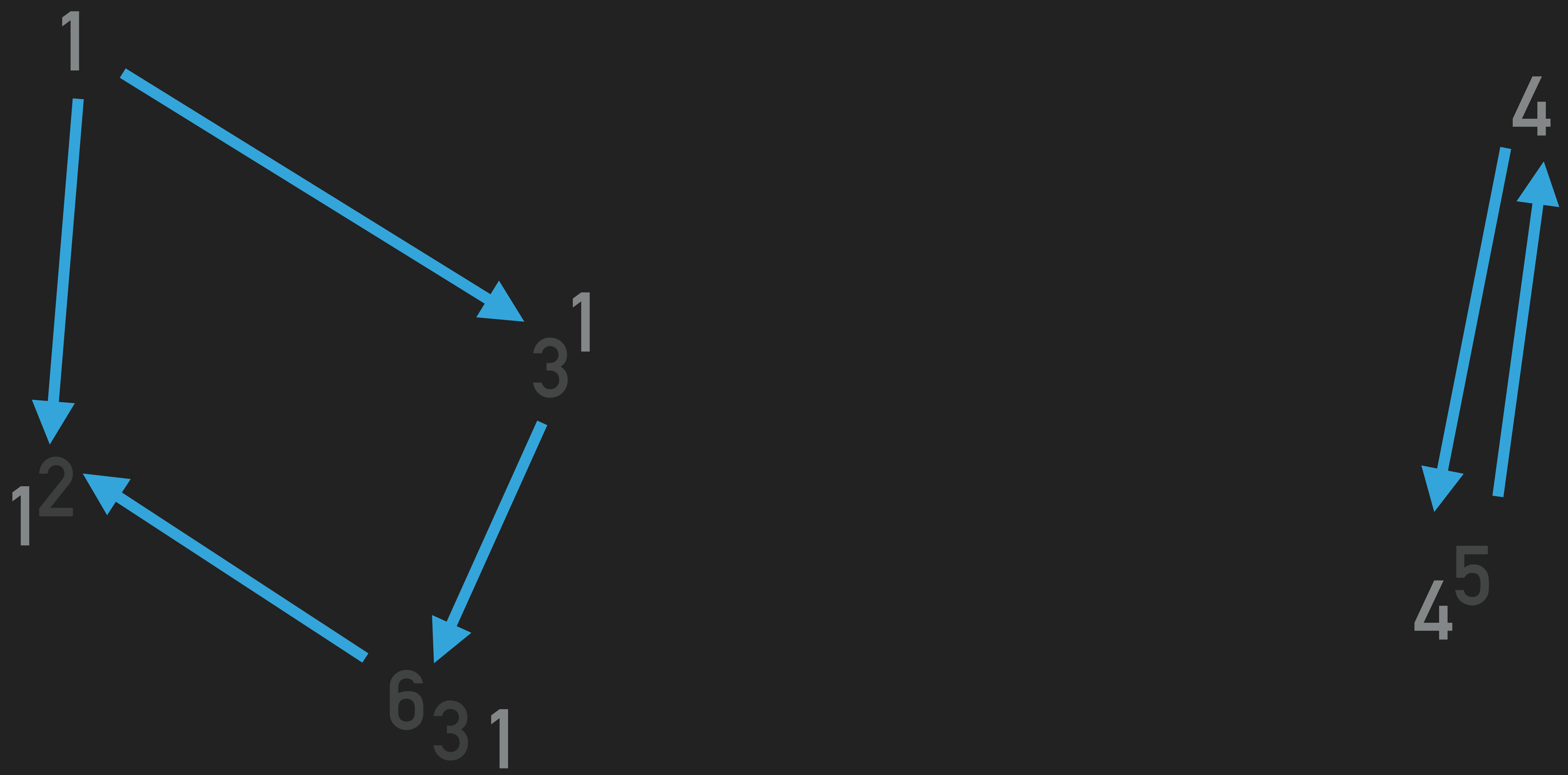
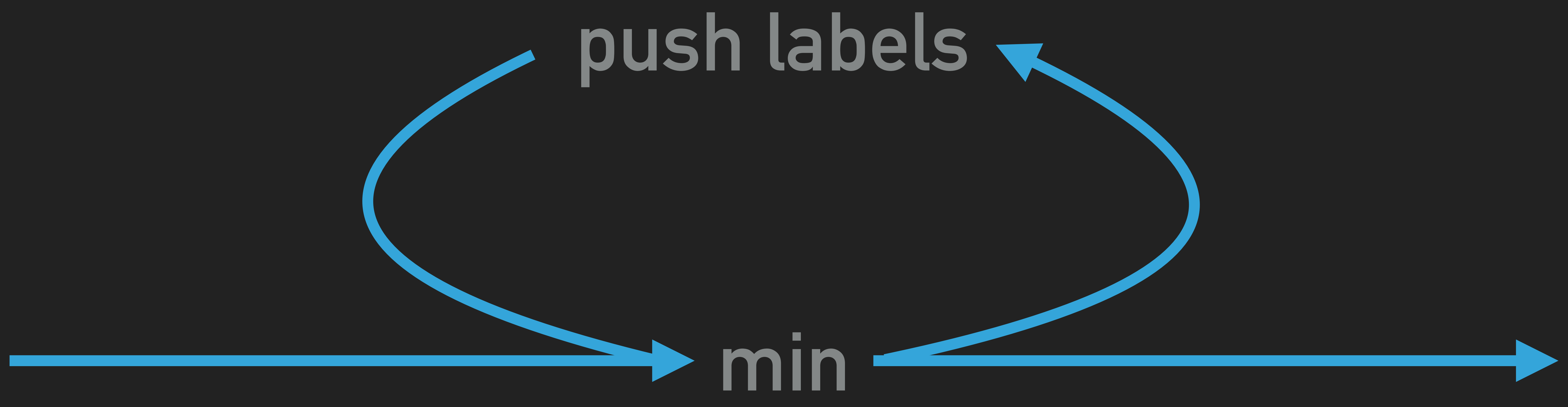


CONNECTED COMPONENTS

GRAPH PROCESSING IN DATAFLOW: CYCLES!



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CONTEXT: PROGRAMMING MODEL

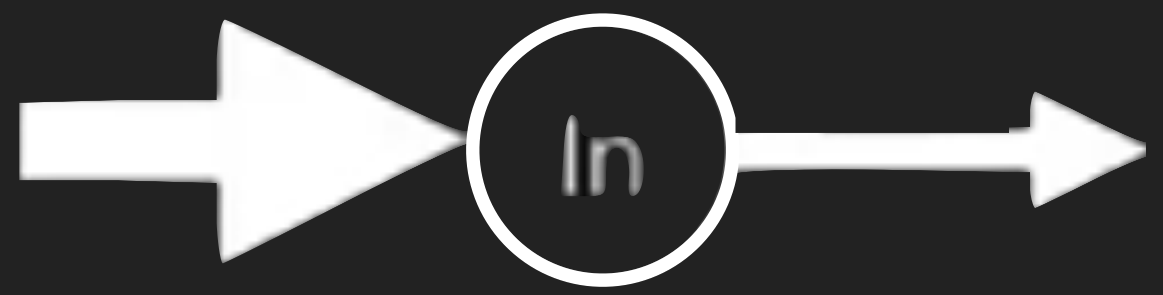
STREAMING

BATCH

GRAPH

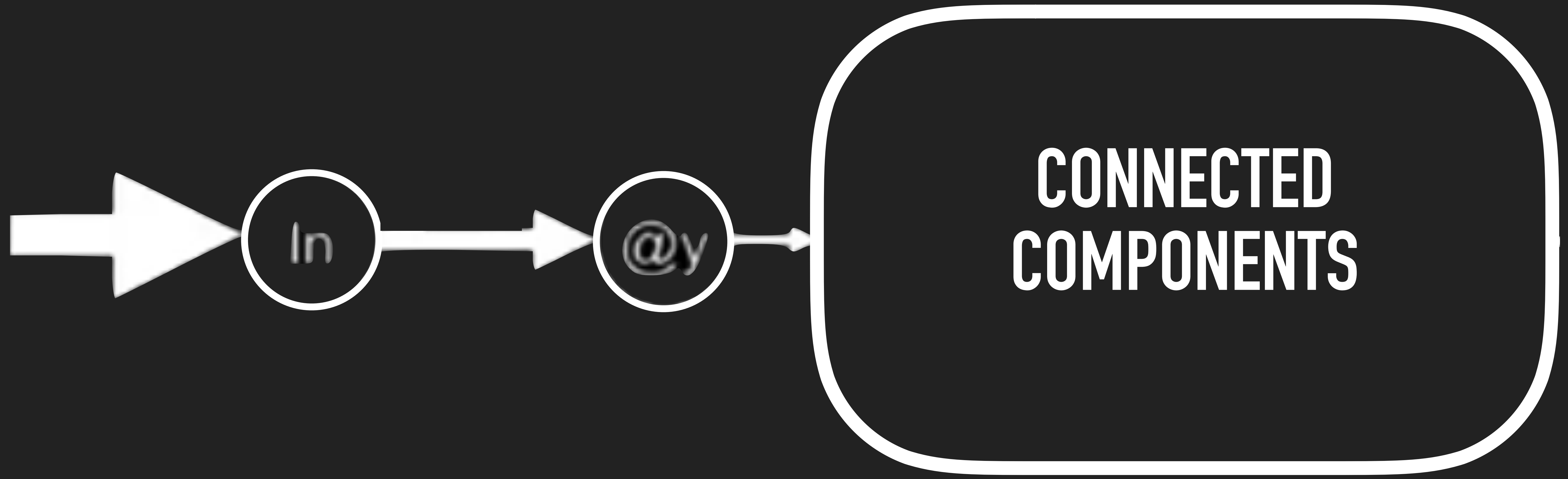
CONTEXT: PROGRAMMING MODEL

STREAMING BATCH GRAPH



CONTEXT: PROGRAMMING MODEL

STREAMING	BATCH	GRAPH



CONTEXT: PROGRAMMING MODEL

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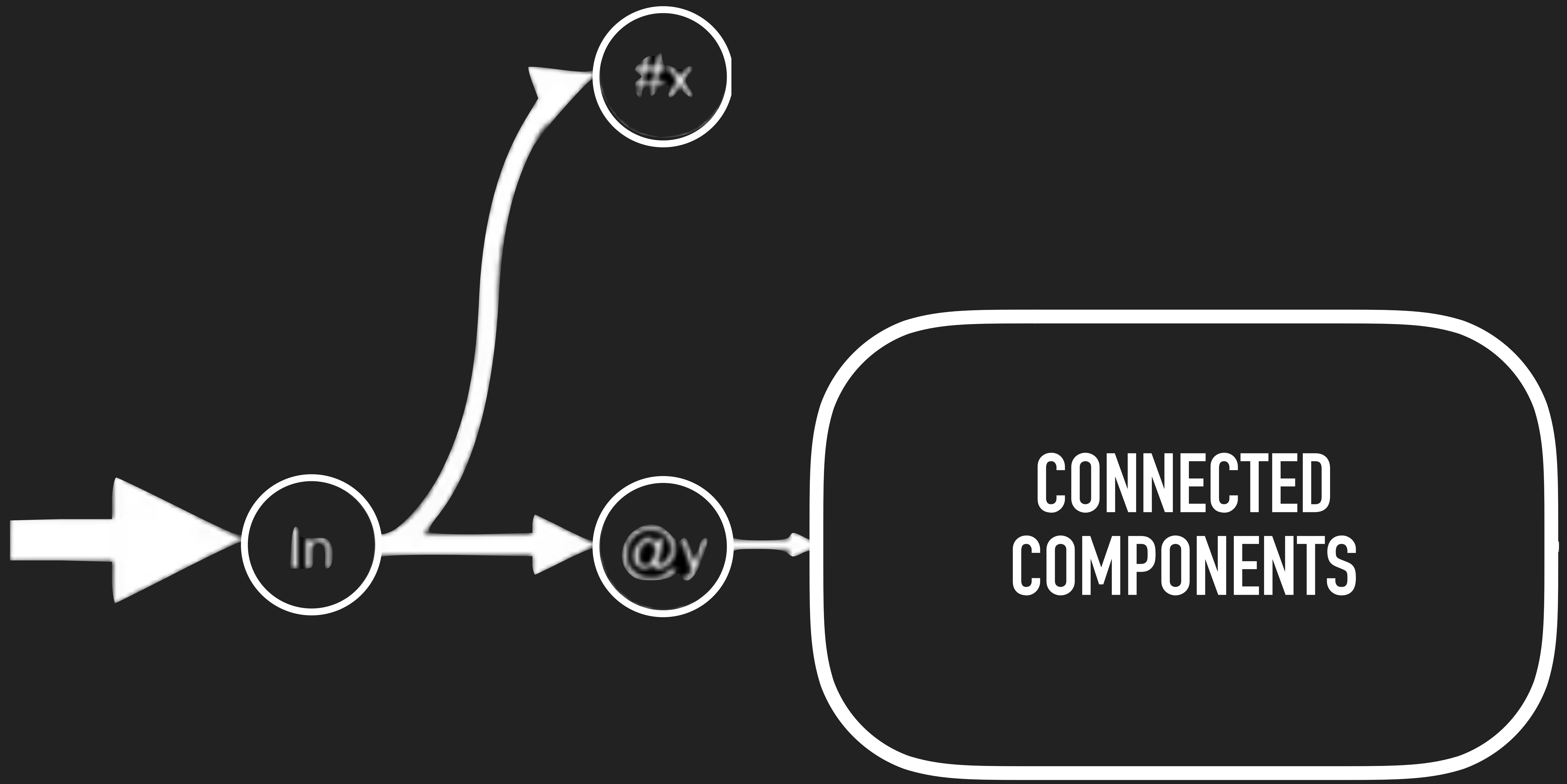

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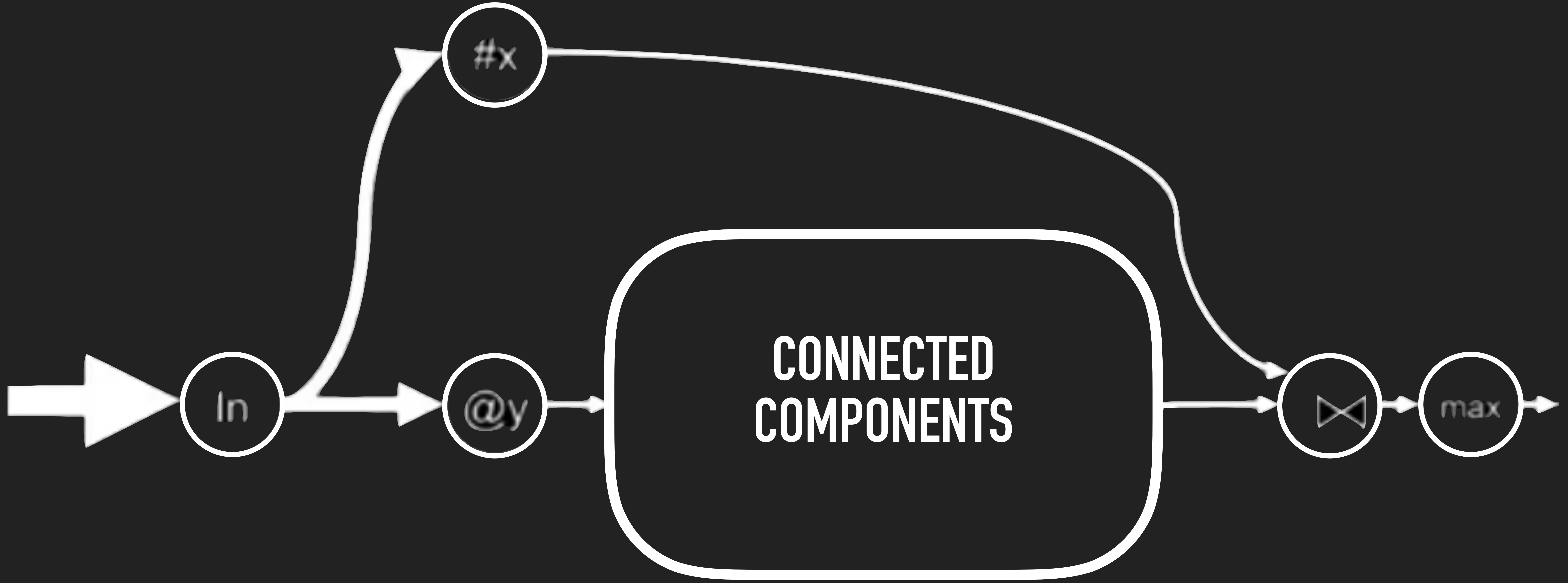

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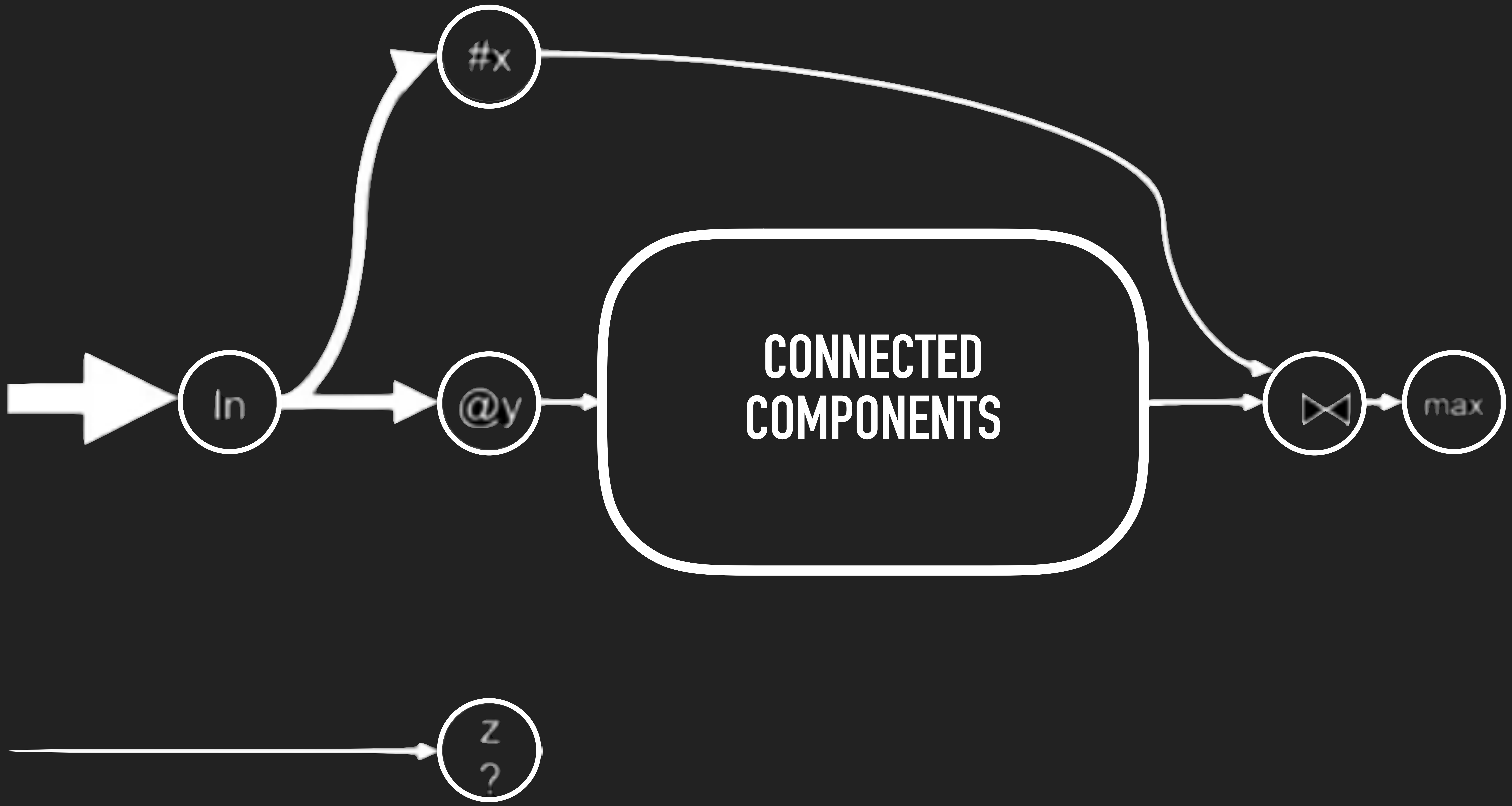

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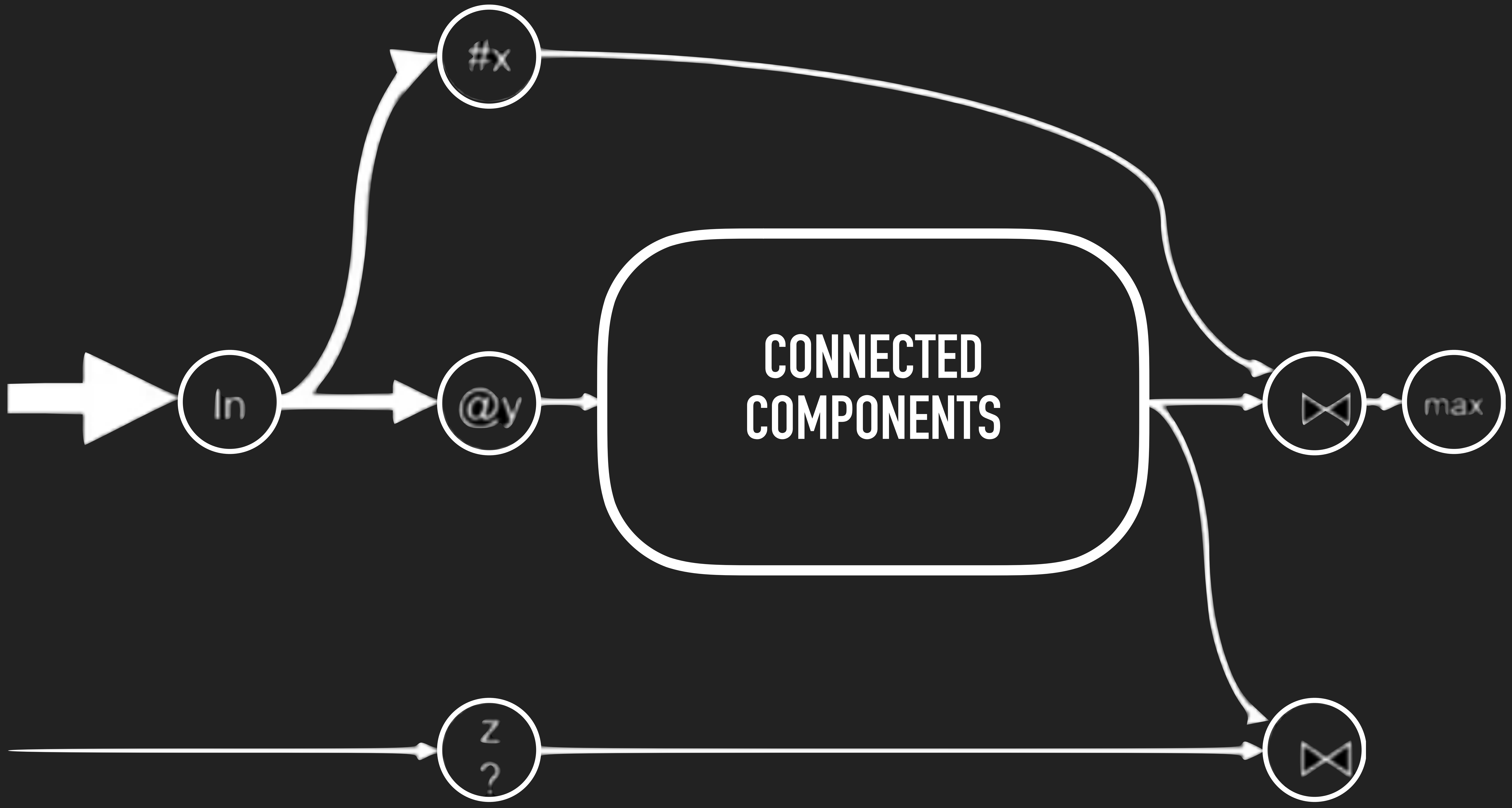

CONTEXT: PROGRAMMING MODEL

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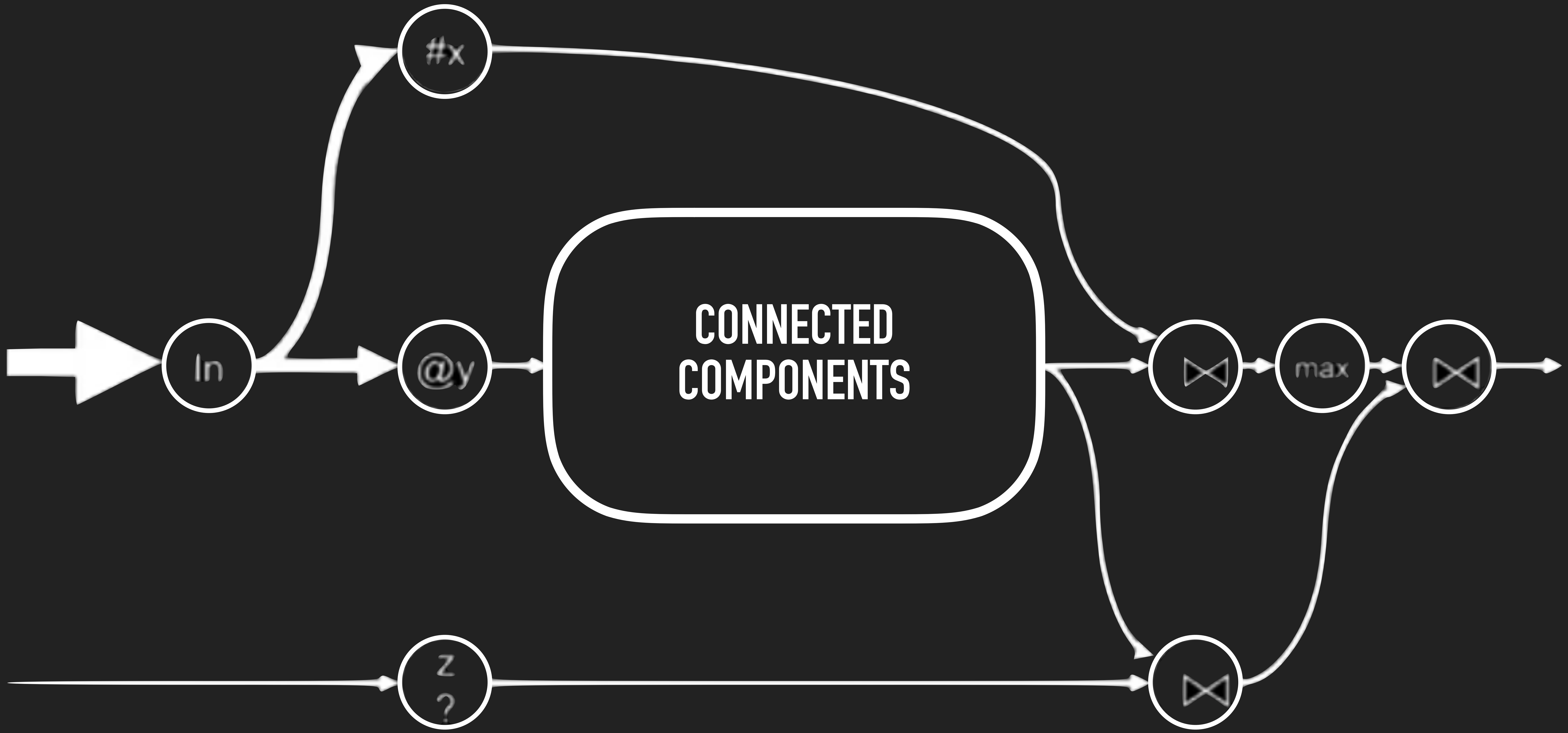
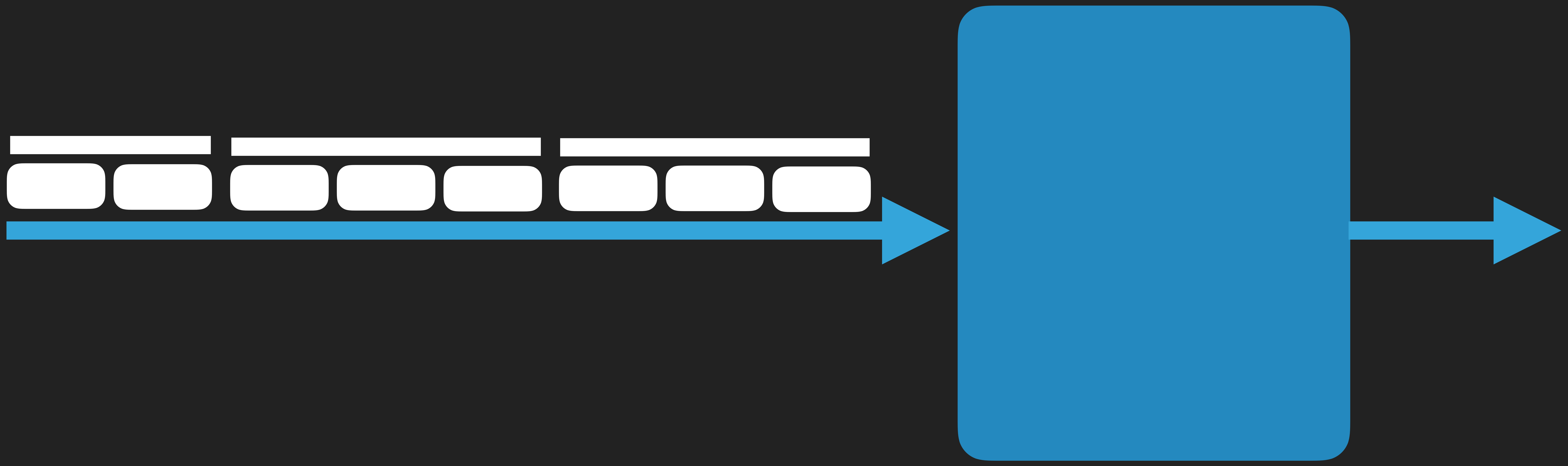


> ACHIEVE THE PERFORMANCE OF SPECIALIZED FRAMEWORK, PROVIDE THE FLEXIBILITY OF A GENERIC FRAMEWORK.

Derek Murray

AGGREGATION IN ASYNCHRONOUS MODEL



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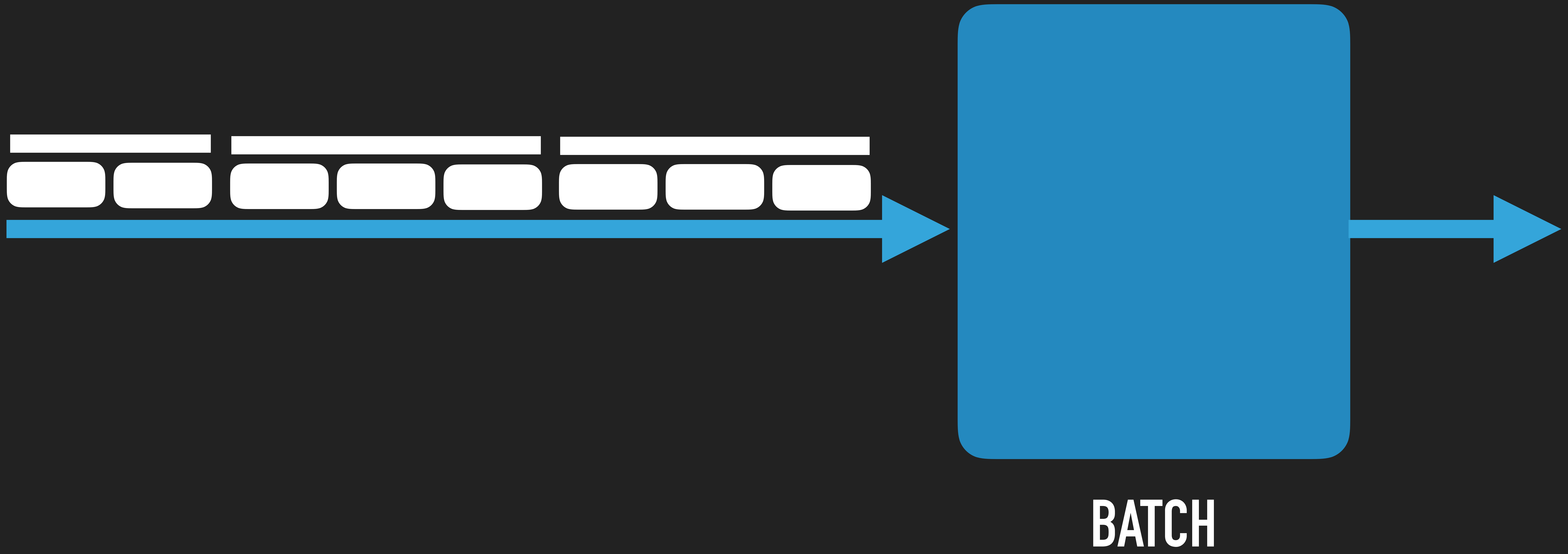

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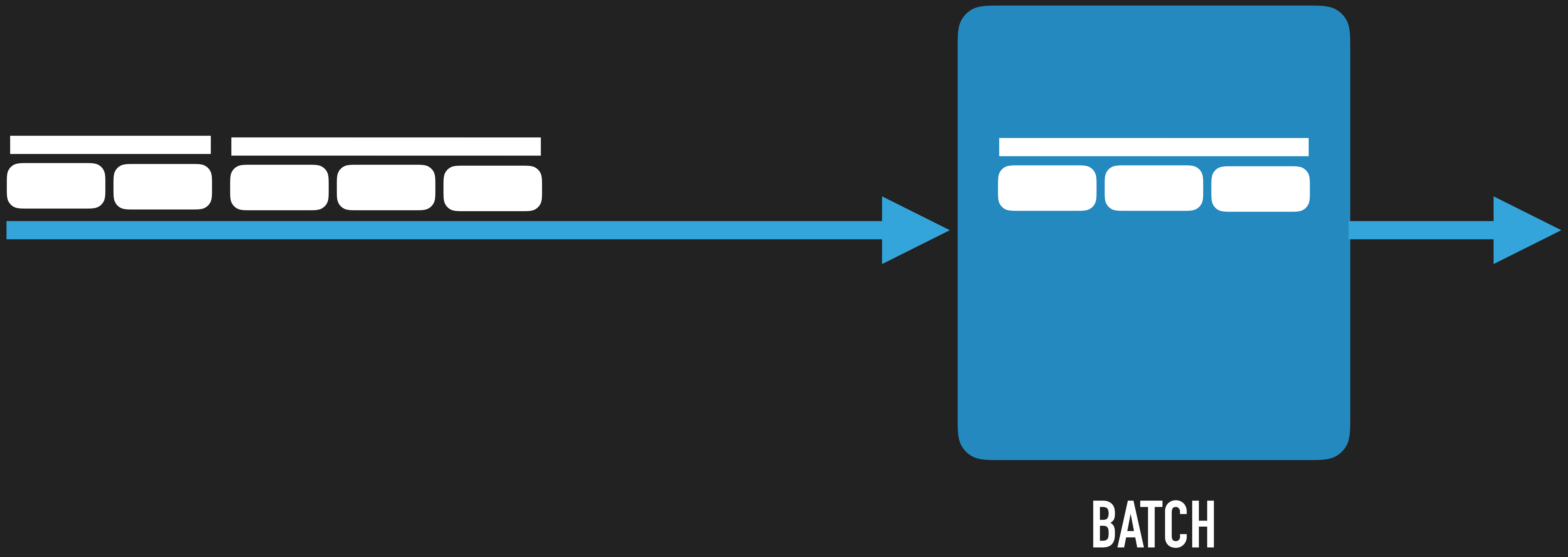

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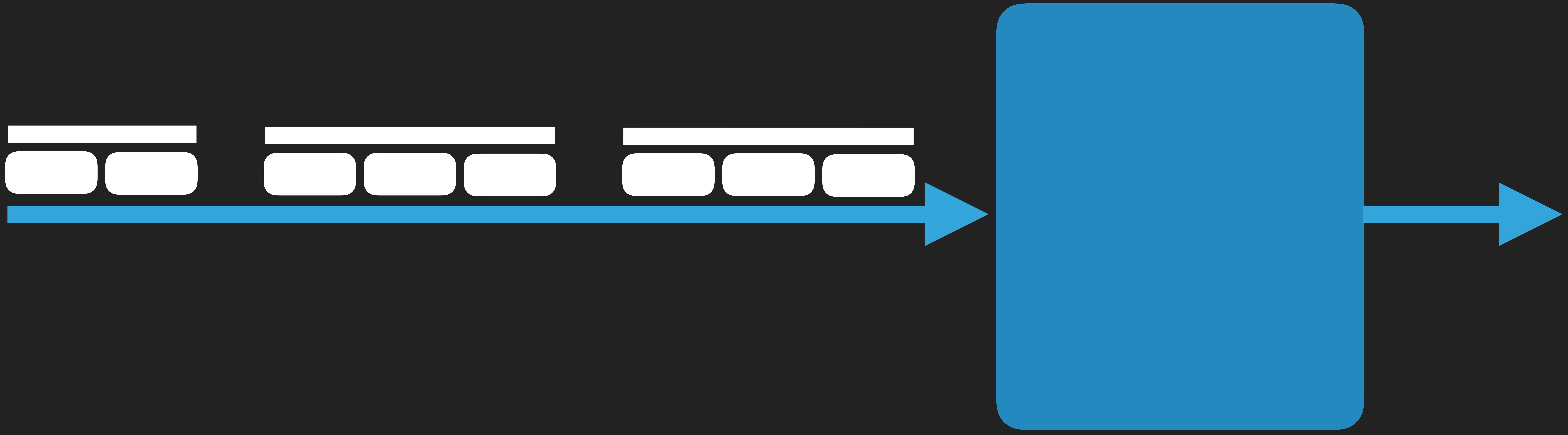

STREAMING

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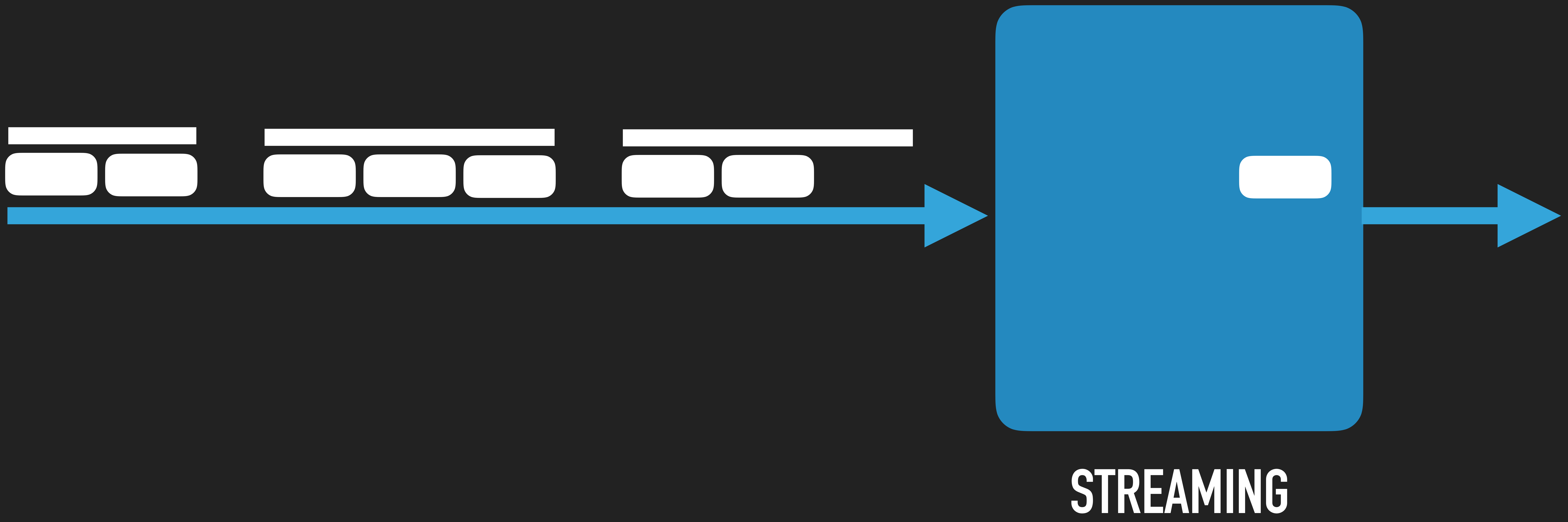

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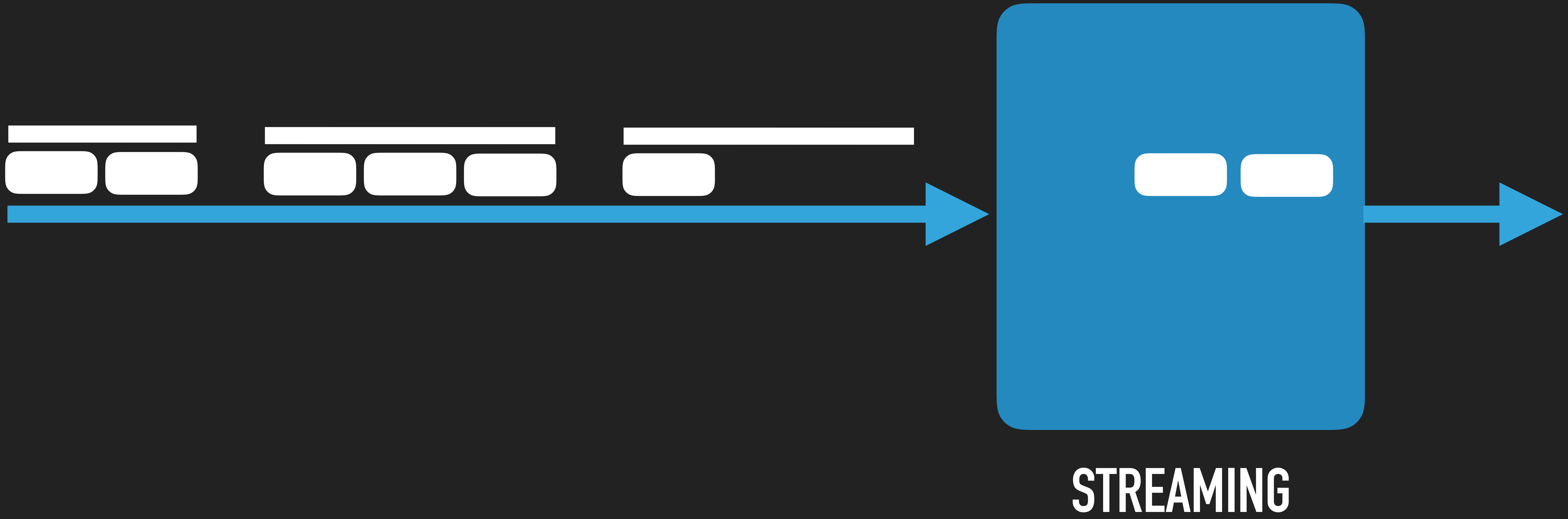

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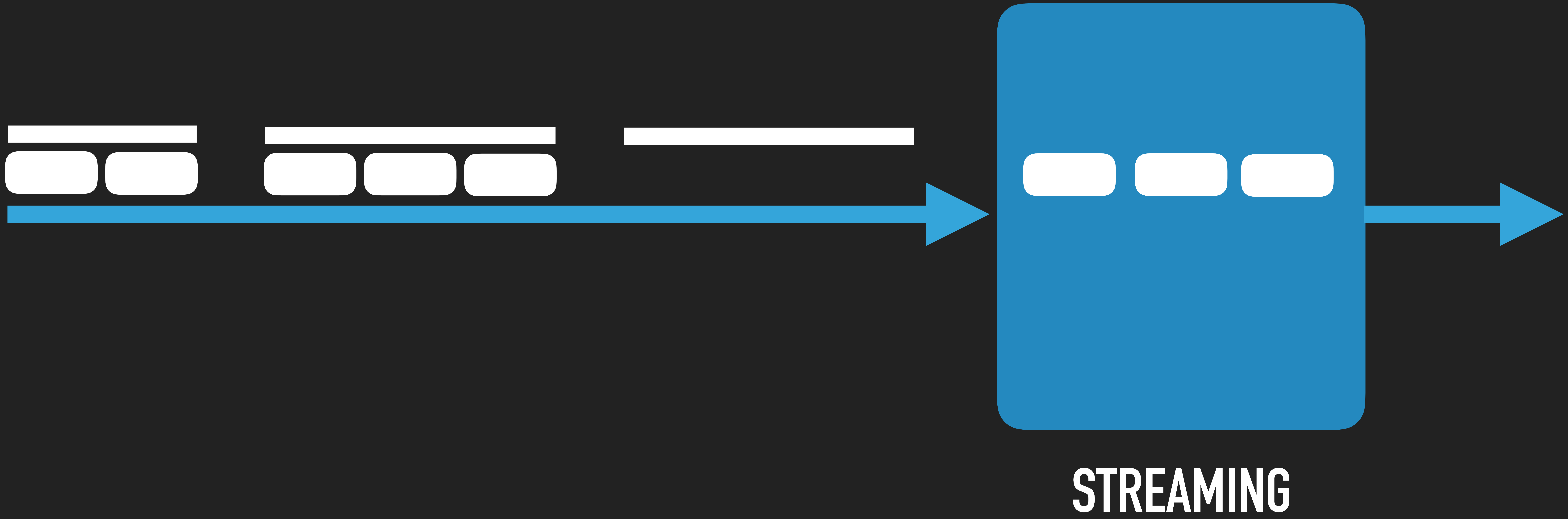

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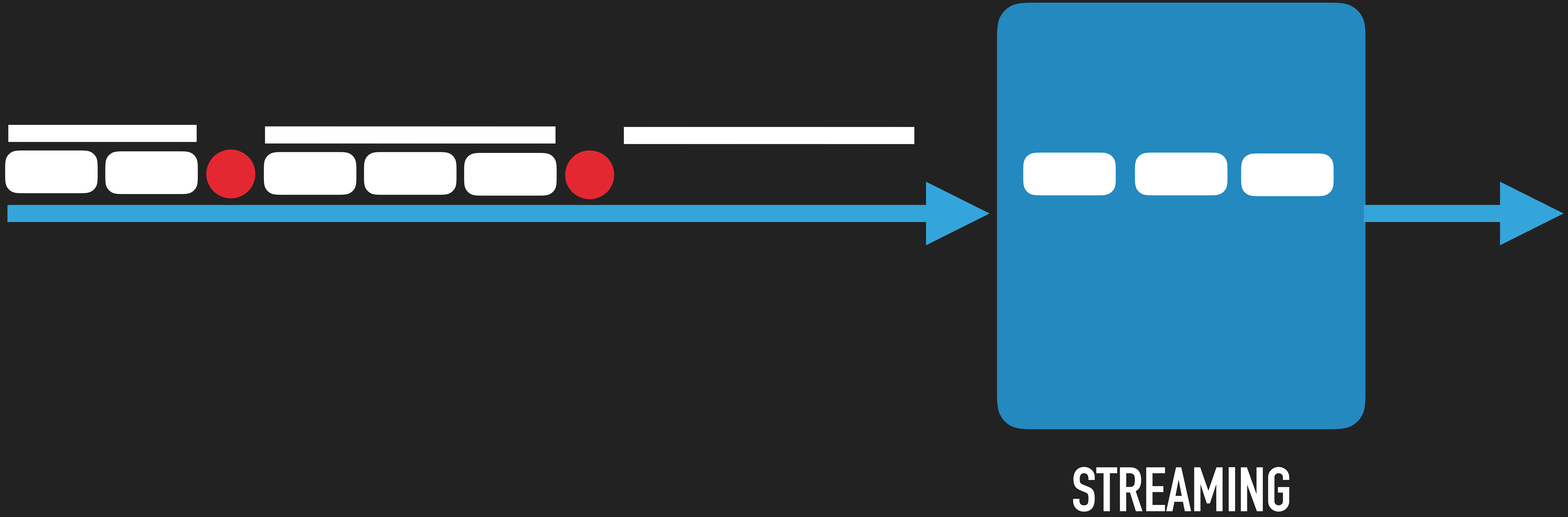

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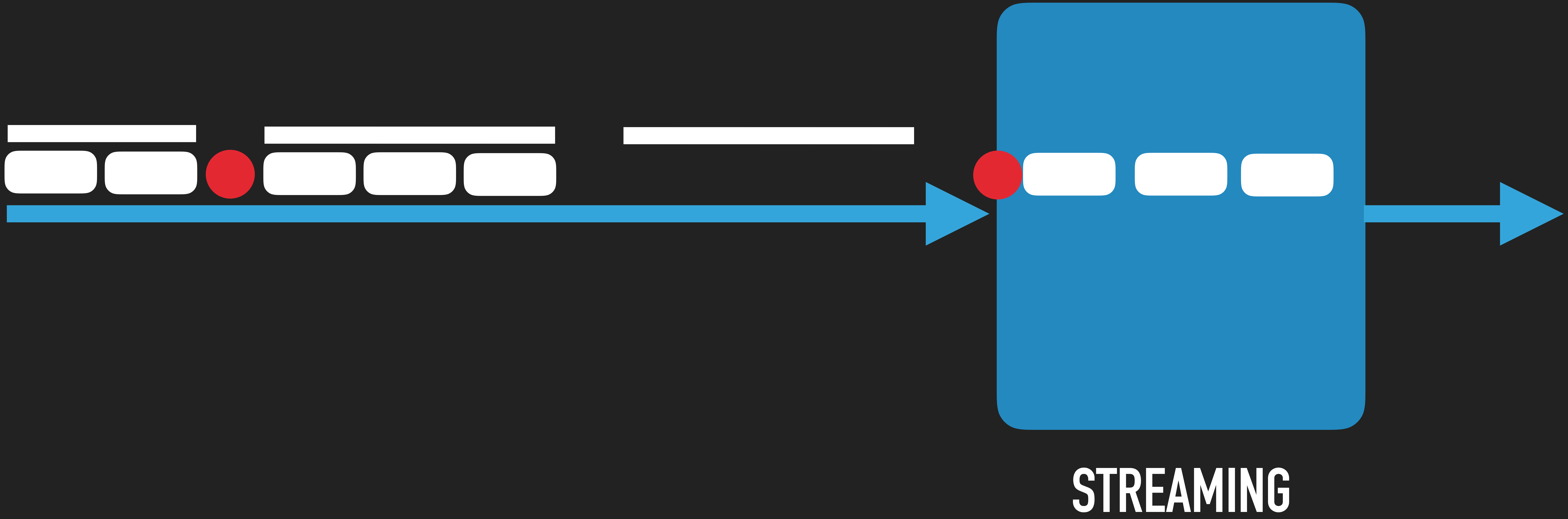

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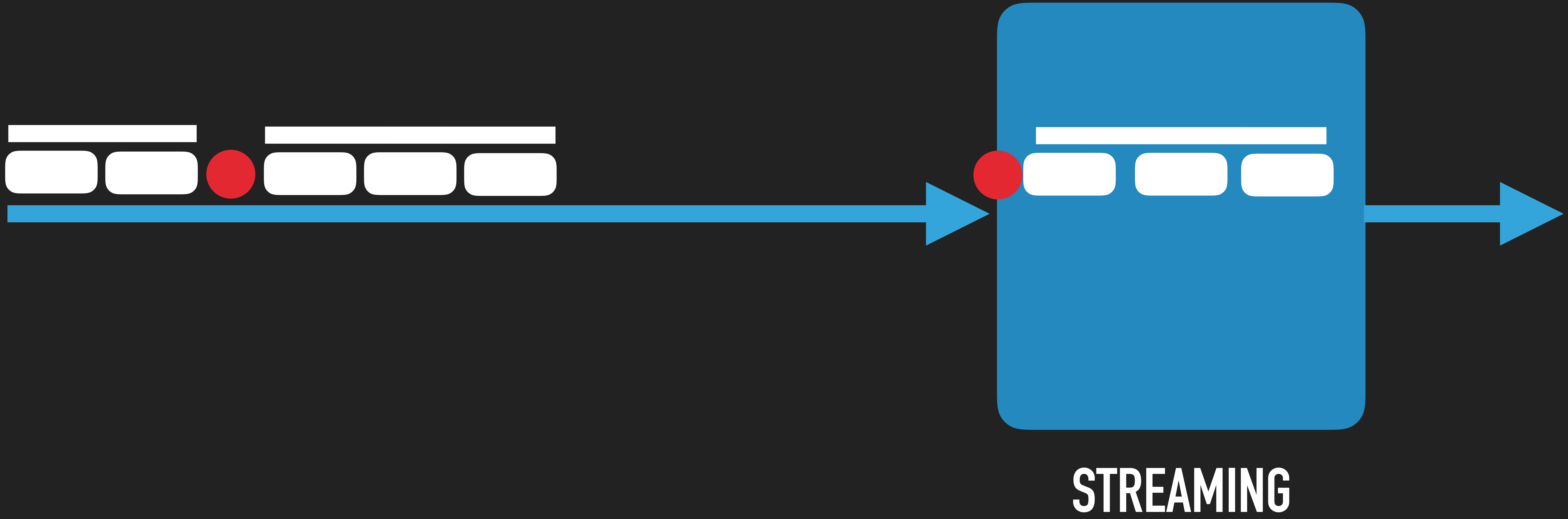

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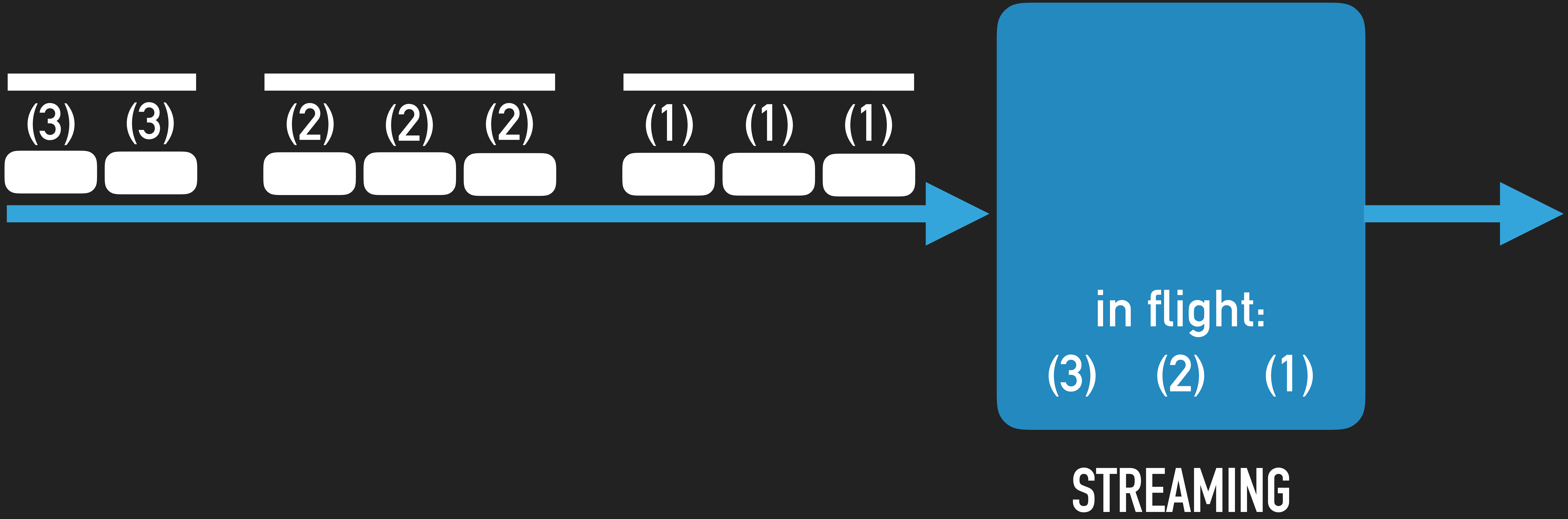

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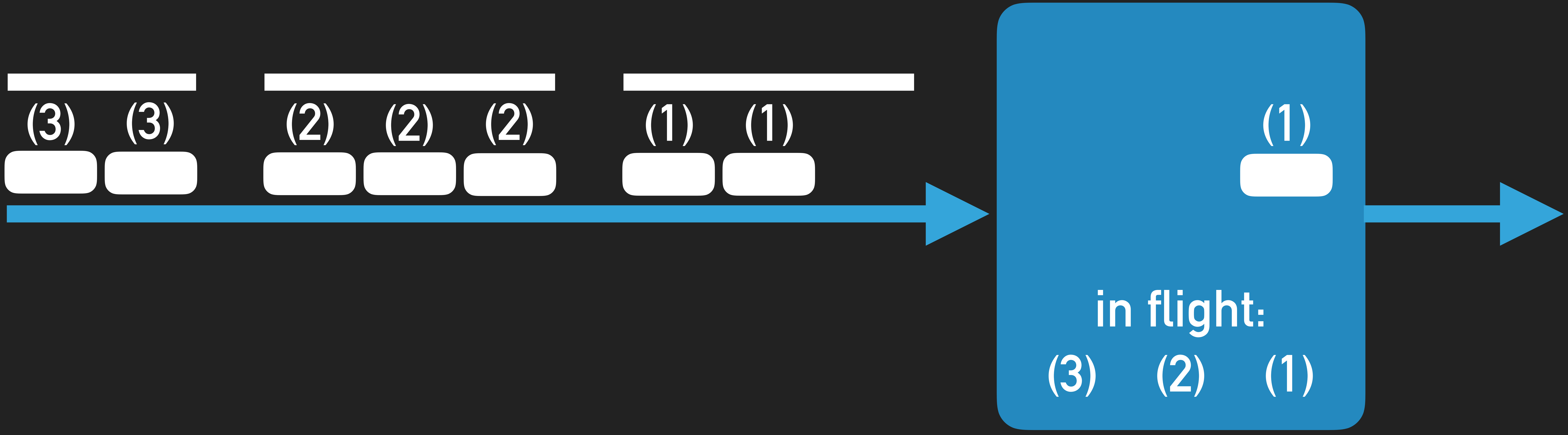

STREAMING

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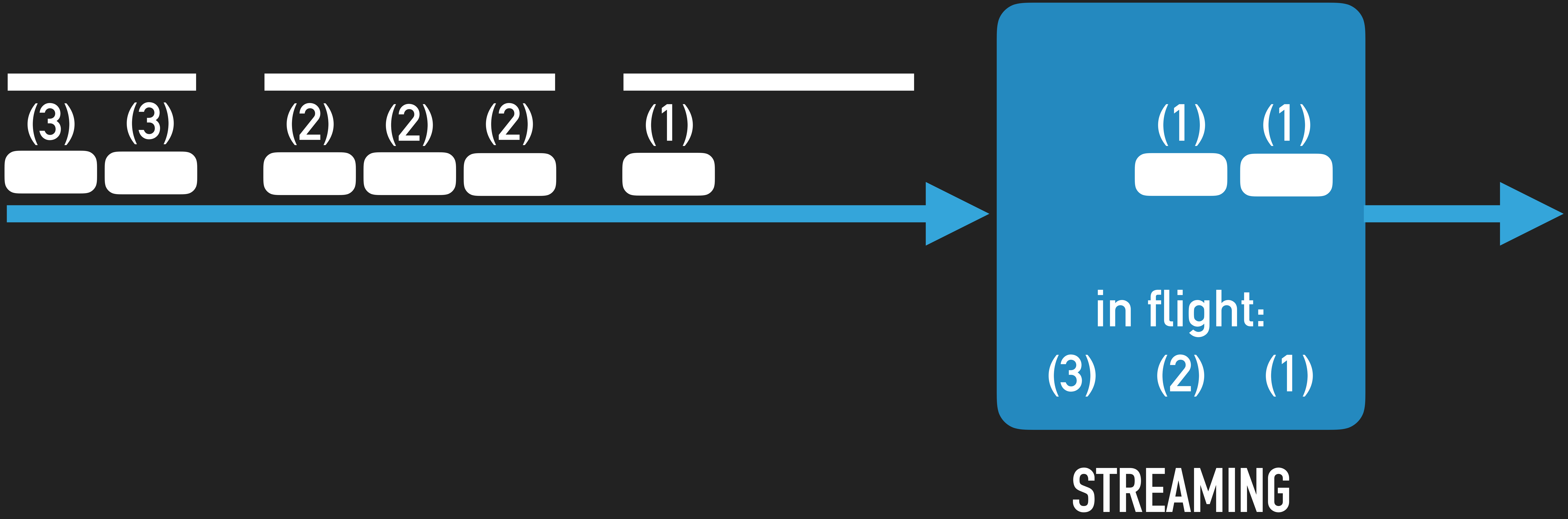

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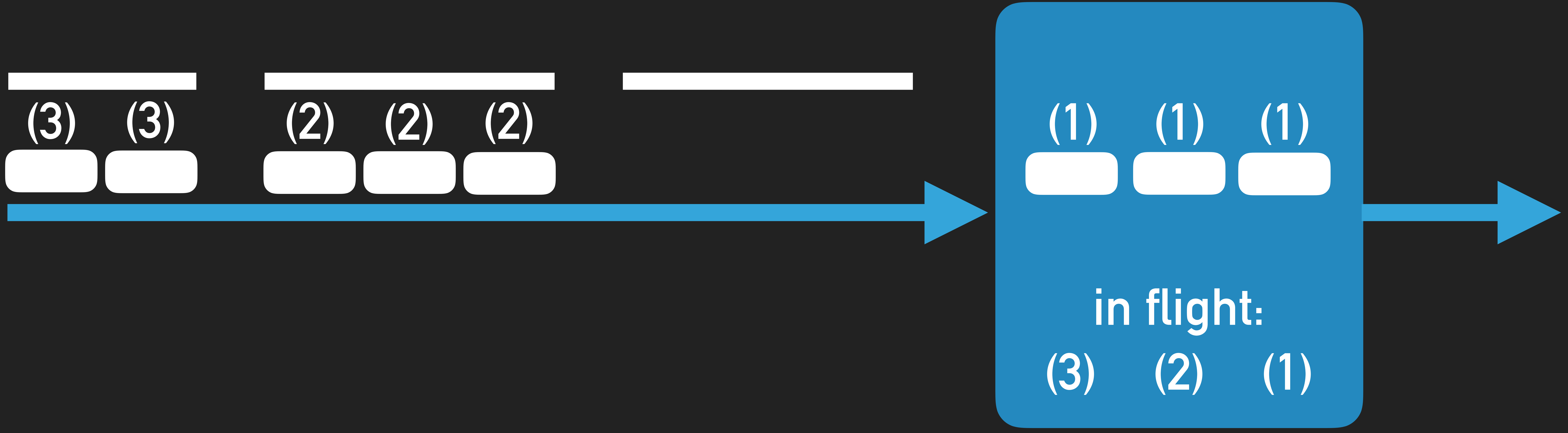

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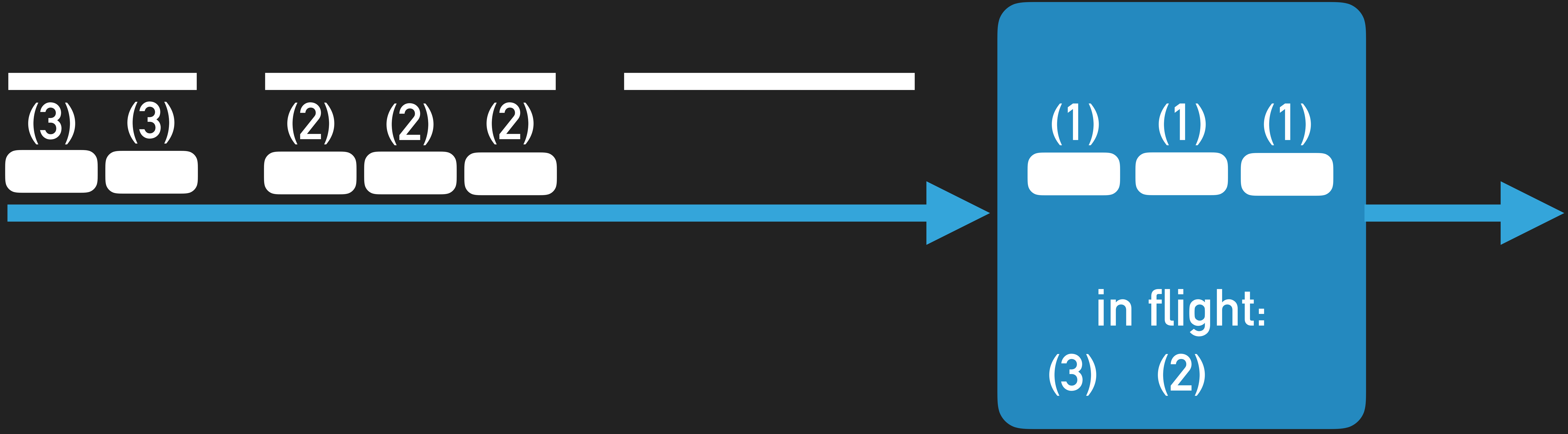

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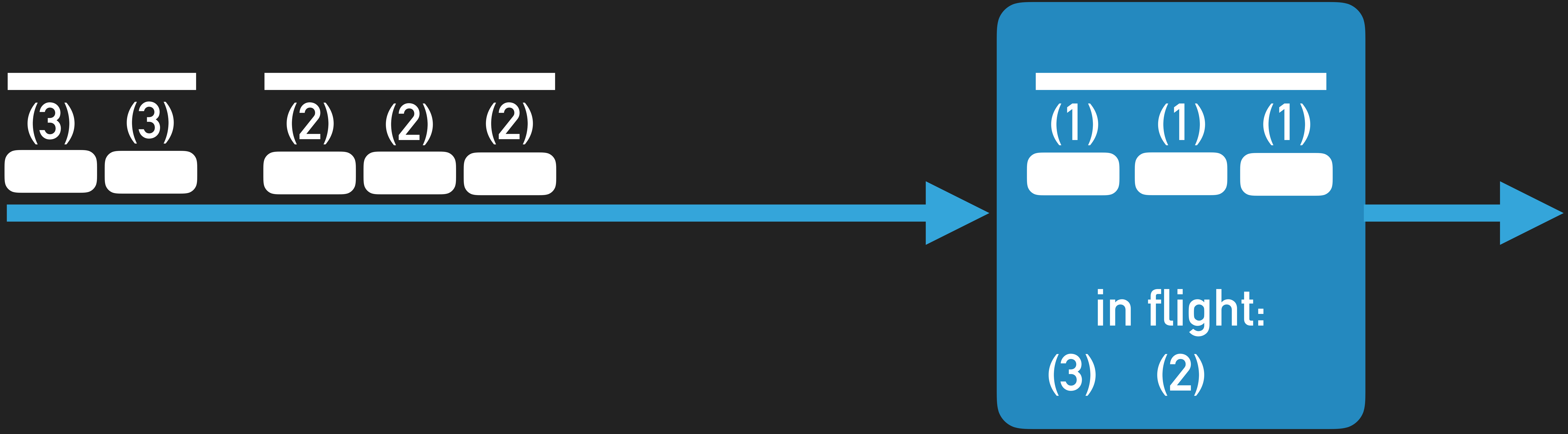
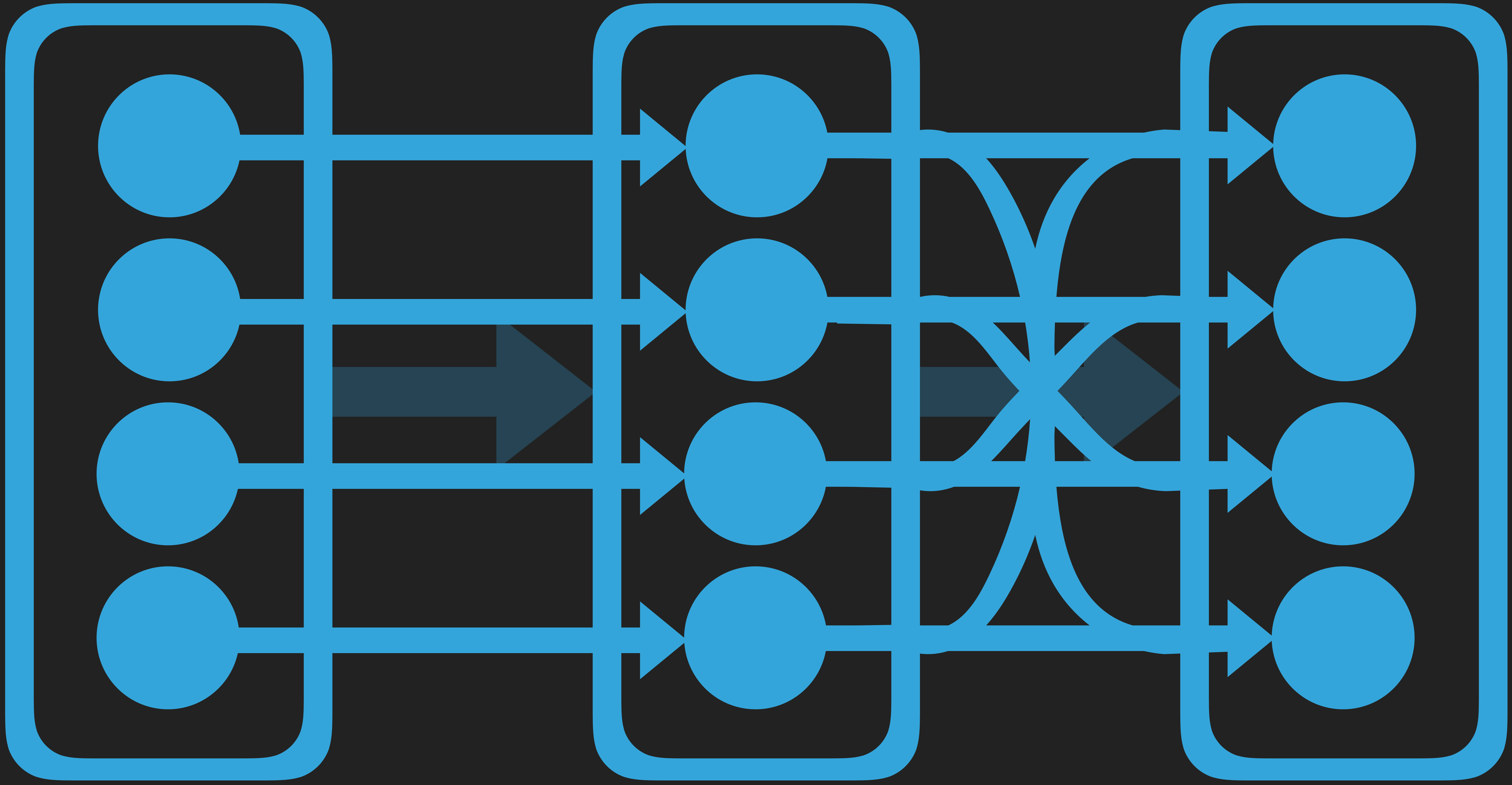


STREAMING

PROGRESS TRACKING



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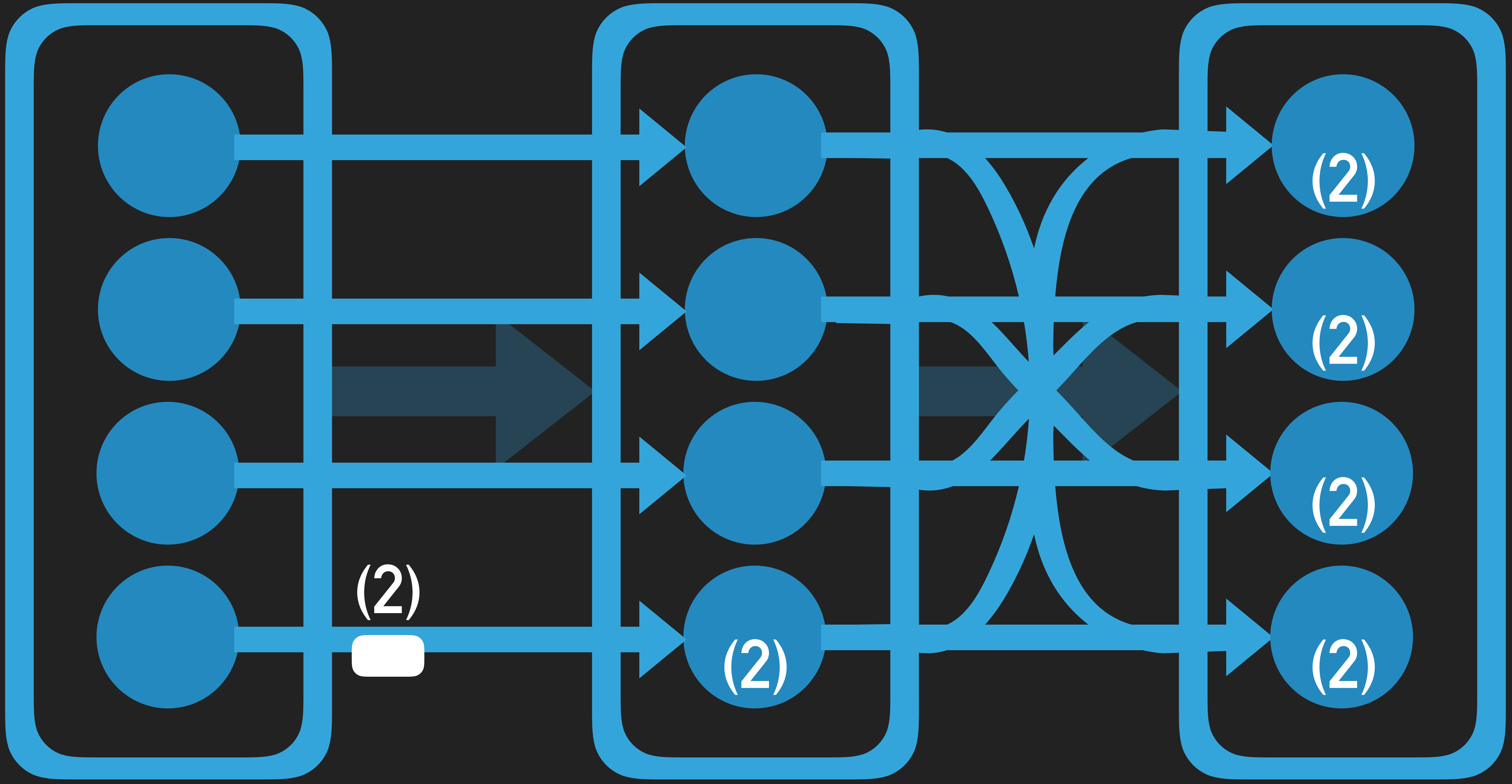

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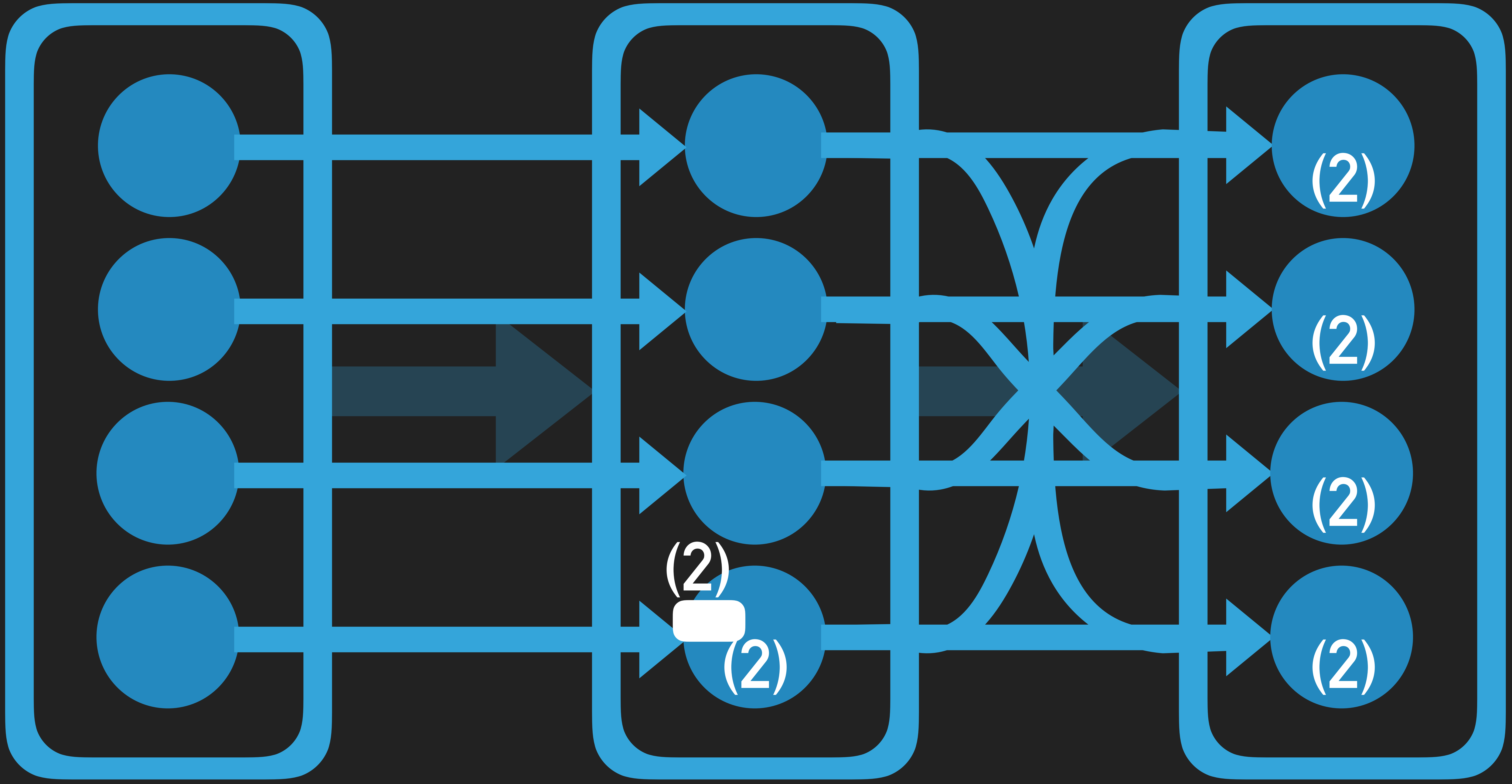

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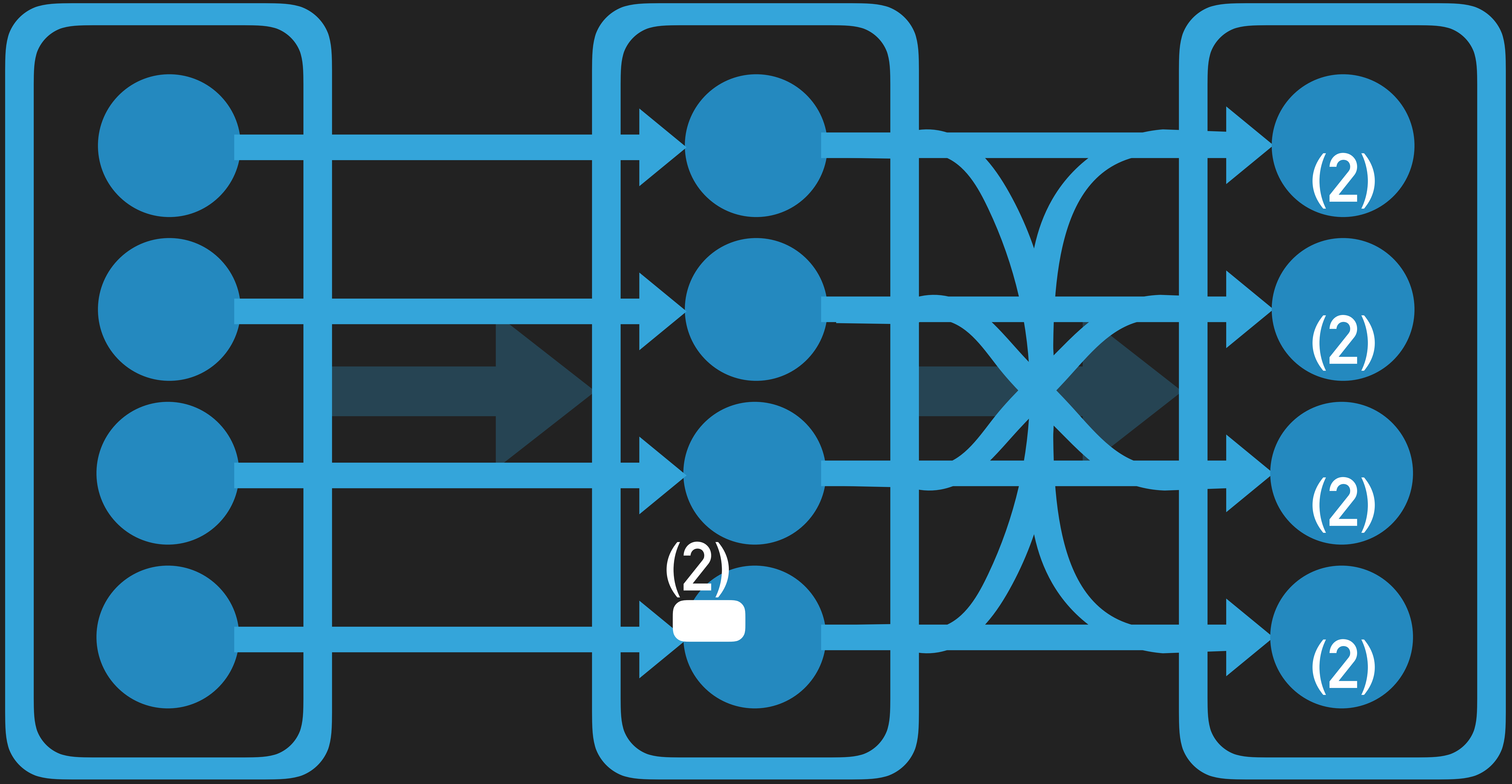

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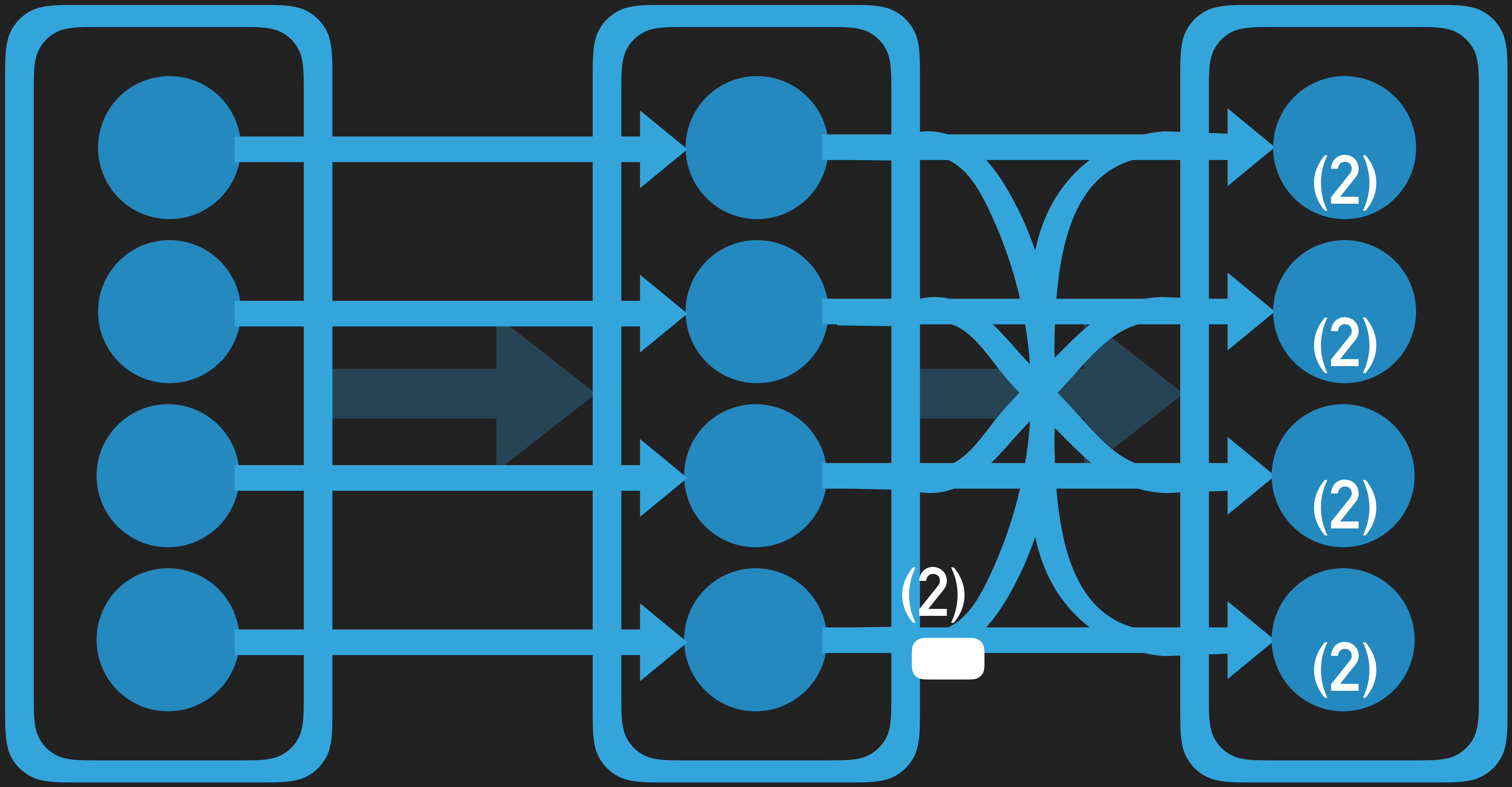

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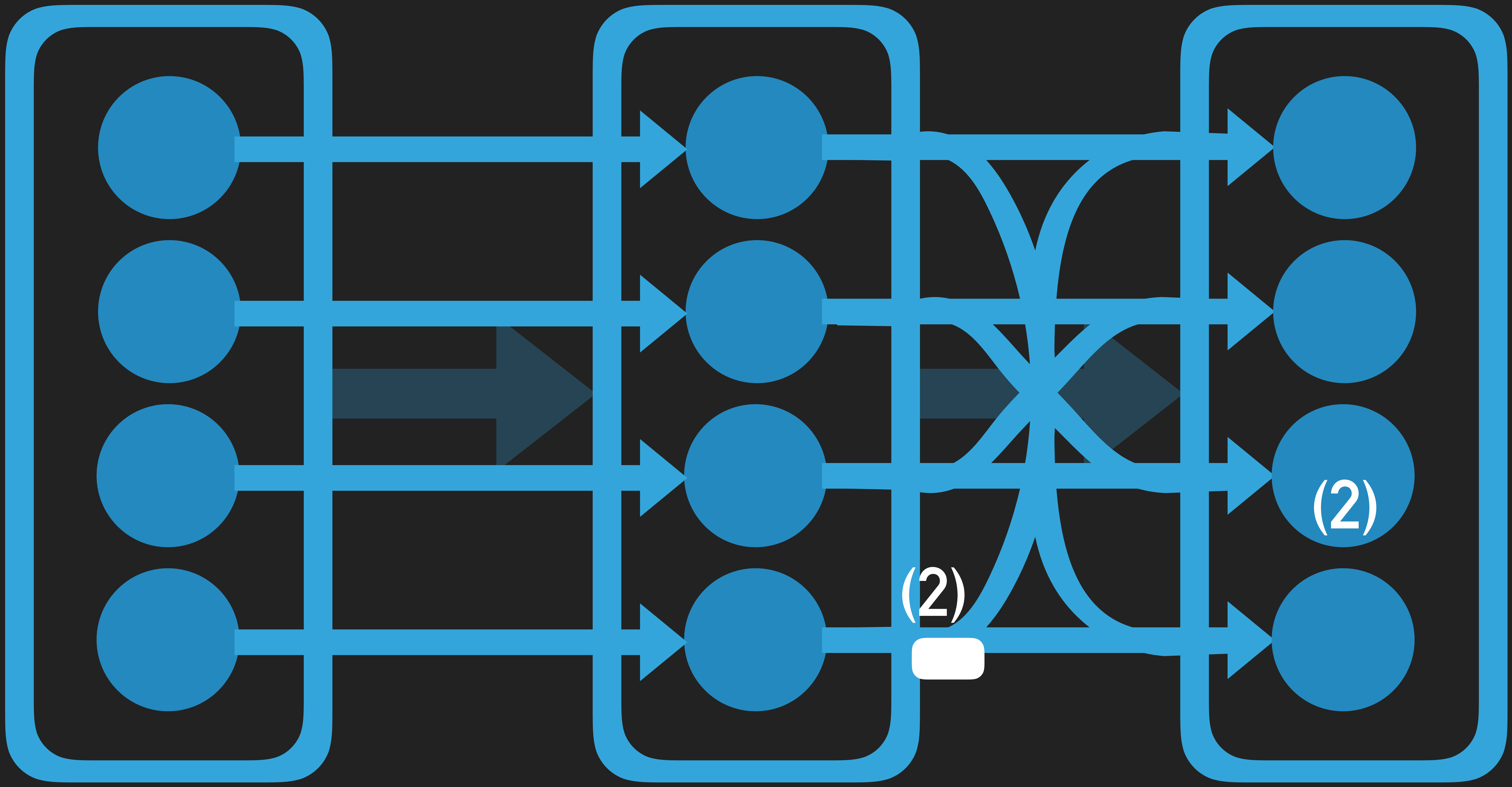
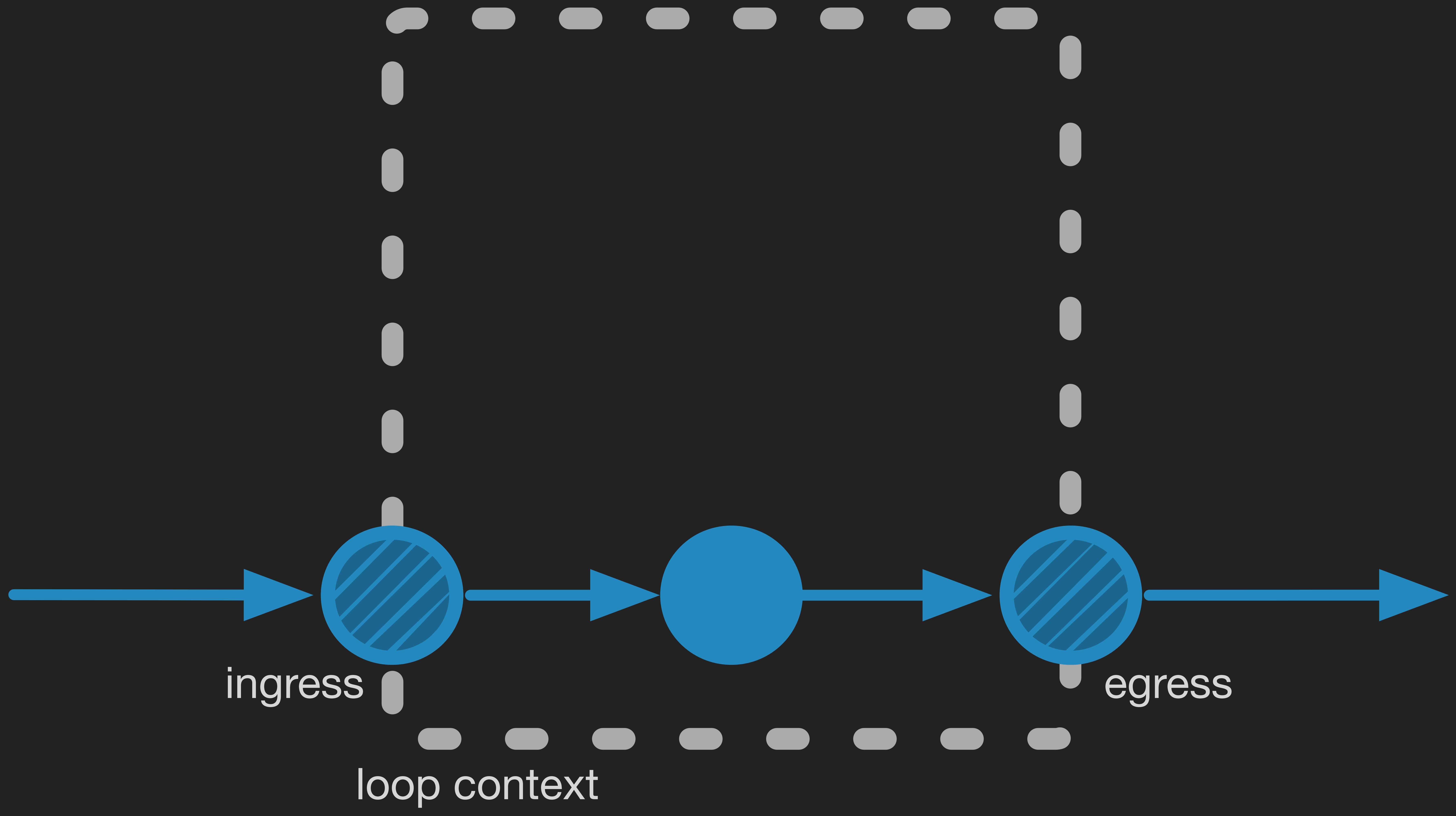


CYCLICAL DATAFLOW: LOOP CONTEXTS



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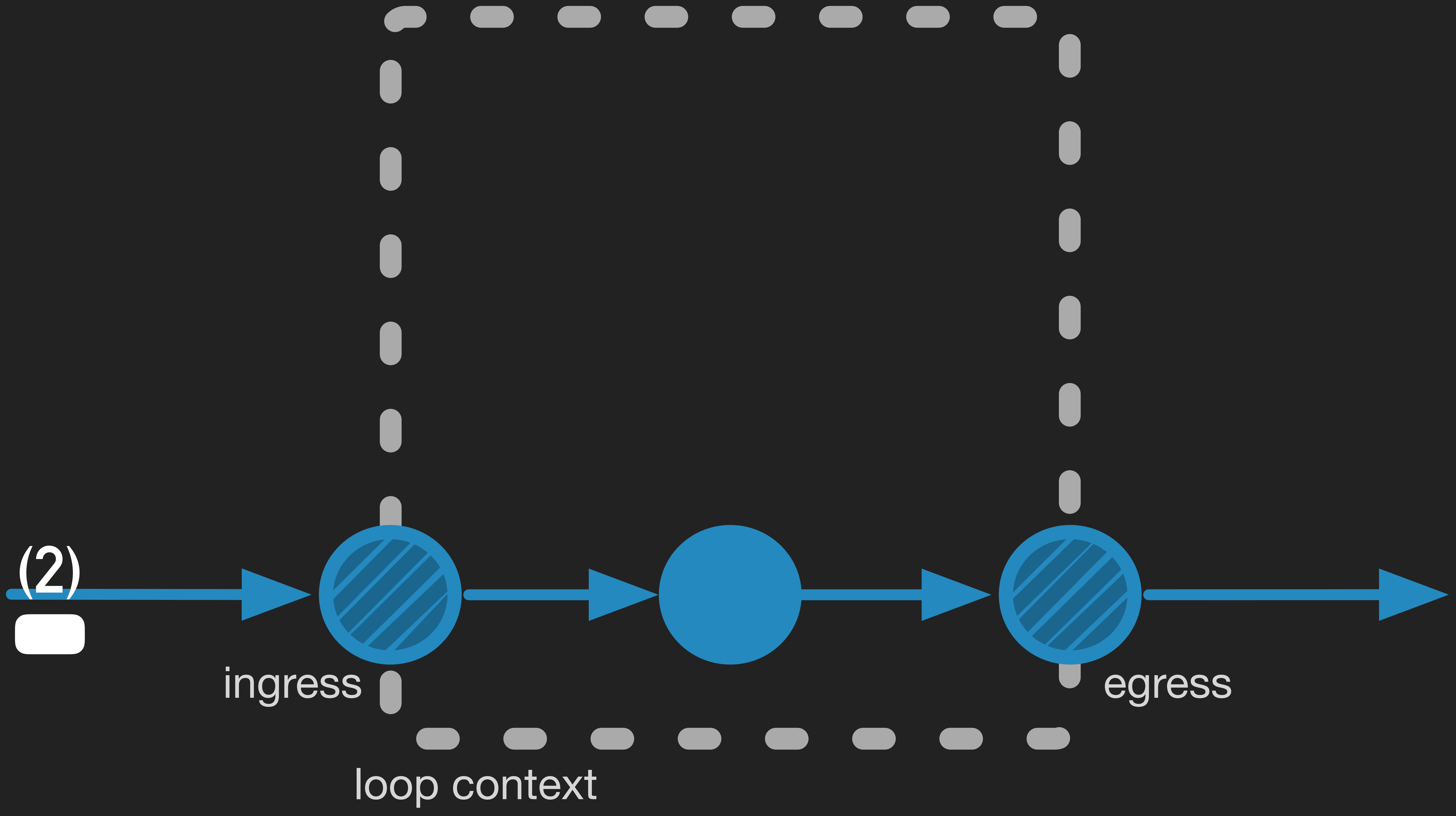

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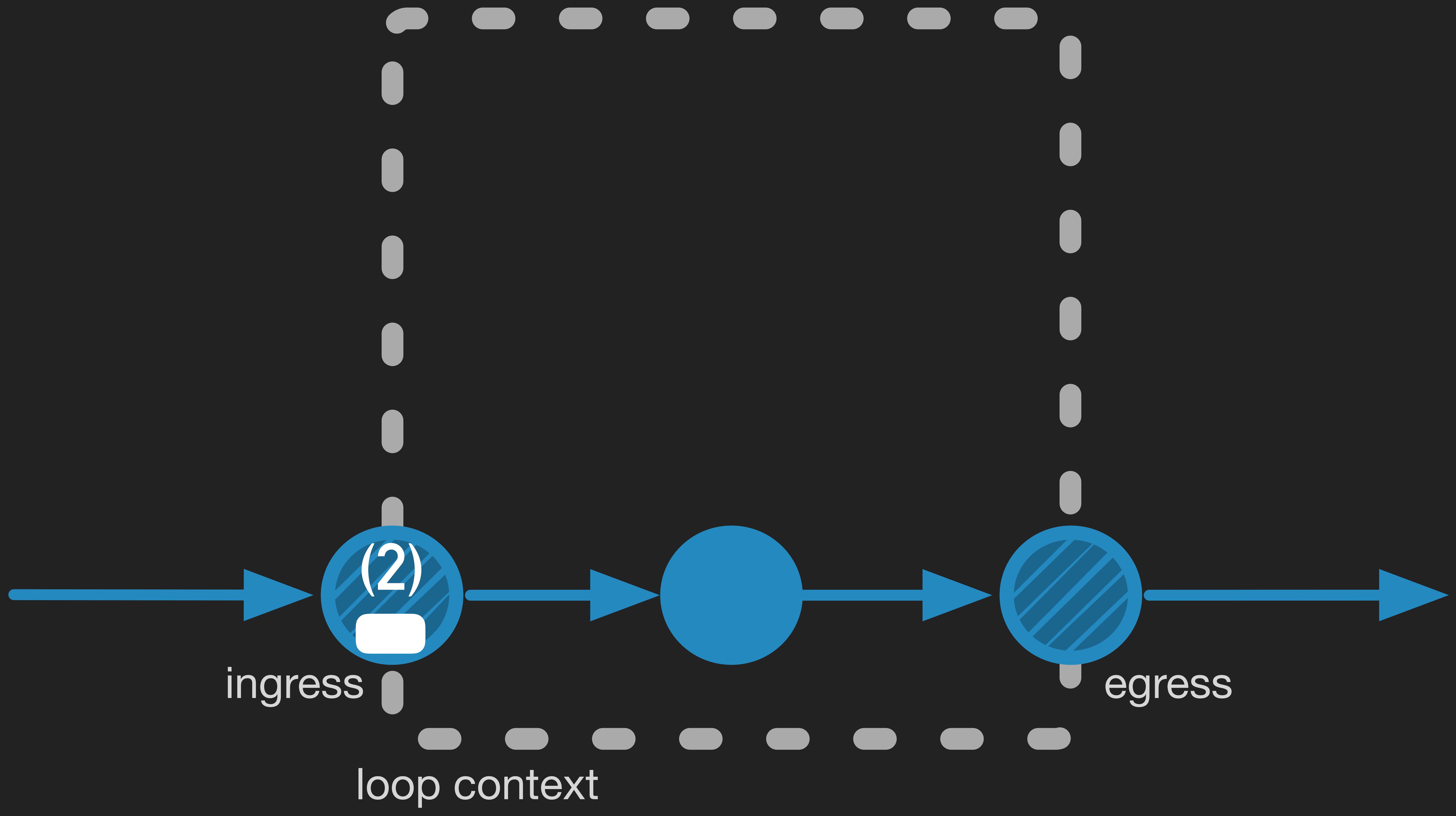

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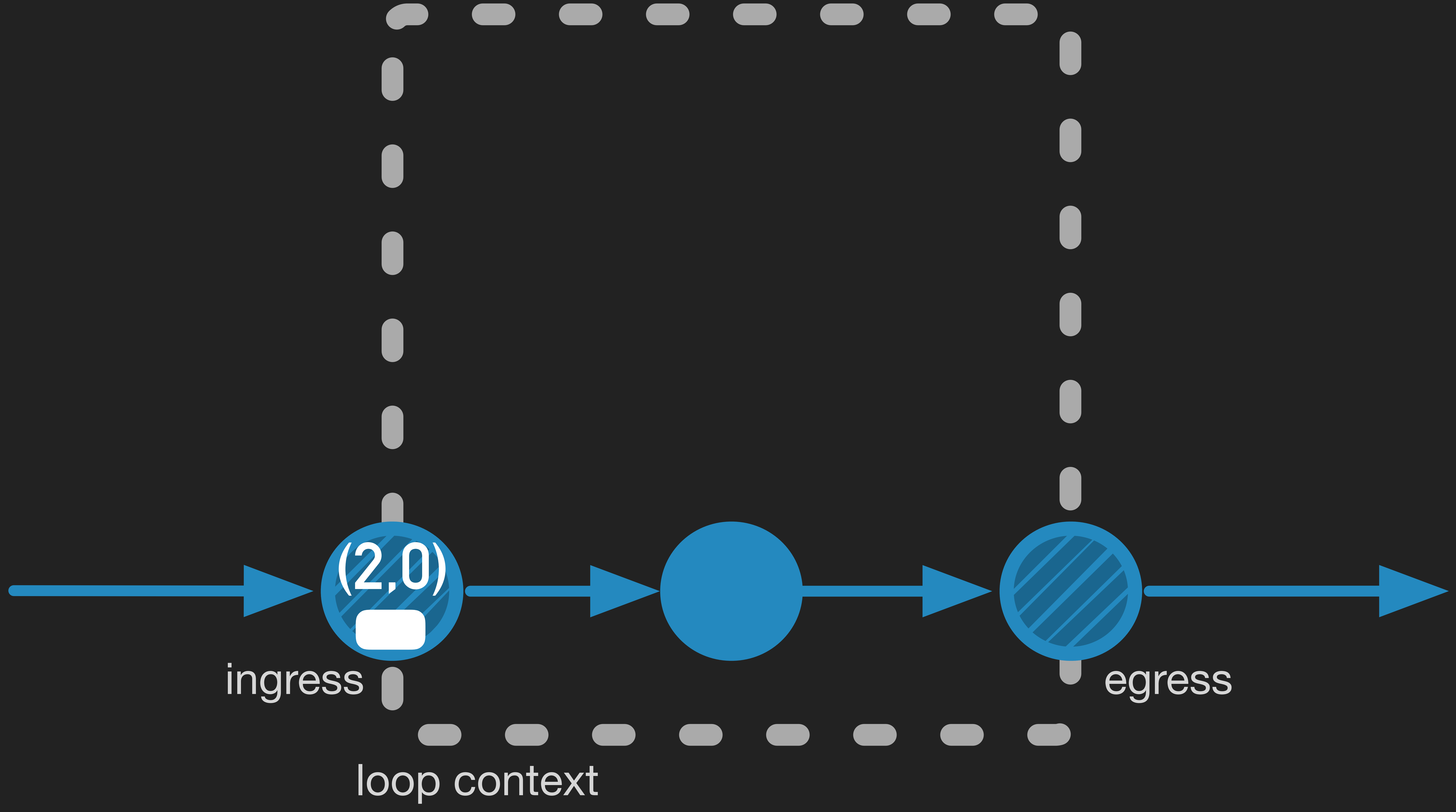

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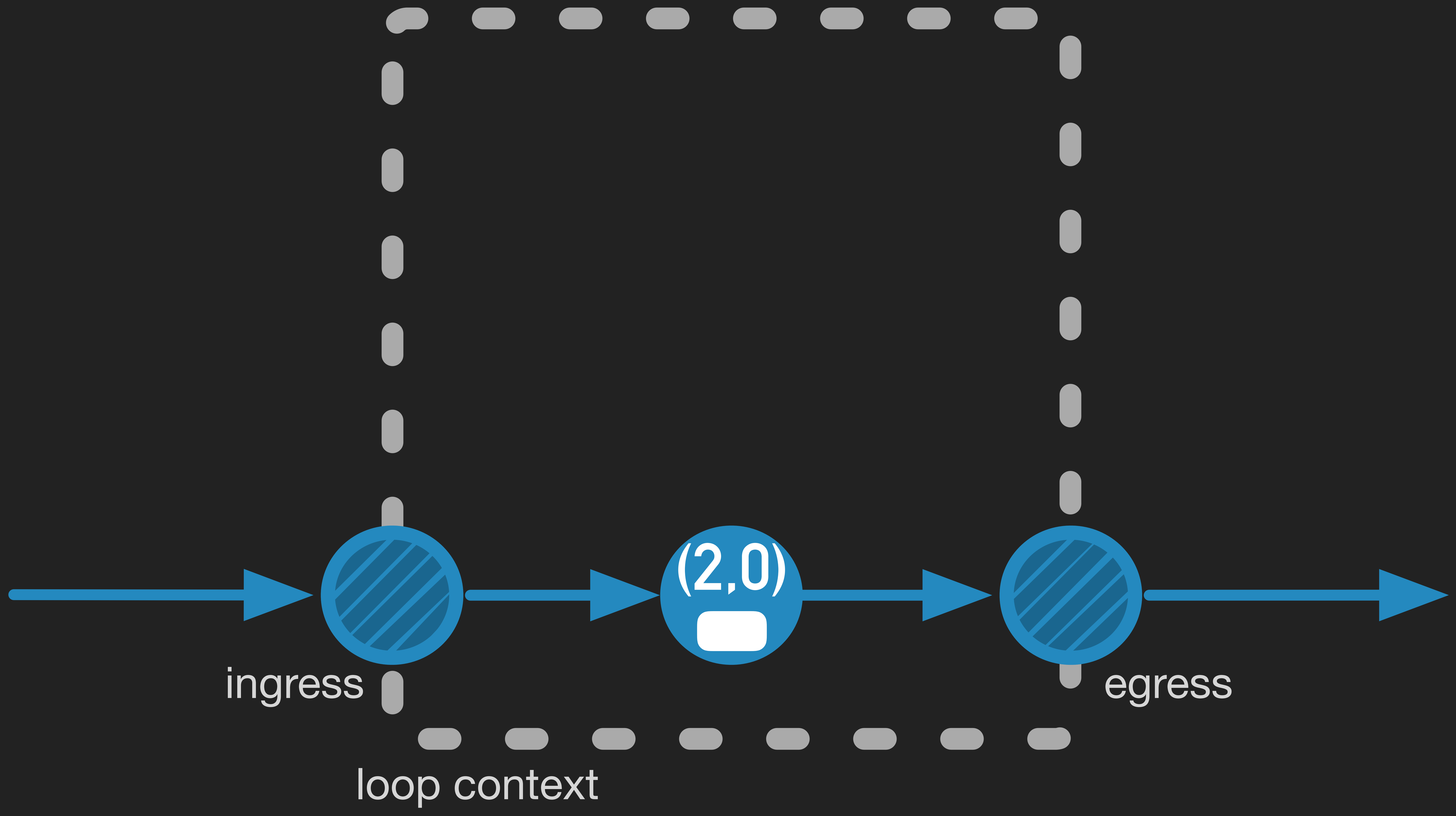

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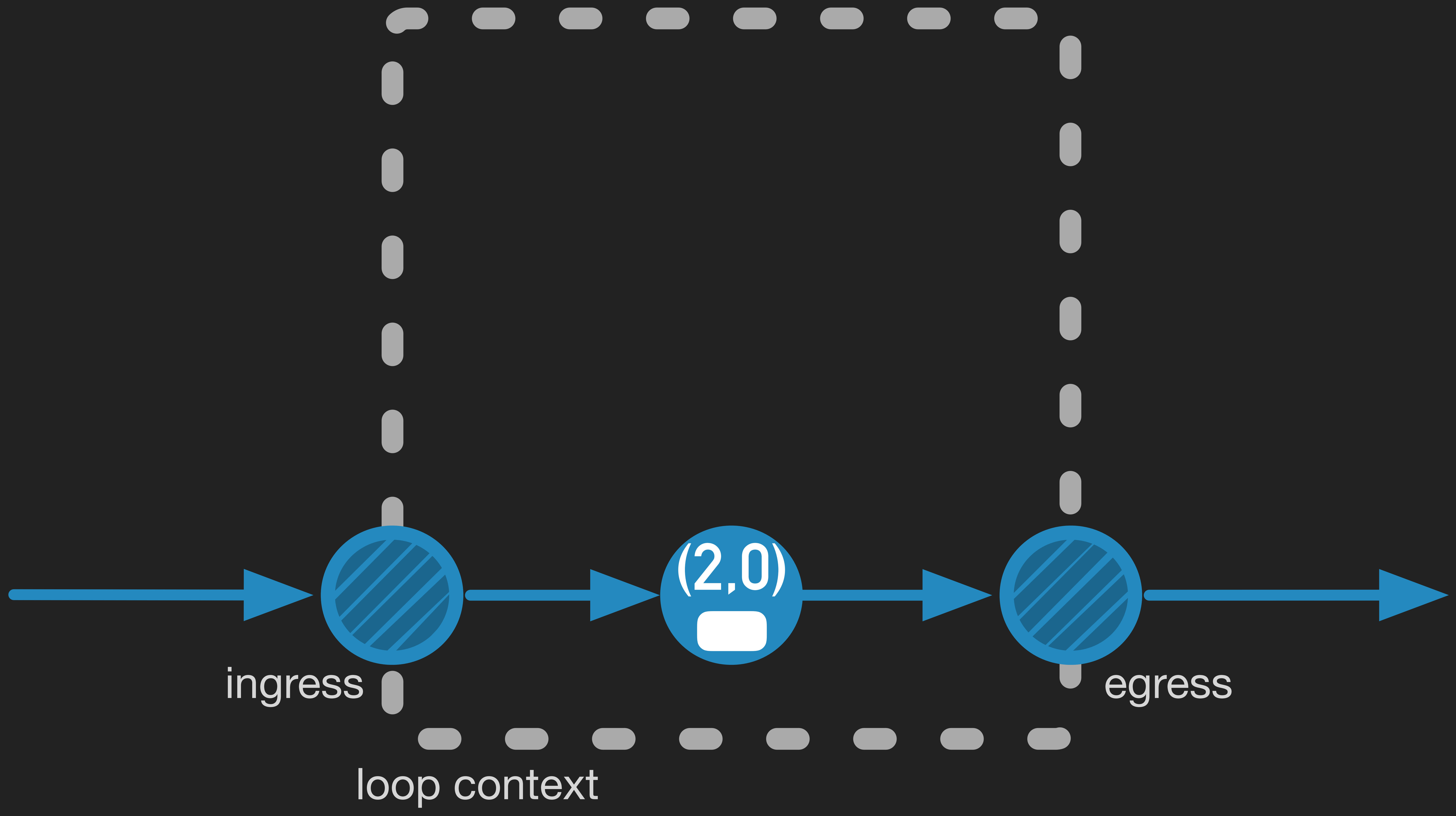

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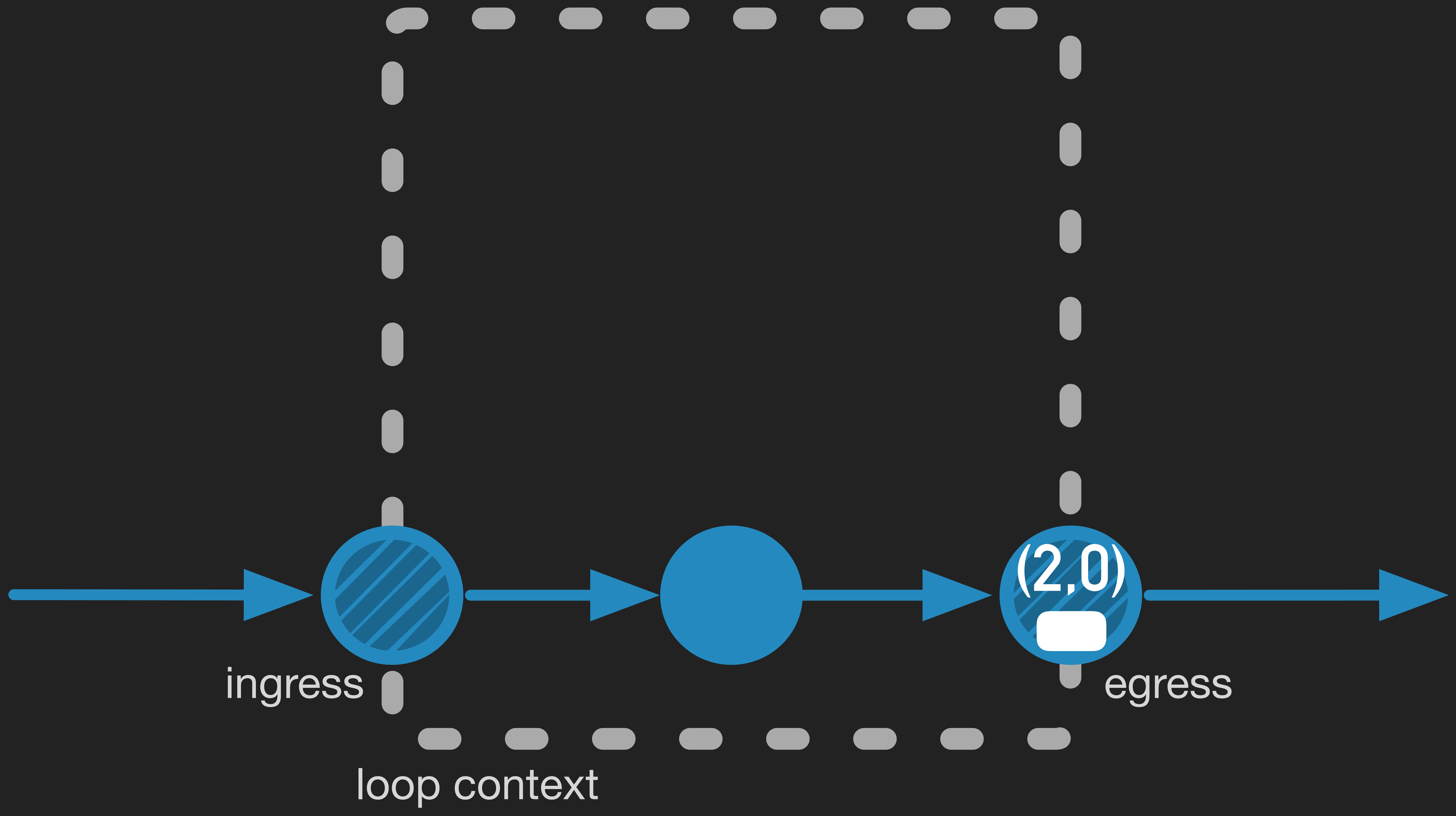

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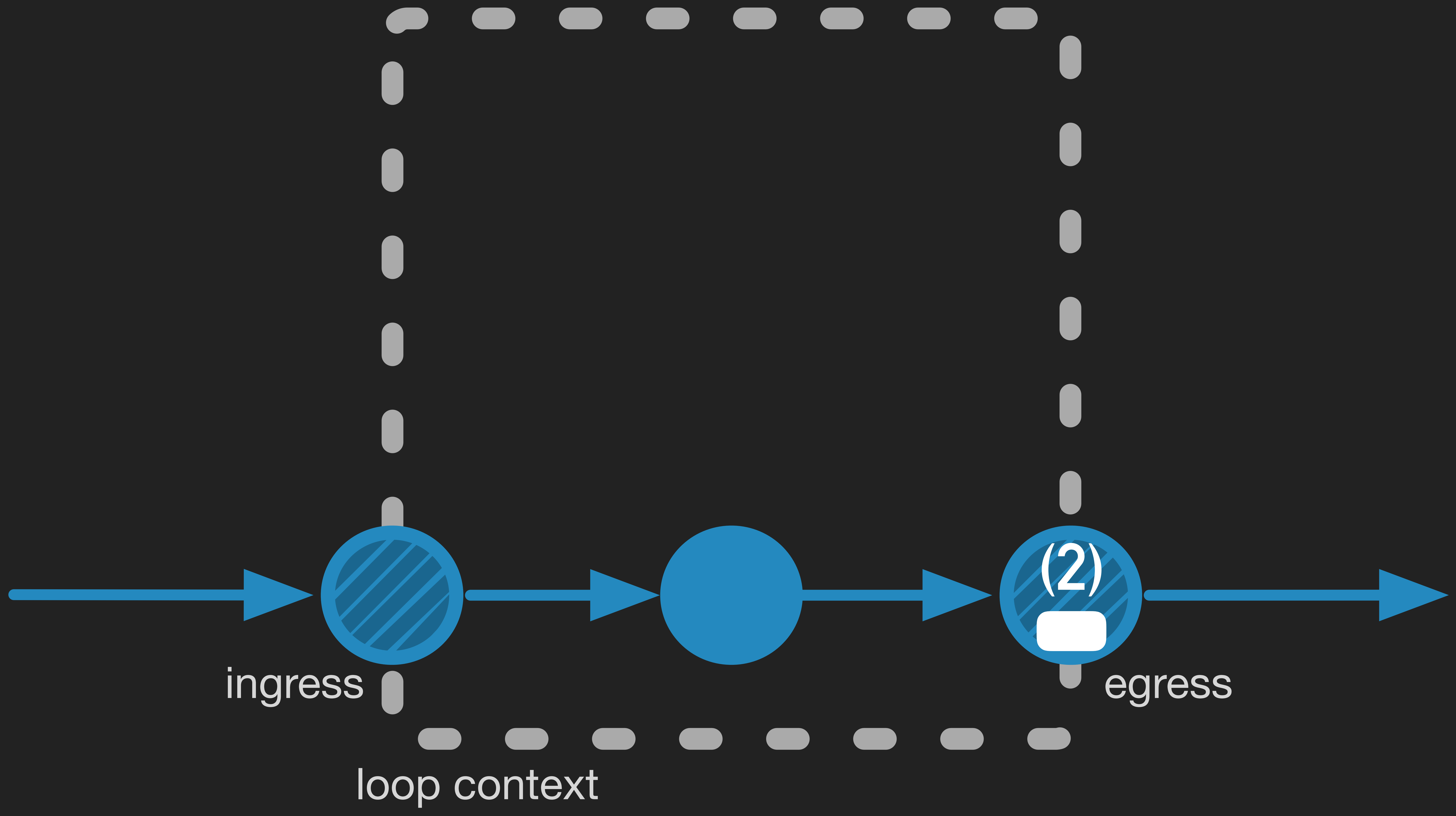

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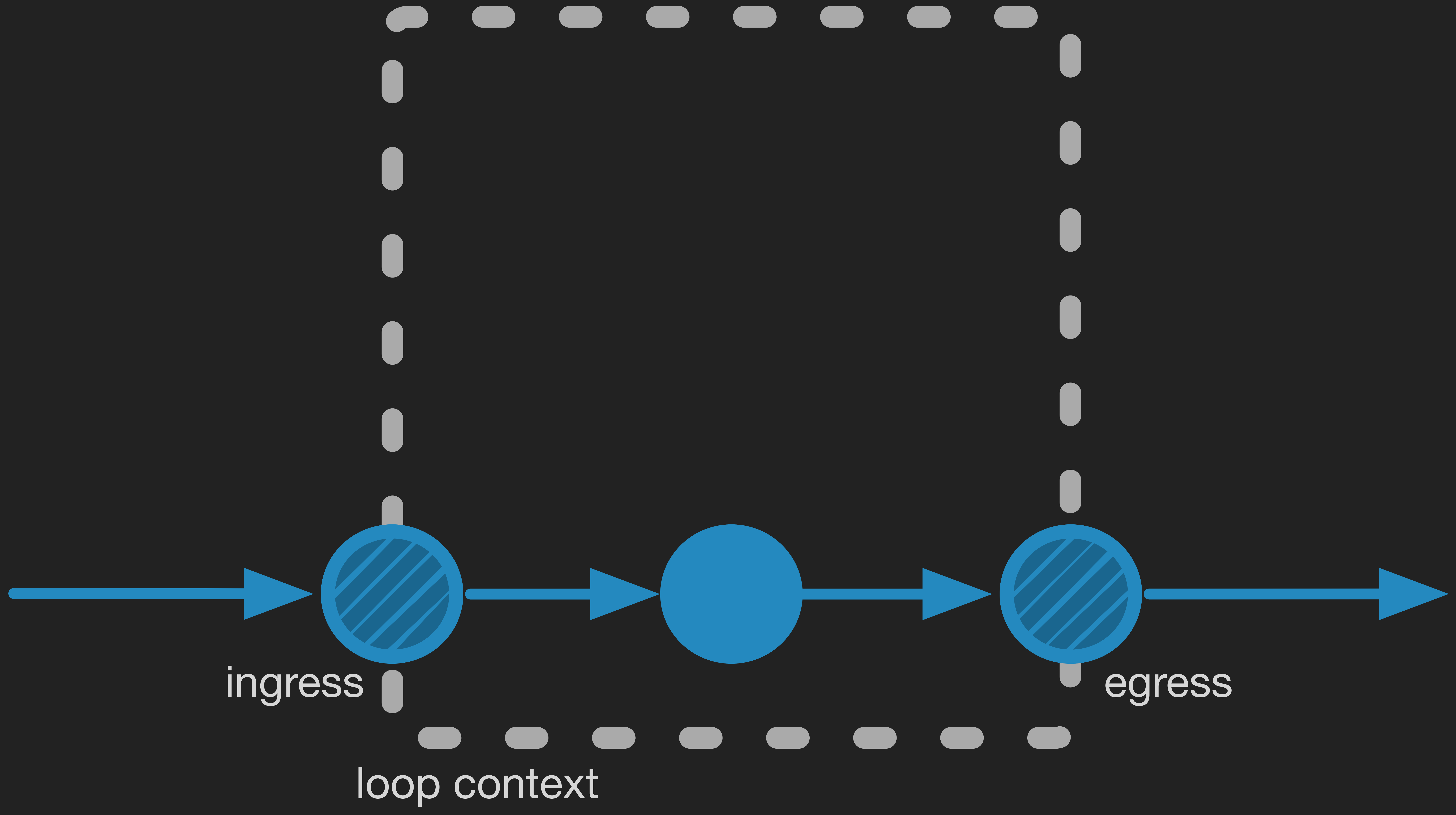

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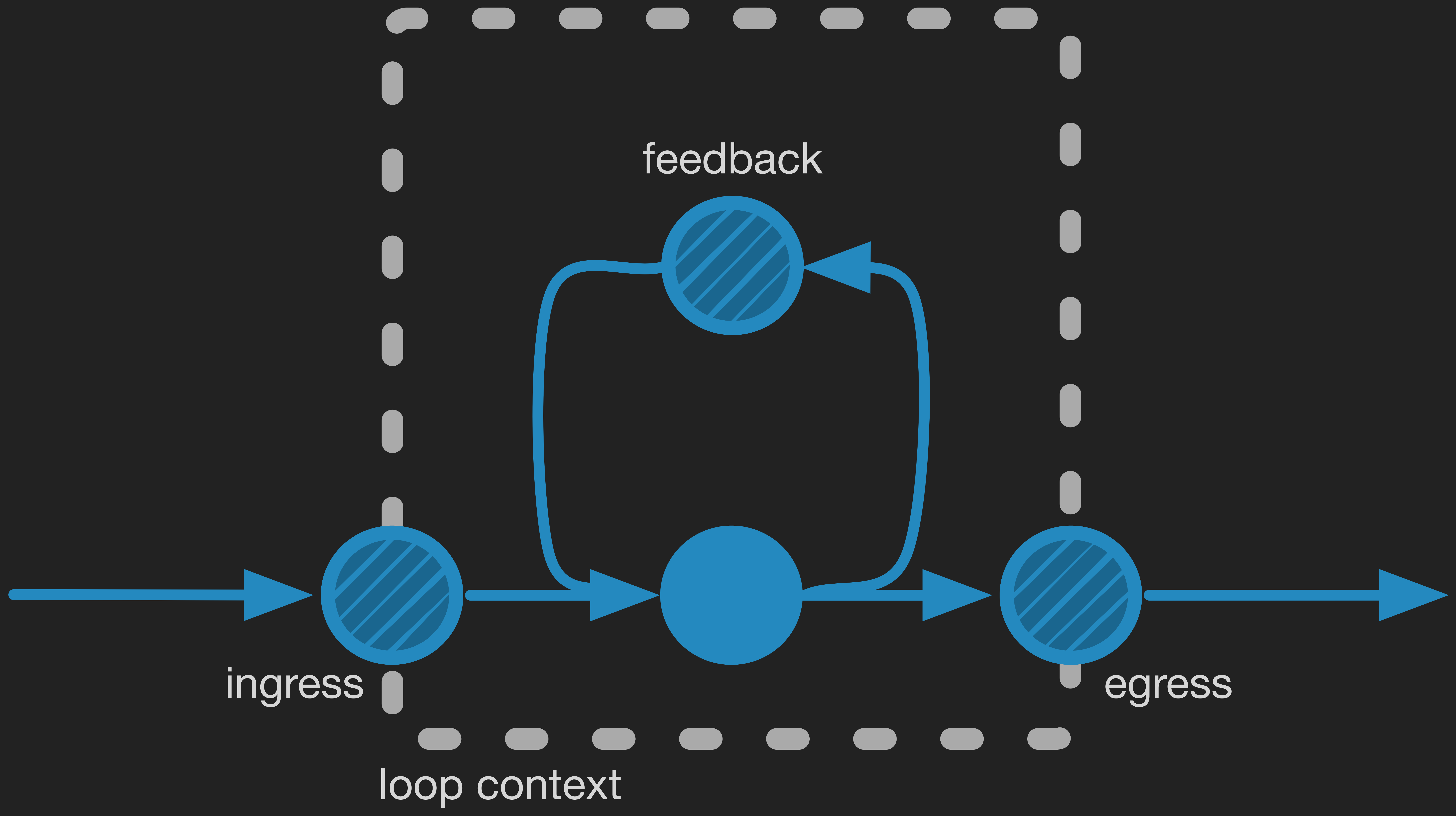

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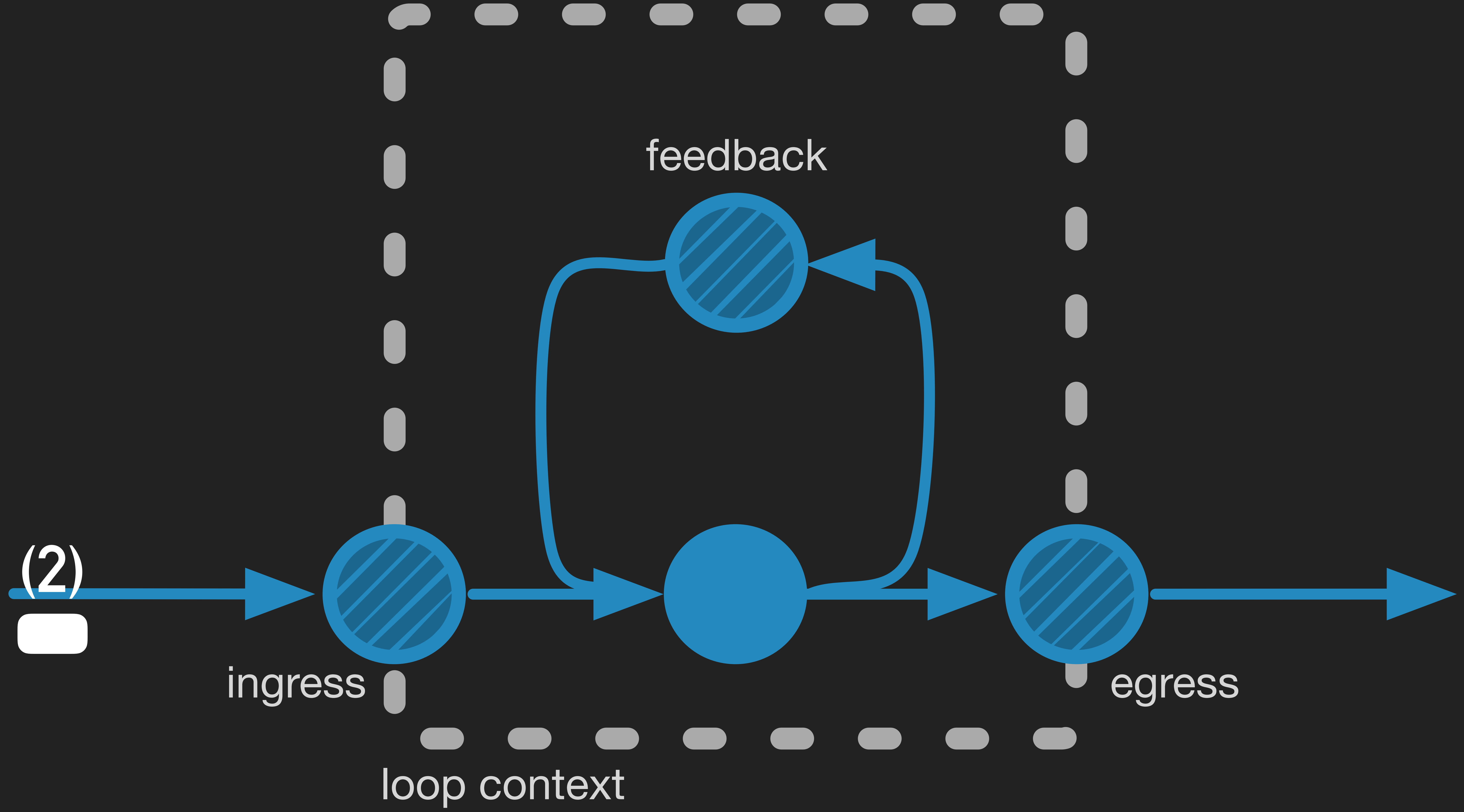

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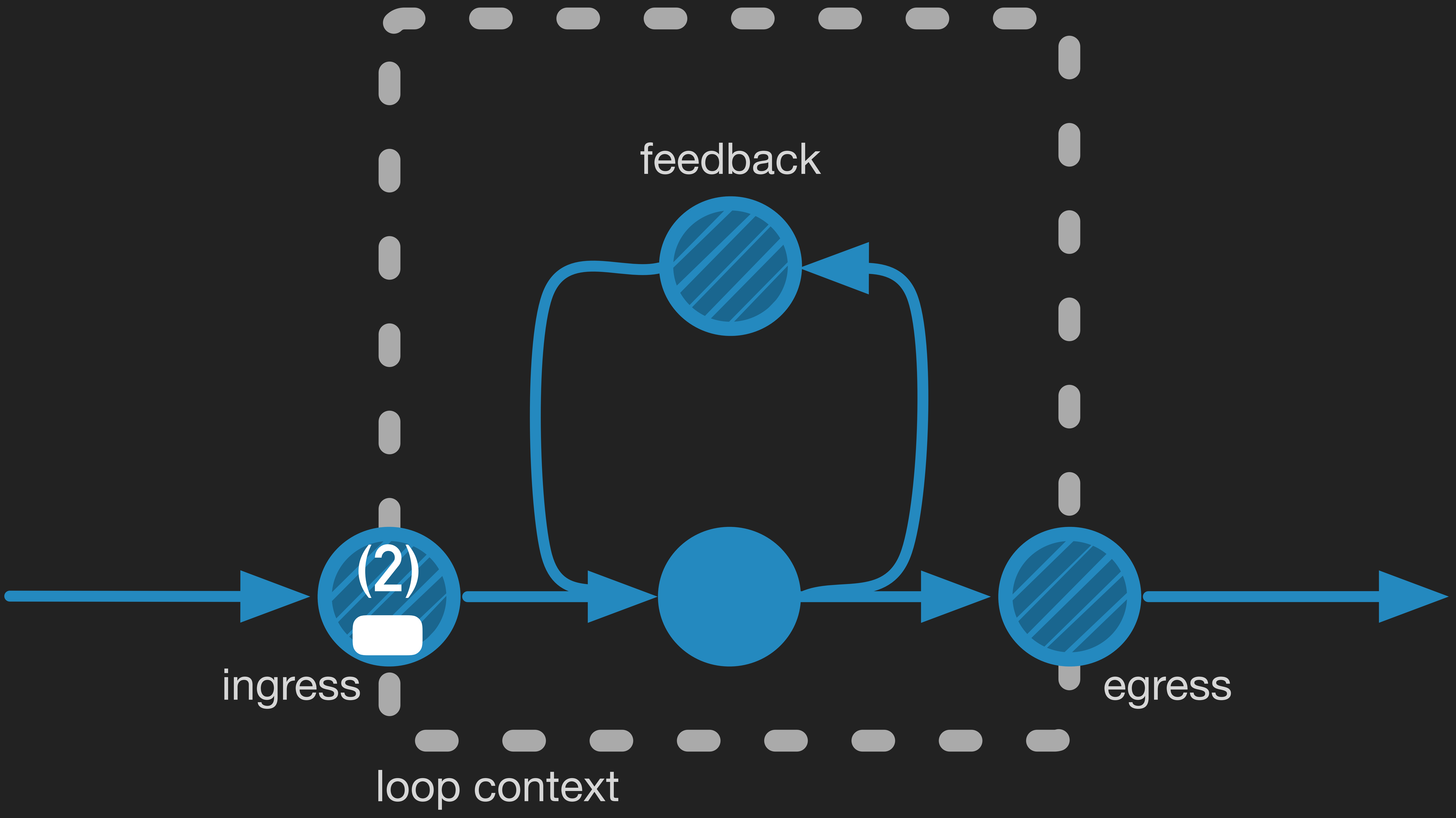

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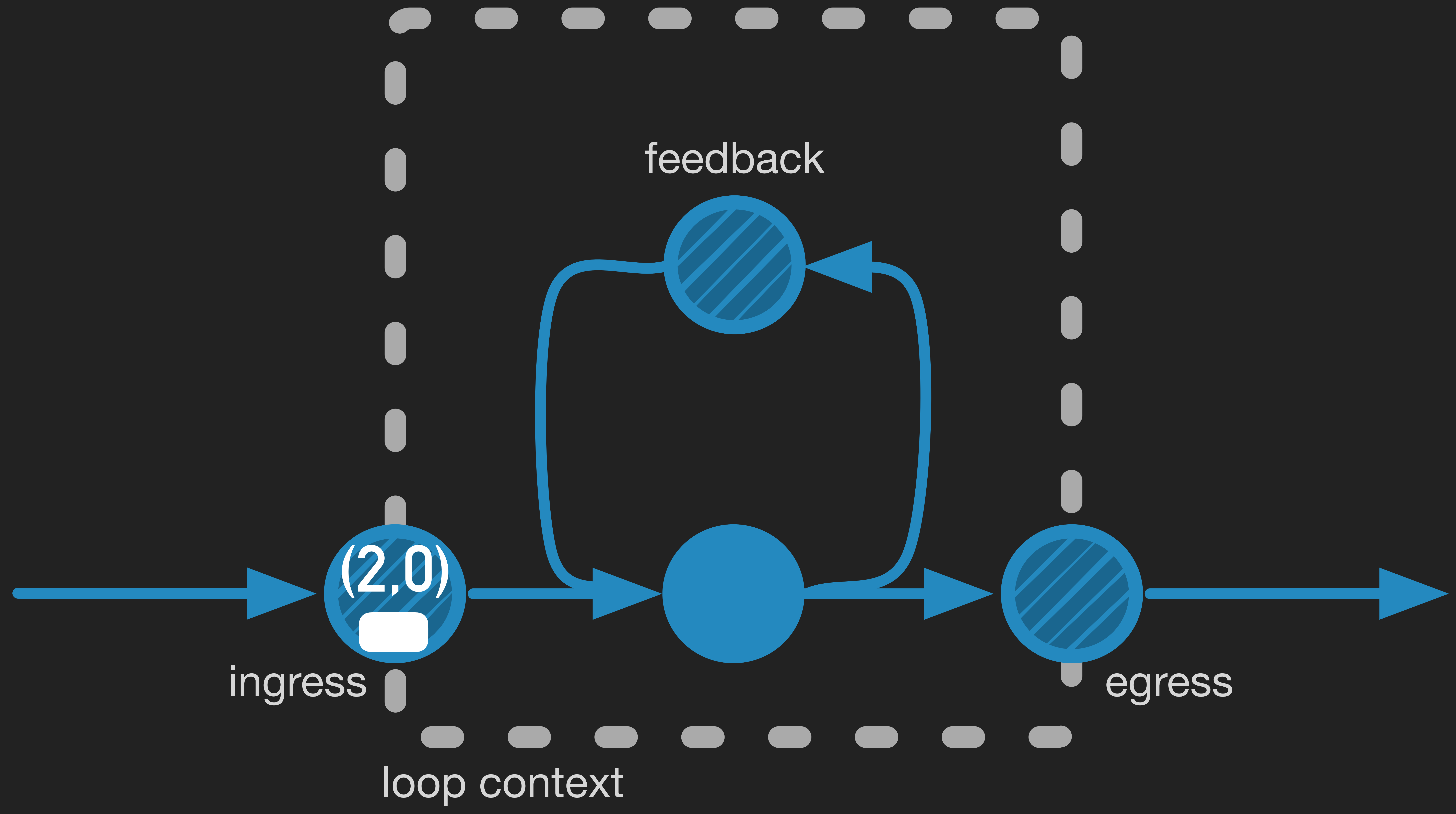

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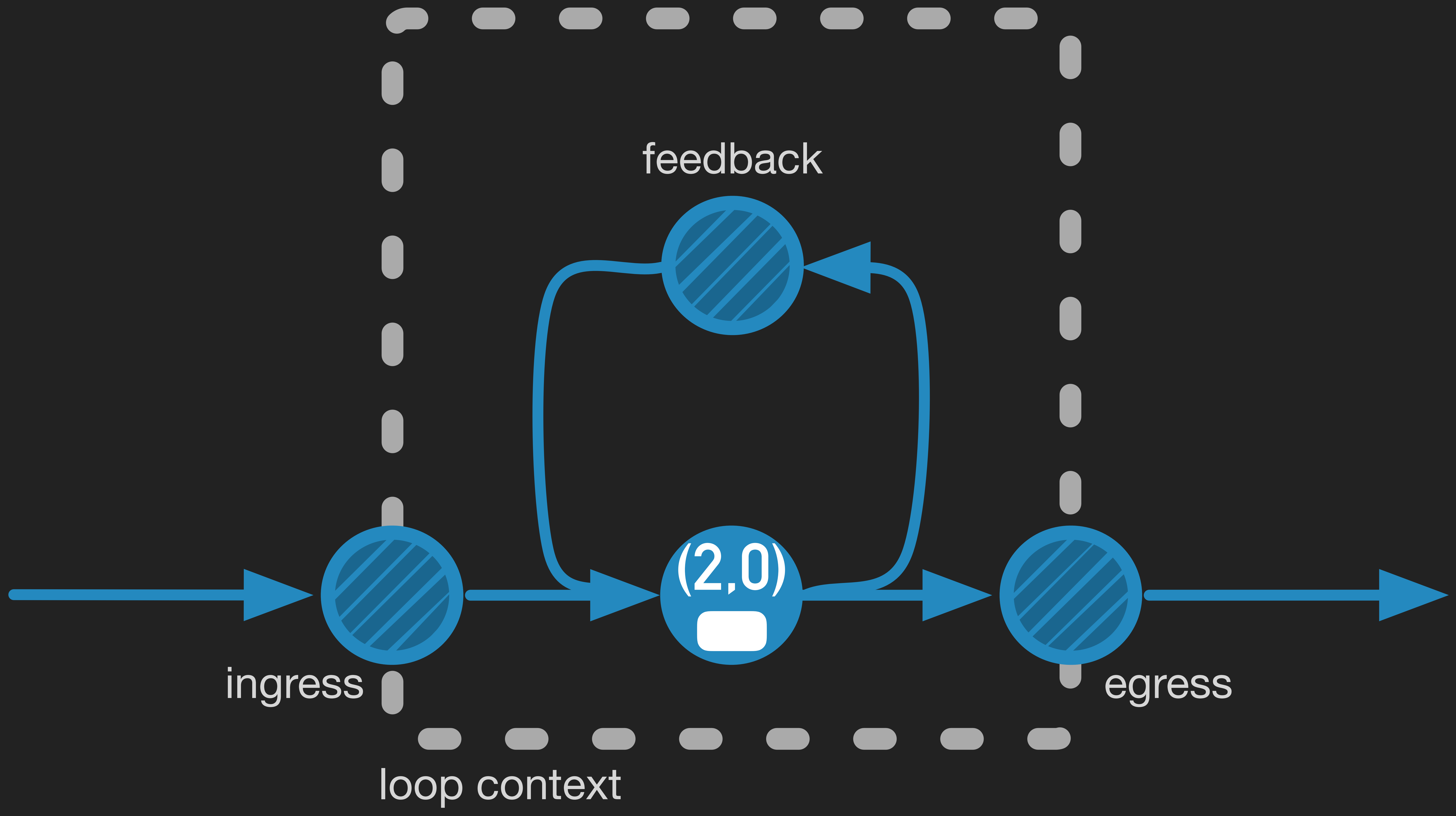

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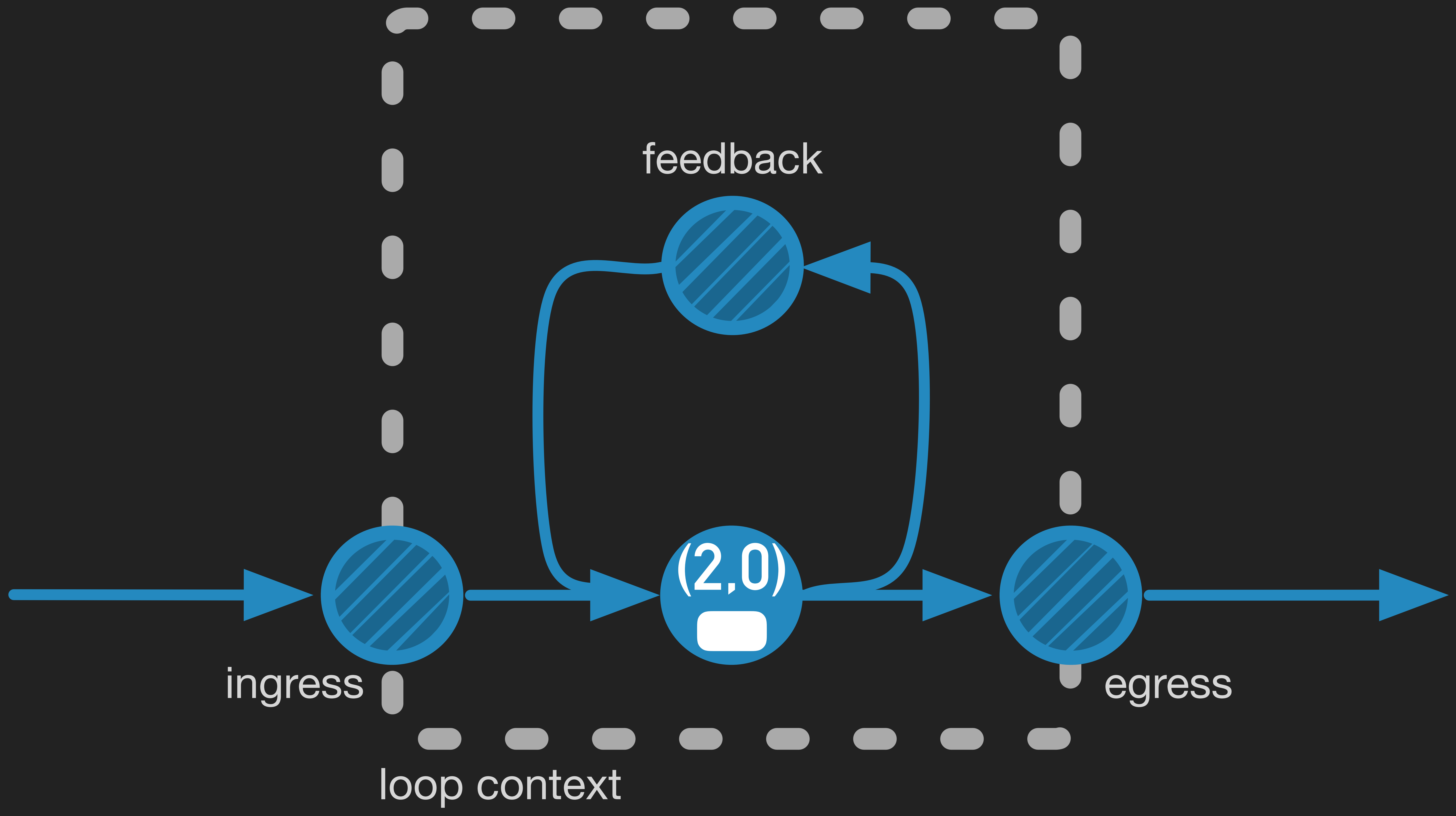

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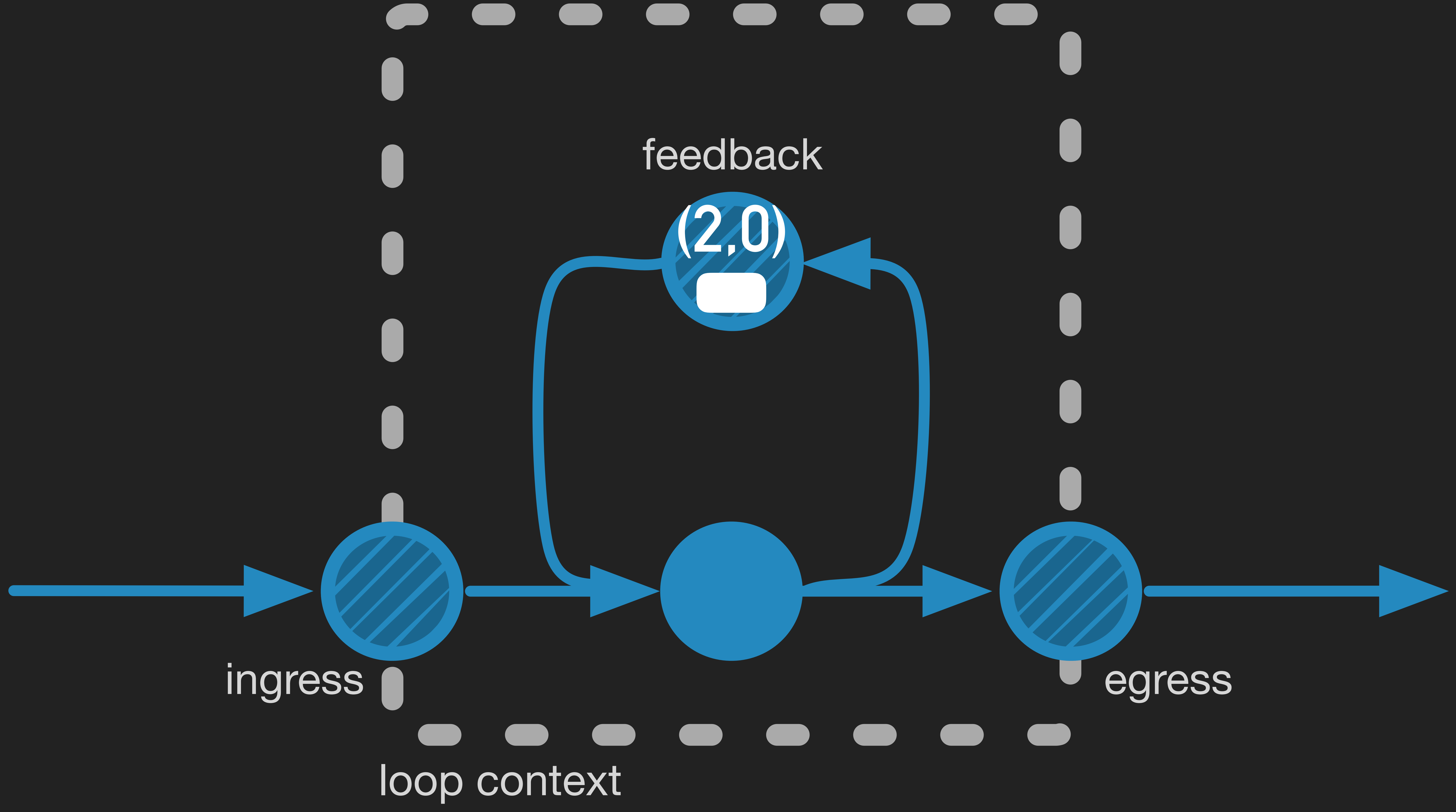

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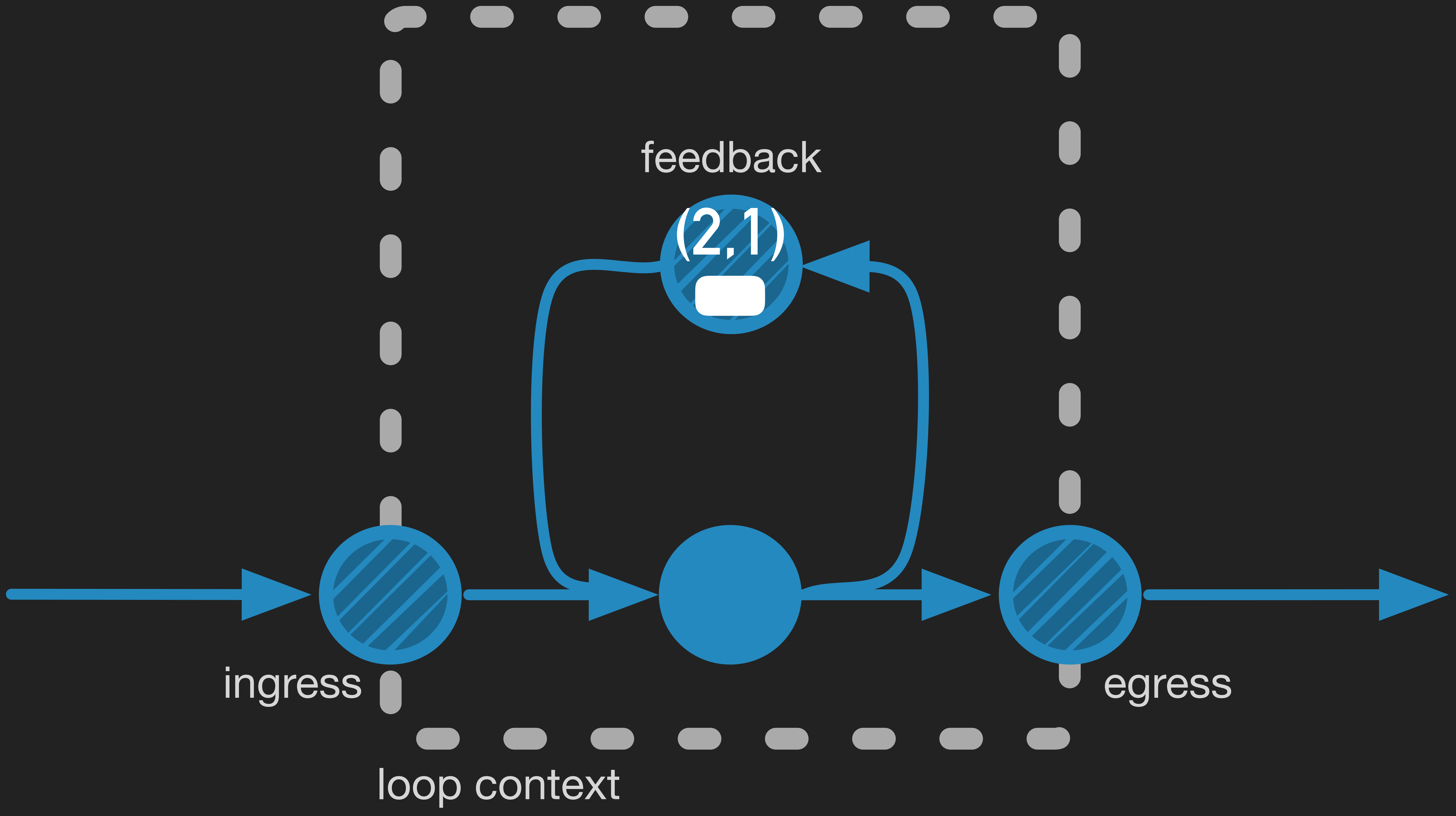

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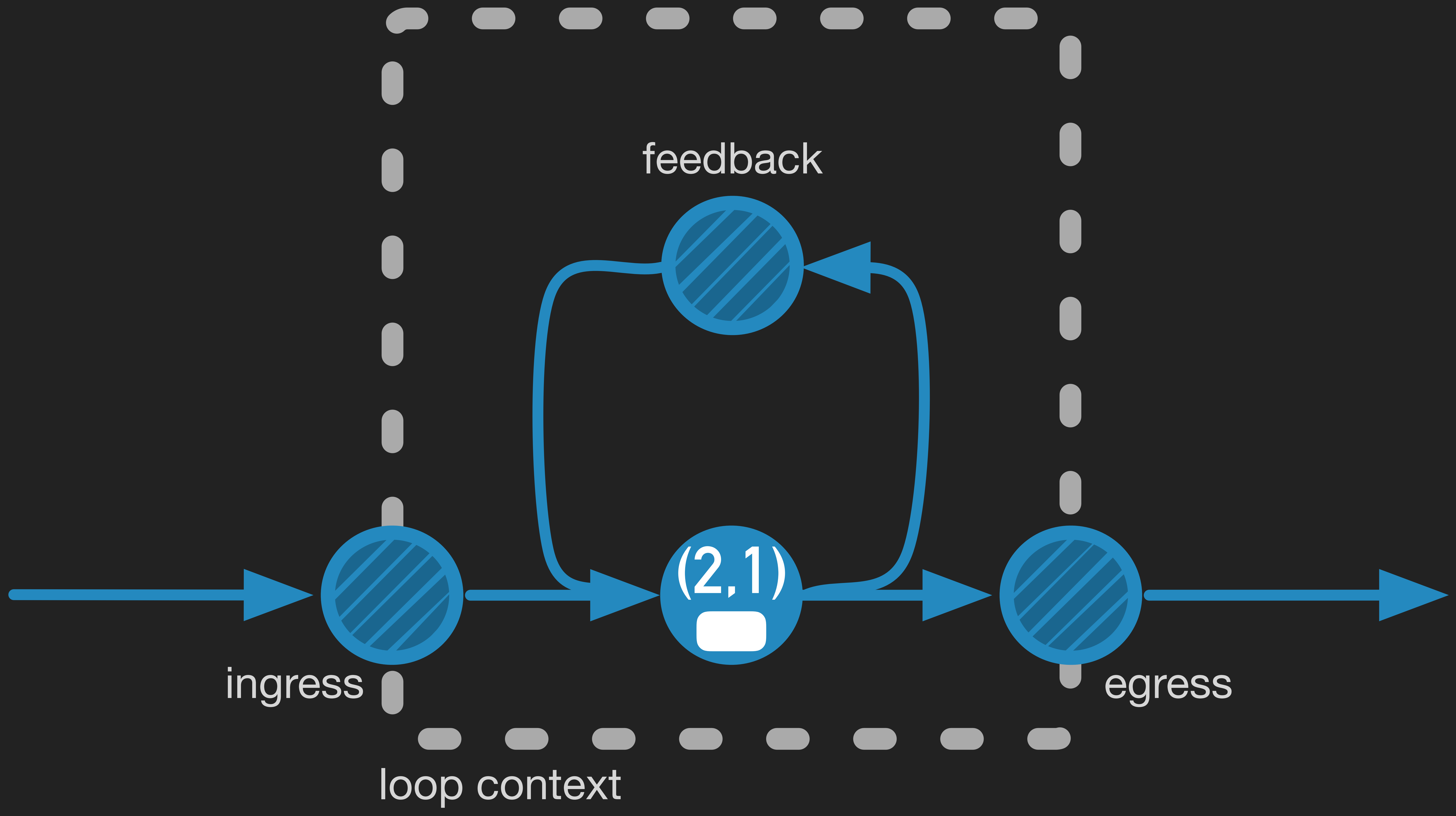

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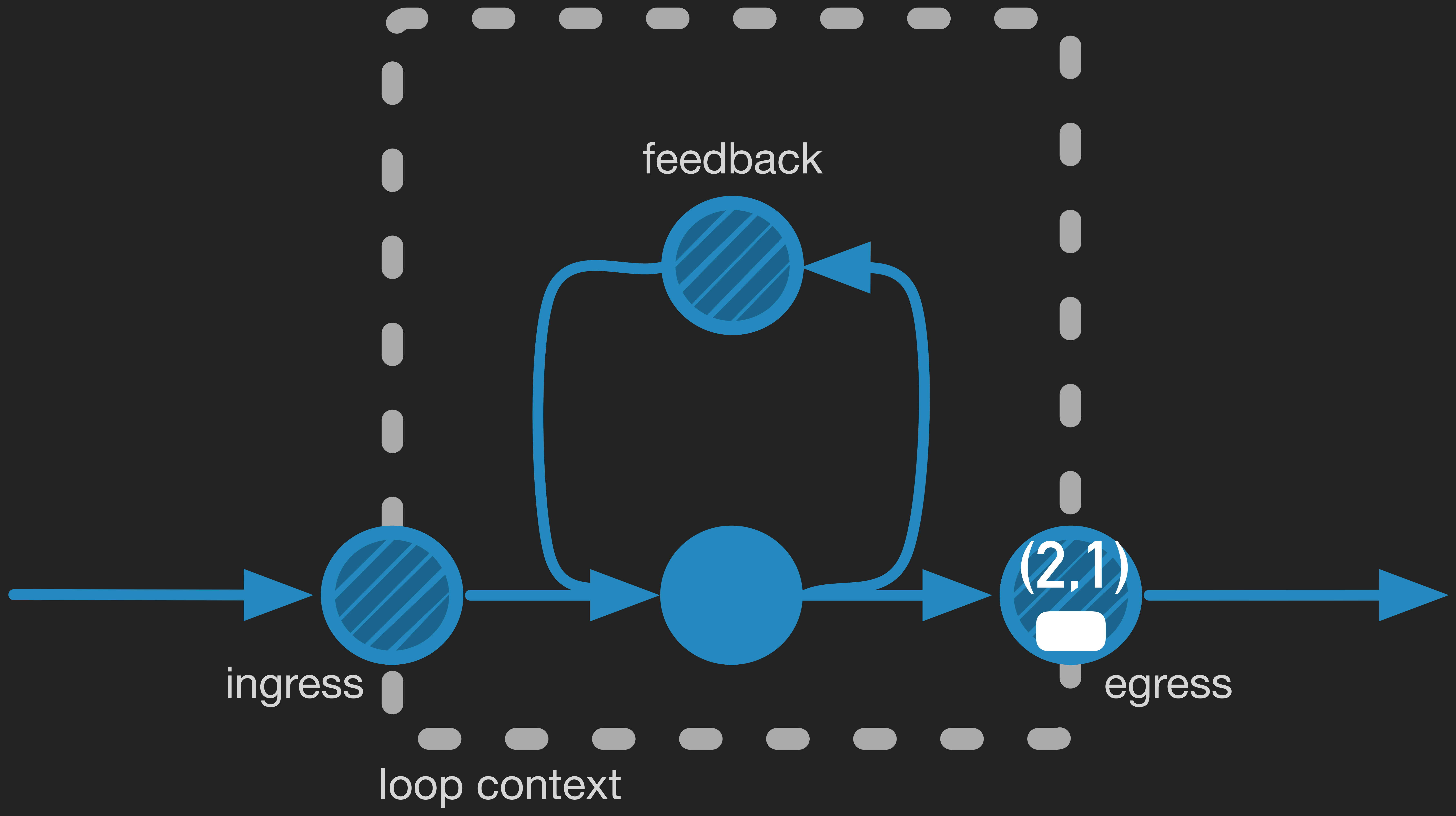

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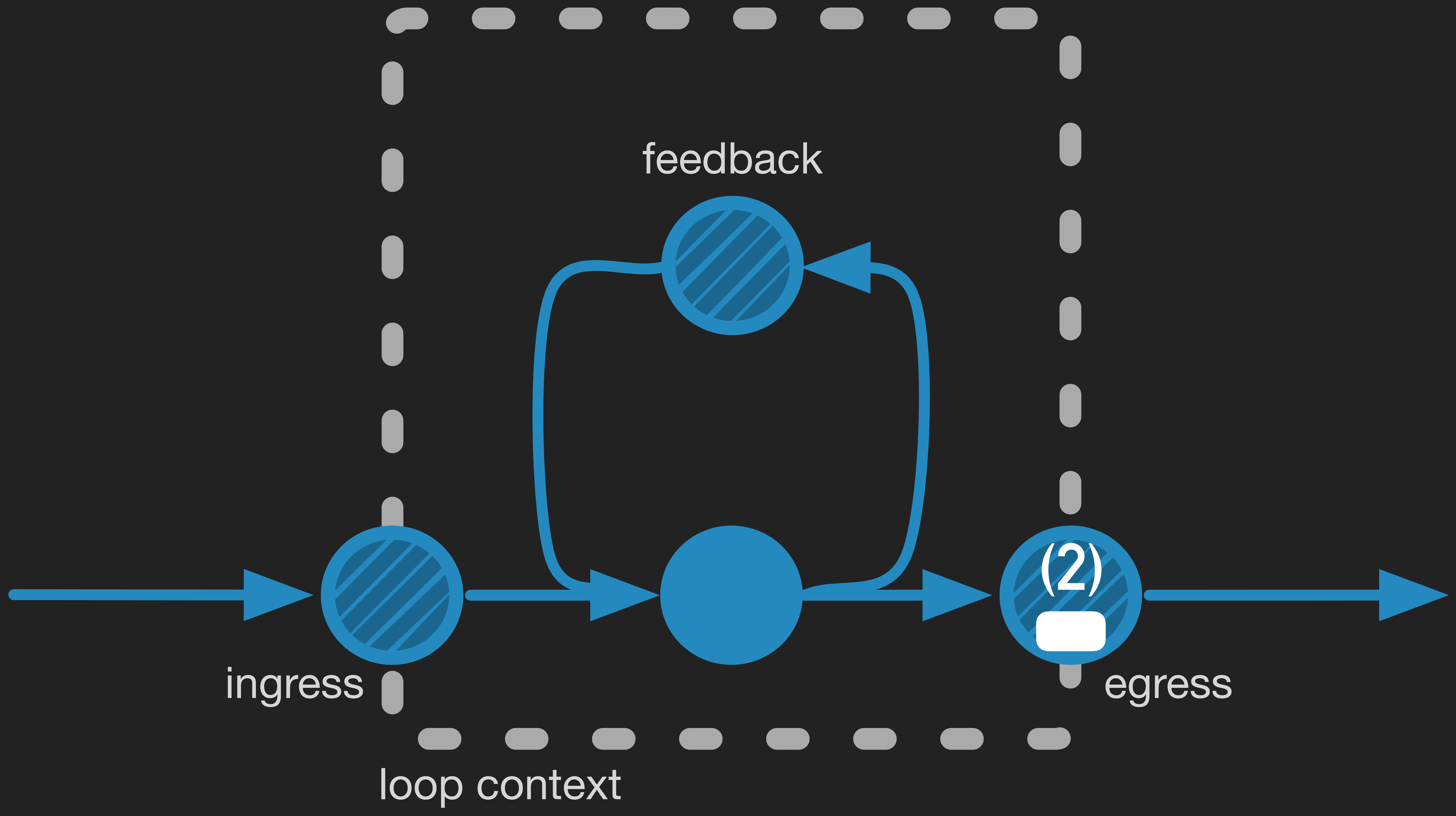

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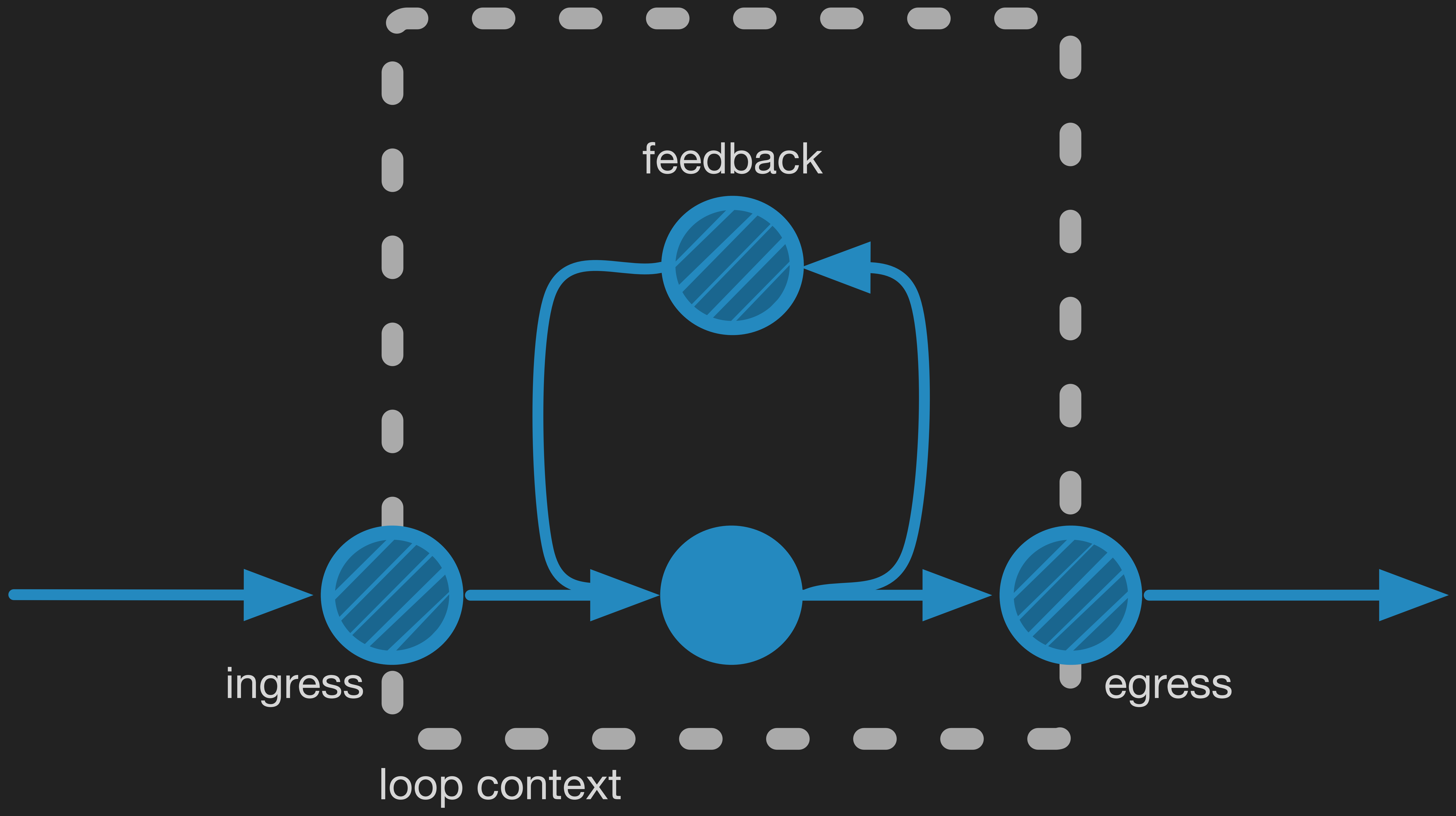

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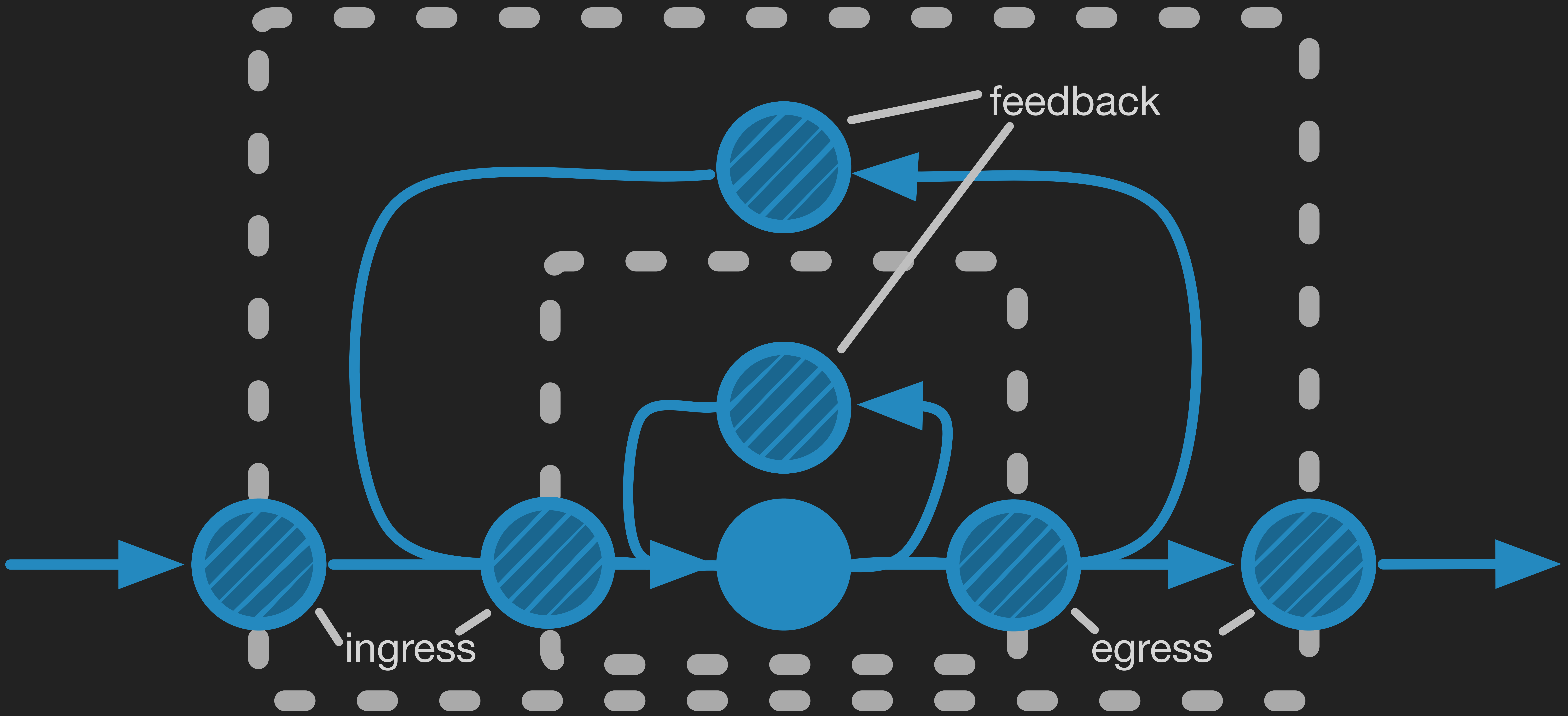

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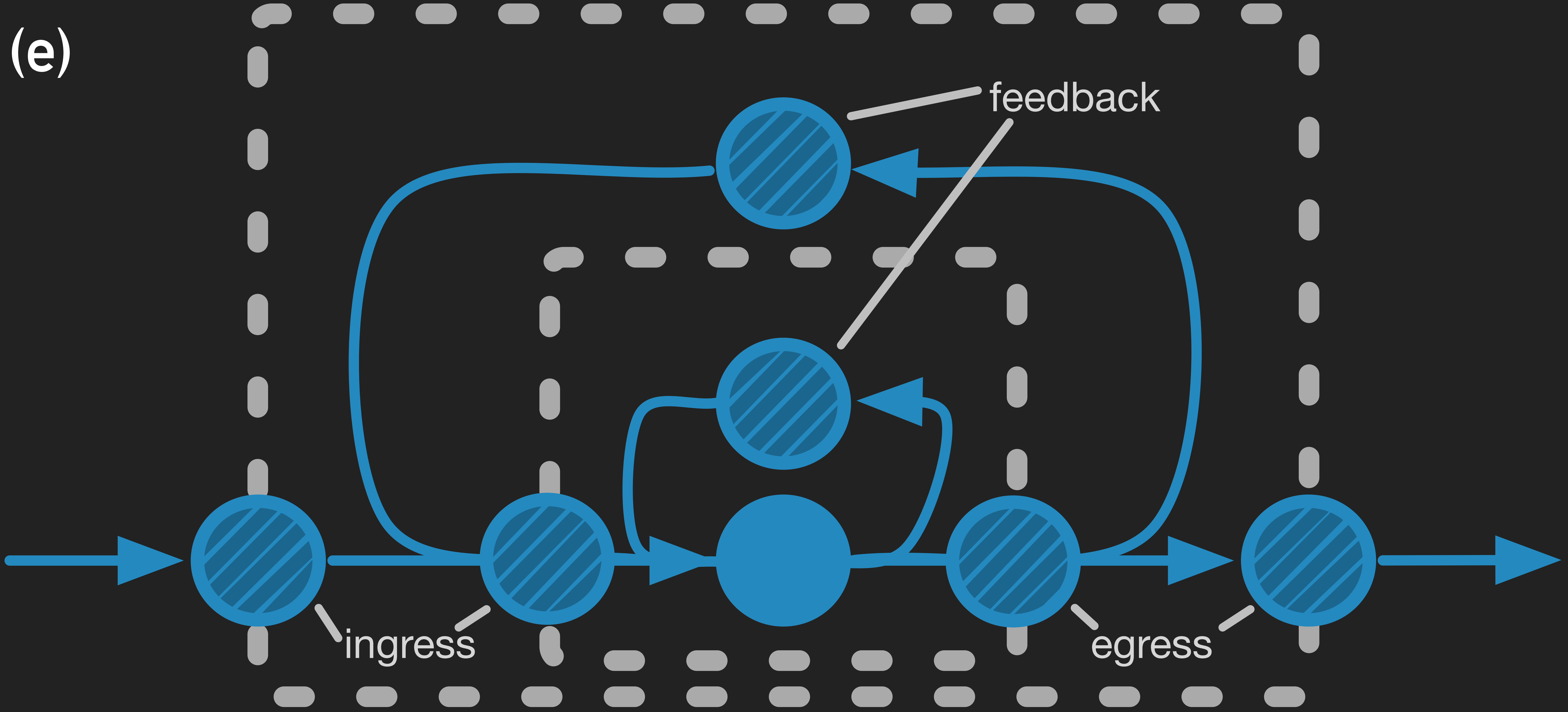

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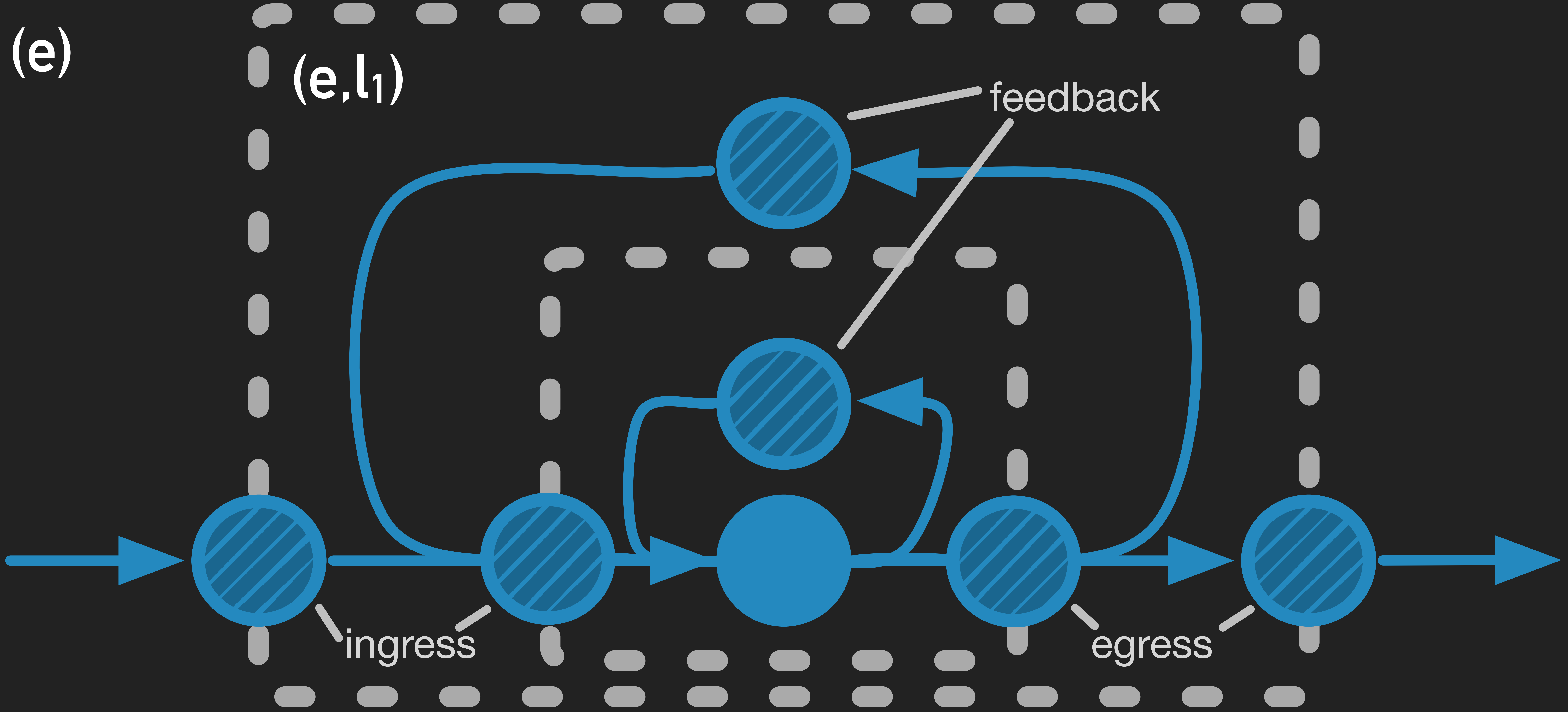
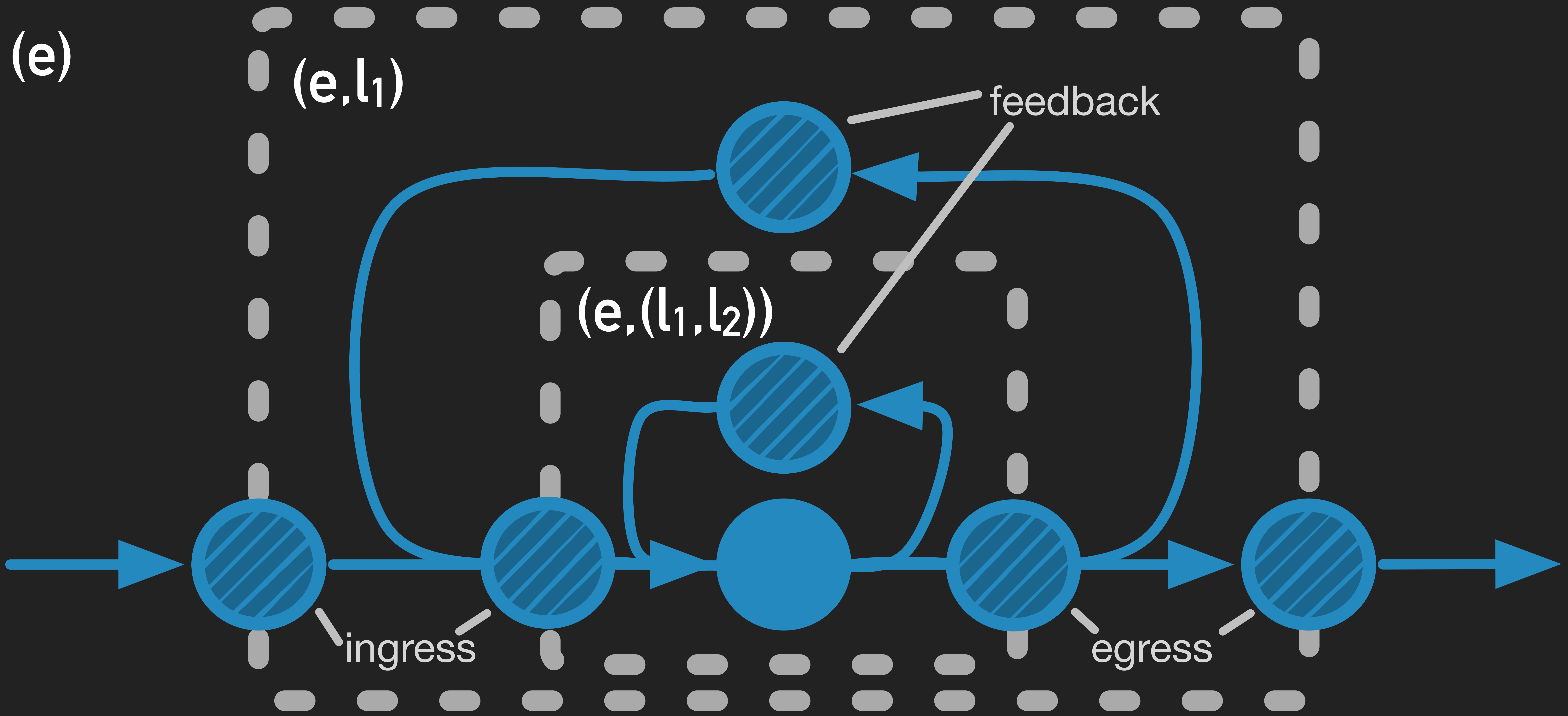
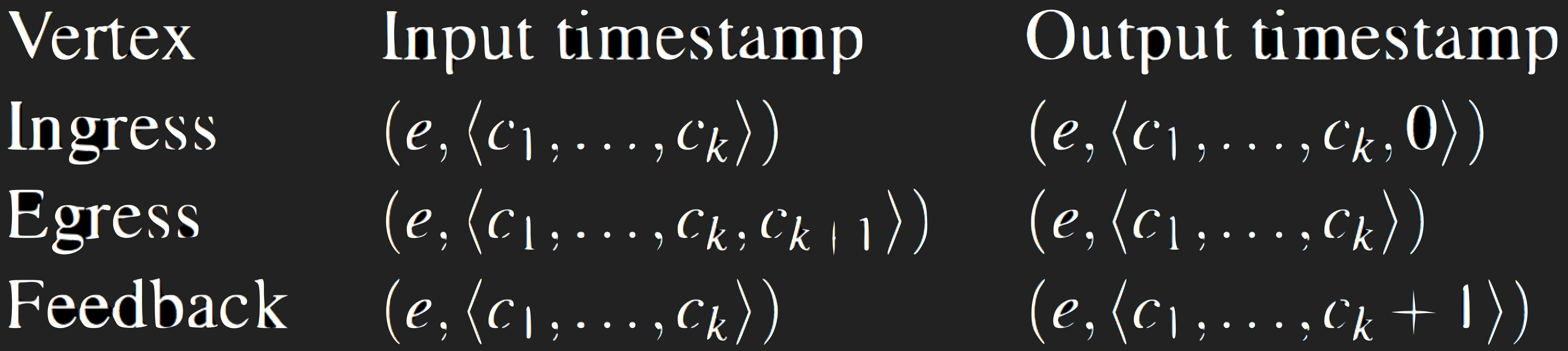


CYCLICAL DATAFLOW: LOOP CONTEXTS



CYCLICAL DATAFLOW: TIMESTAMPS IN LOOP CONTEXTS

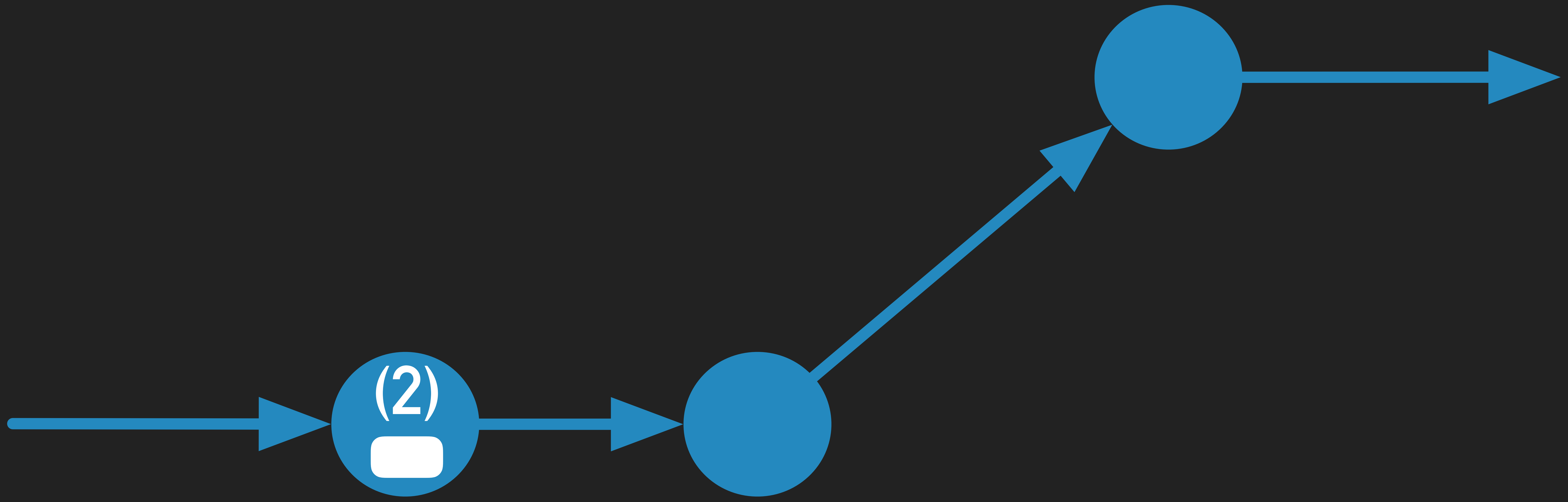


Vertex	Input timestamp	Output timestamp
Ingress	$(e, \langle c_1, \ldots, c_k \rangle)$	$(e, \langle c_1, \ldots, c_k, 0 \rangle)$
Egress	$(e, \langle c_1, \ldots, c_k, c_{k+1} \rangle)$	$(e, \langle c_1, \ldots, c_k \rangle)$
Feedback	$(e, \langle c_1, \ldots, c_k \rangle)$	$(e, \langle c_1, \ldots, c_k + 1 \rangle)$

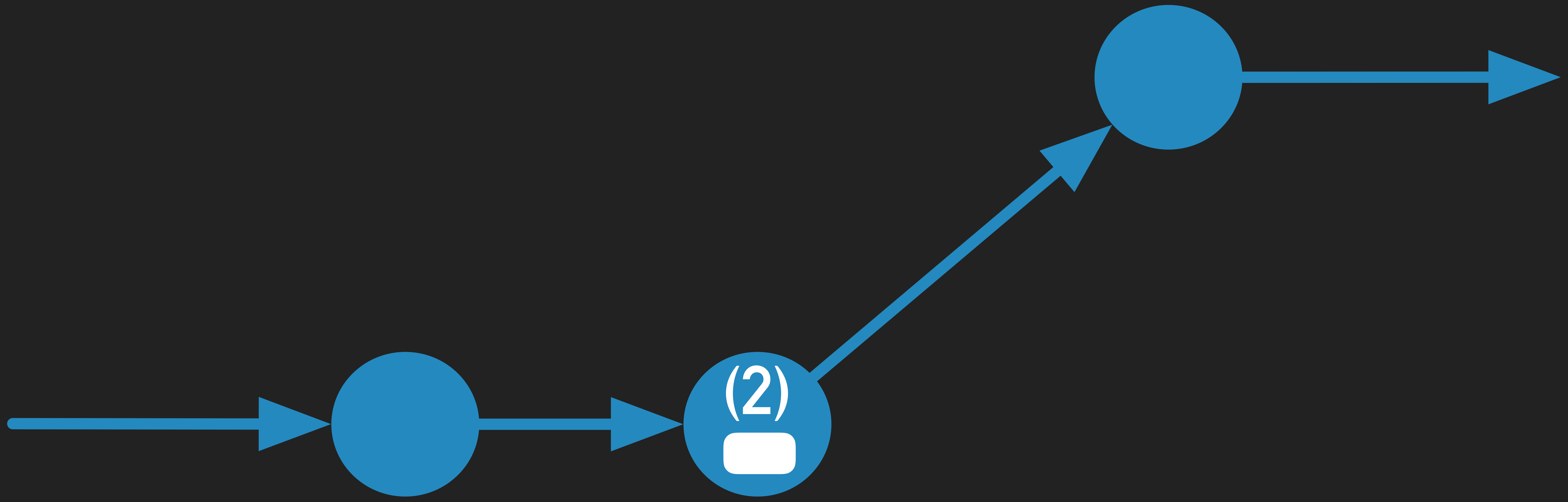
For two timestamps $t_1=(e_1,\mathbf{c}_1)$ and $t_2=(e_2,\mathbf{c}_2)$

$t_1 \leq t_2$ iff. $e_1 \leq e_2$ and $\mathbf{c}_1 \leq \mathbf{c}_2$

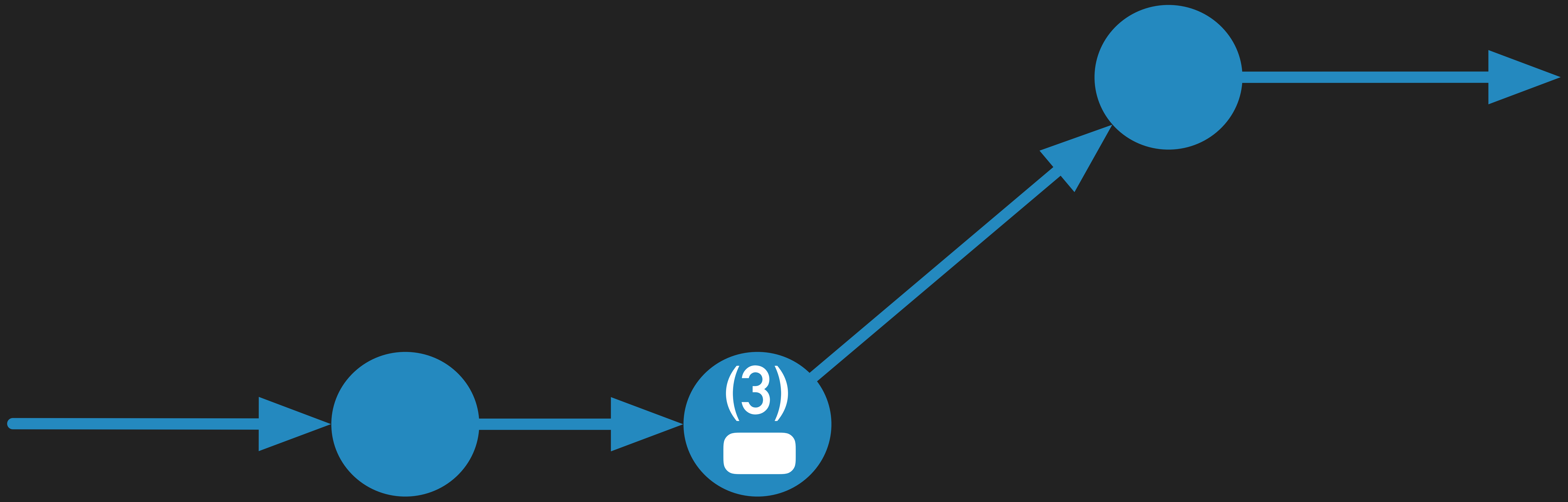
OPERATOR CONTRACT



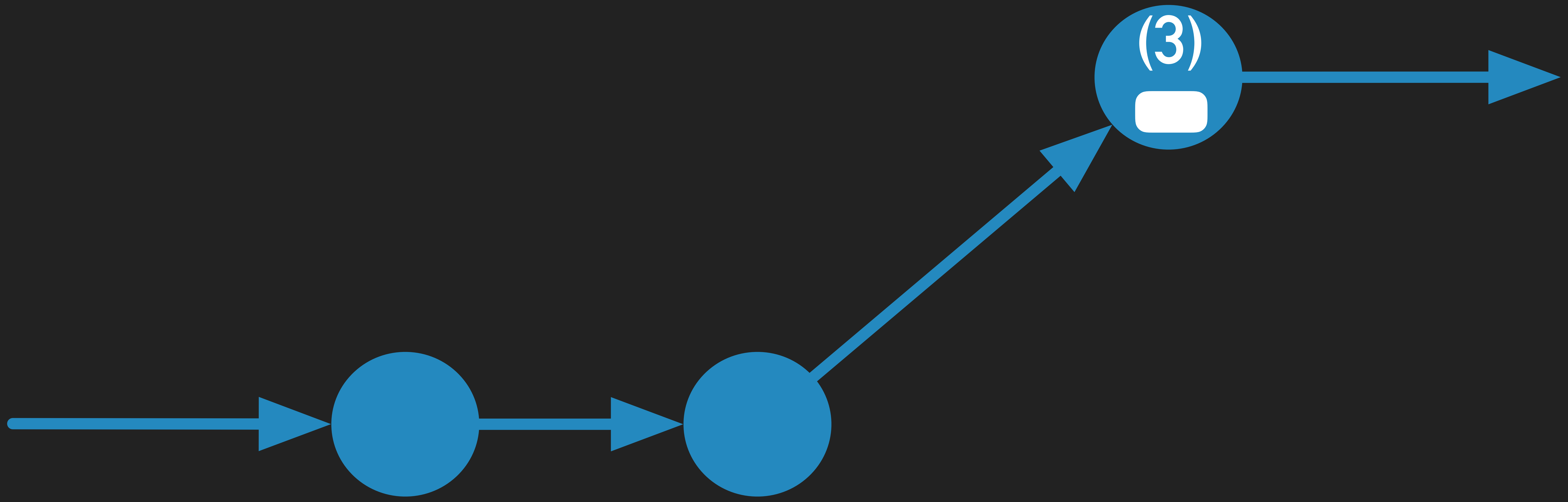
OPERATOR CONTRACT



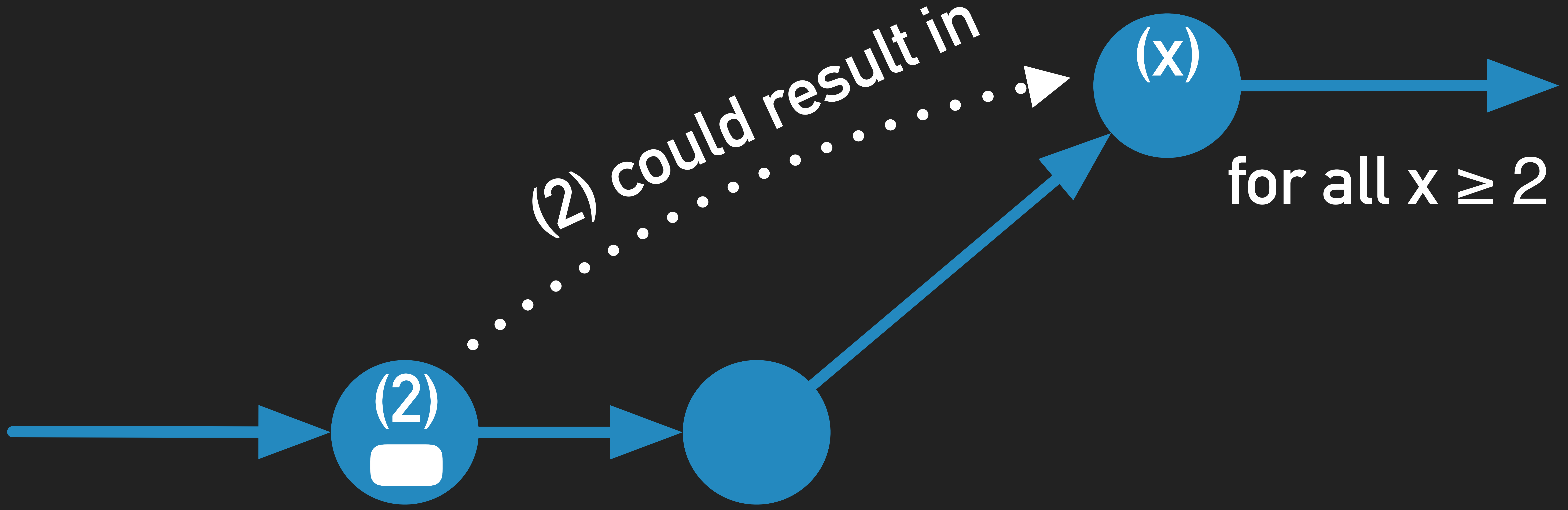
OPERATOR CONTRACT



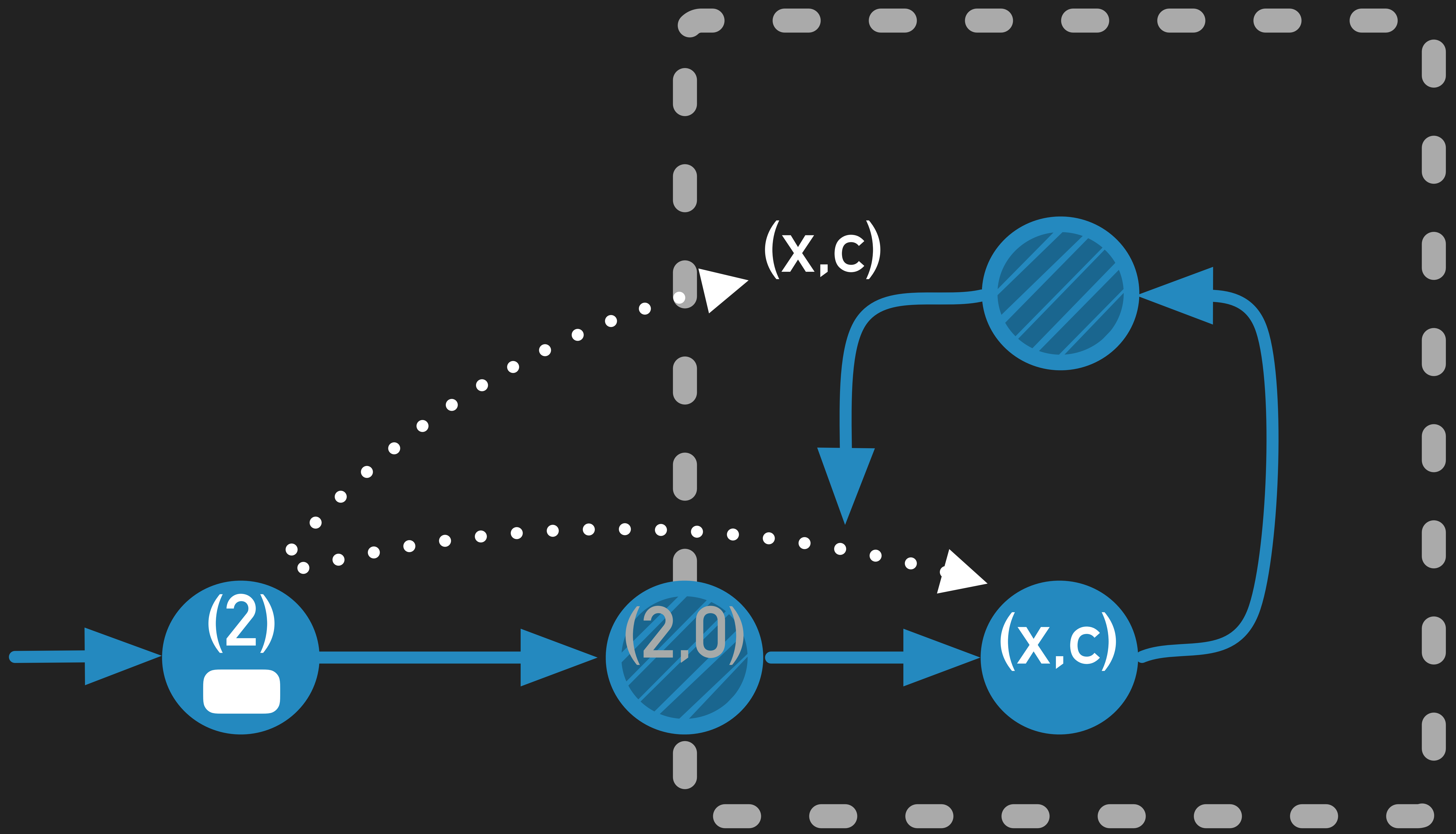
OPERATOR CONTRACT



COULD-RESULT-IN



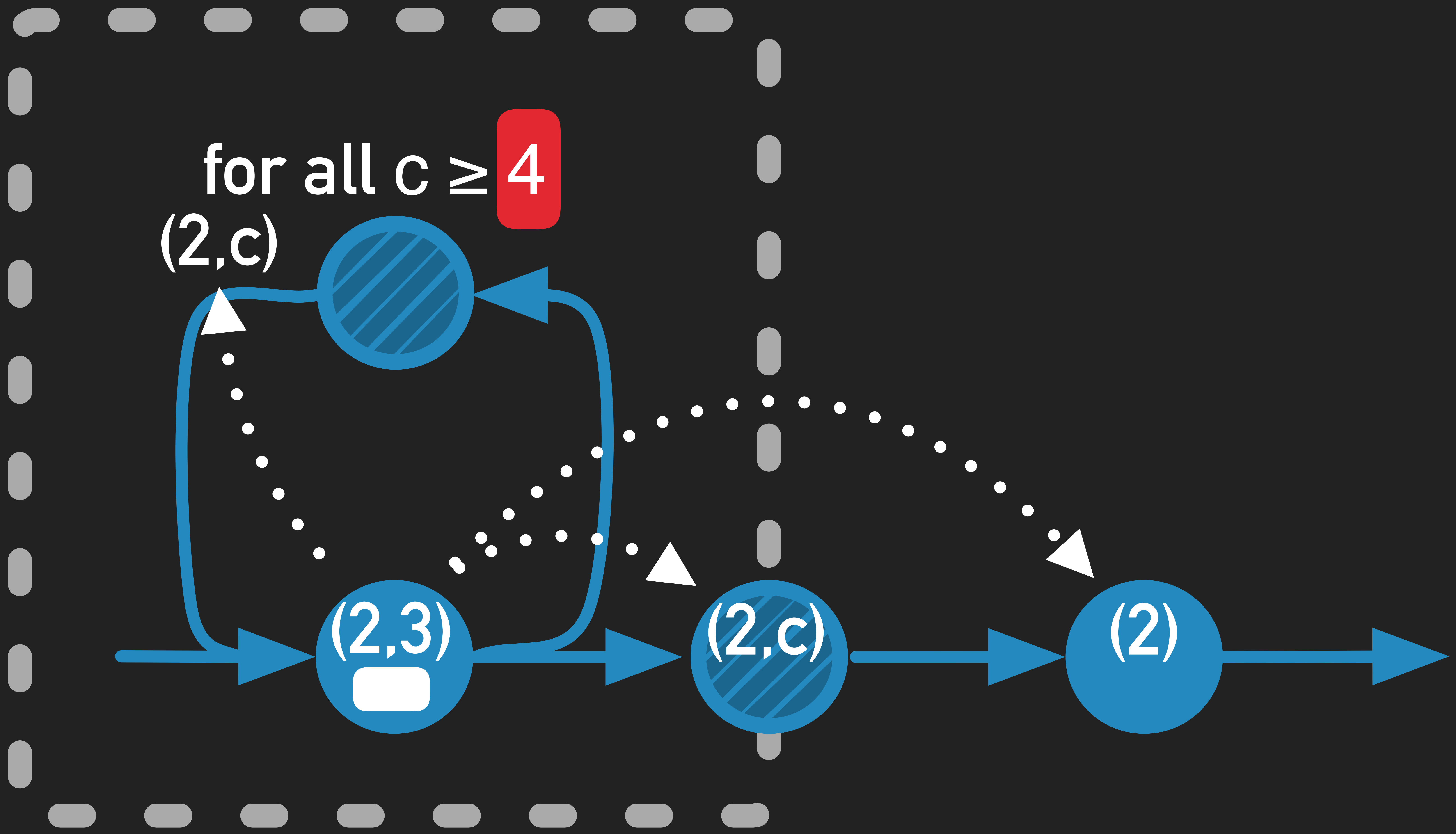
COULD-RESULT-IN



for all x ≥ 2, c ≥ 0

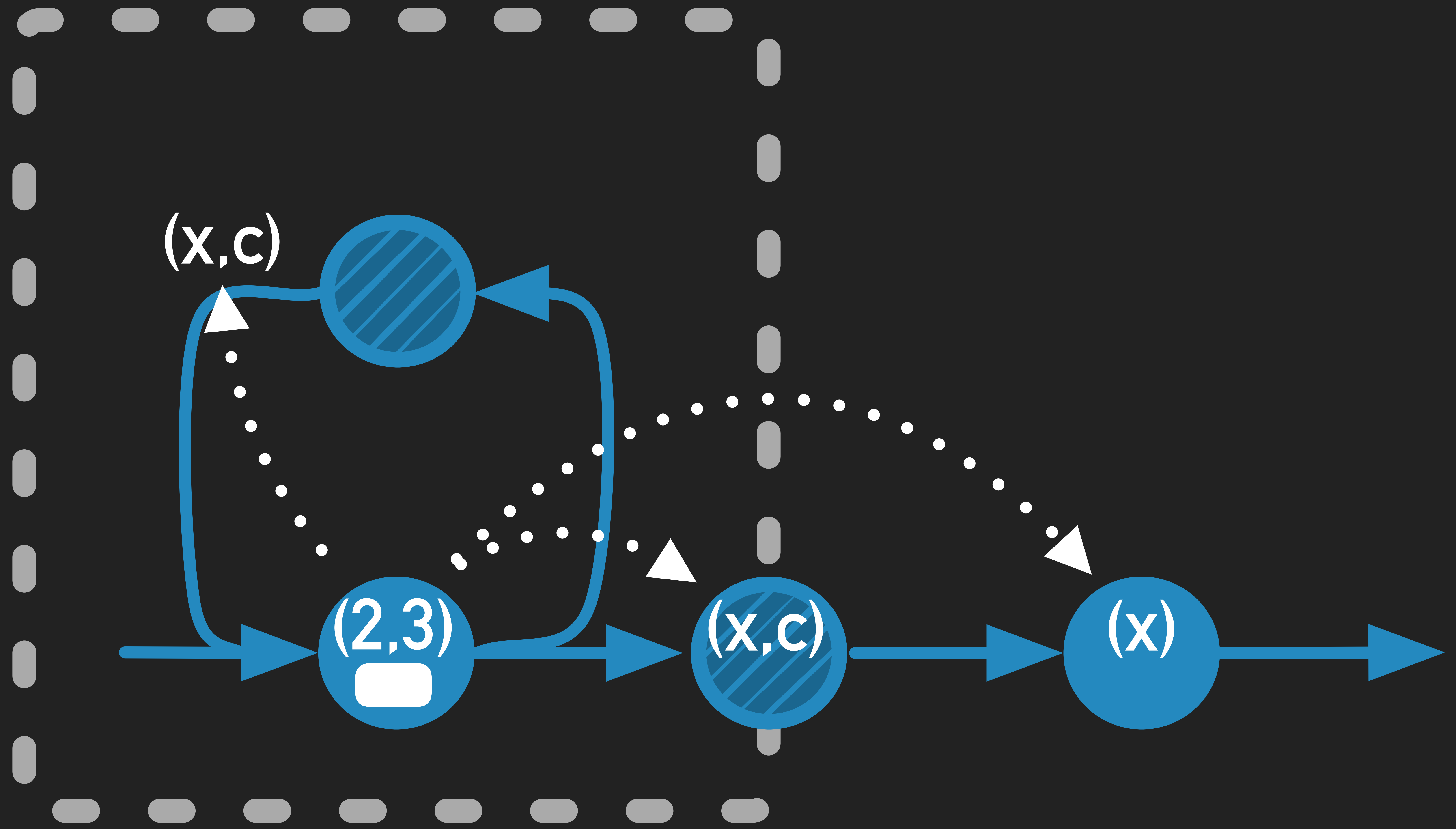
COULD-RESULT-IN

(e = 2, c)



COULD-RESULT-IN

for all c, x so that c ≥ 4 and x ≥ 2



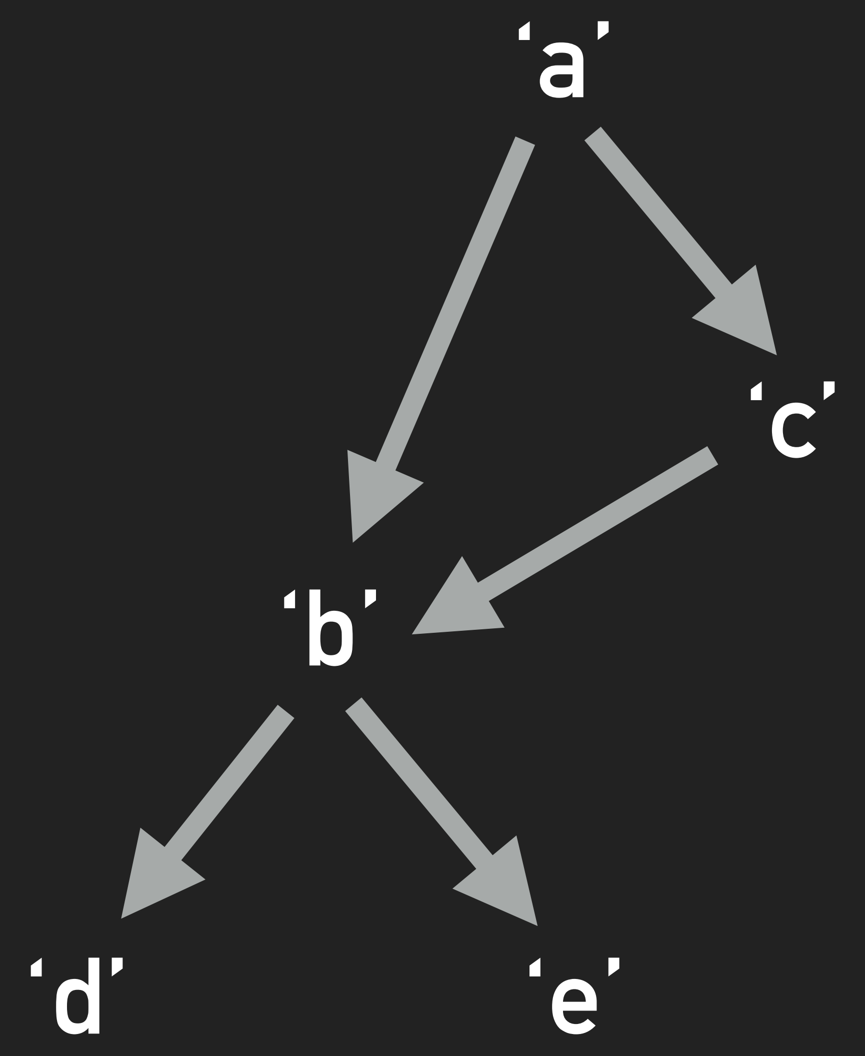
NOT IN THIS TALK

- details about the distributed implementation,
- progress tracking optimization,
- how to prevent micro-stragglers,
- frameworks on top of Naiad / Timely Dataflow,
- performance evaluation.

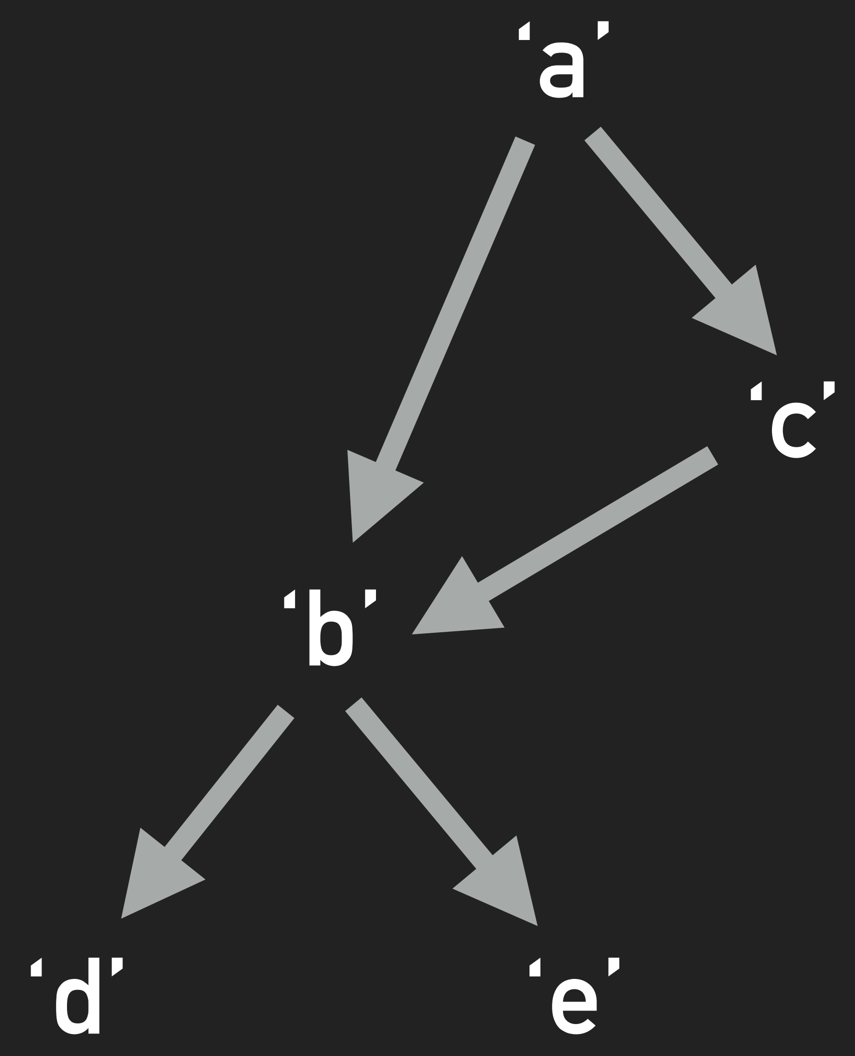
github.com/frankmcsherry/timely-dataflow

TIMELY DATAFLOW IN RUST (❤️).

ITERATIVE GRAPH COMPUTATION IN DATAFLOW.

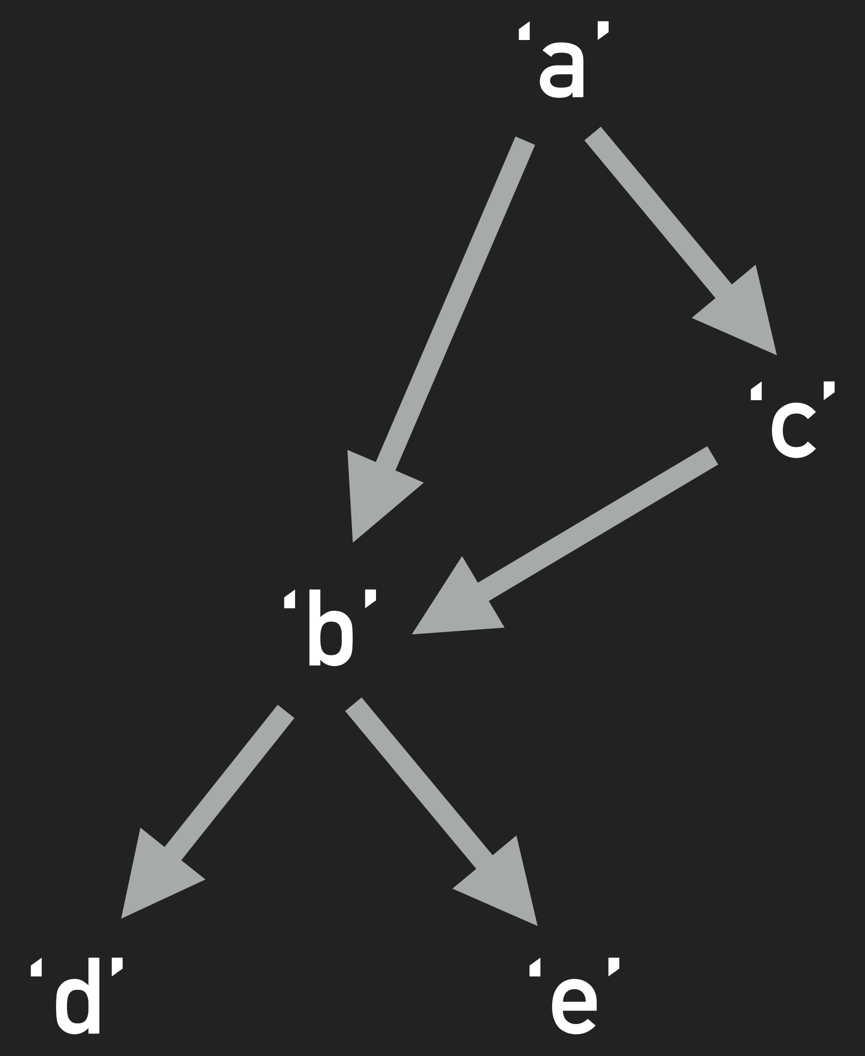


ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)

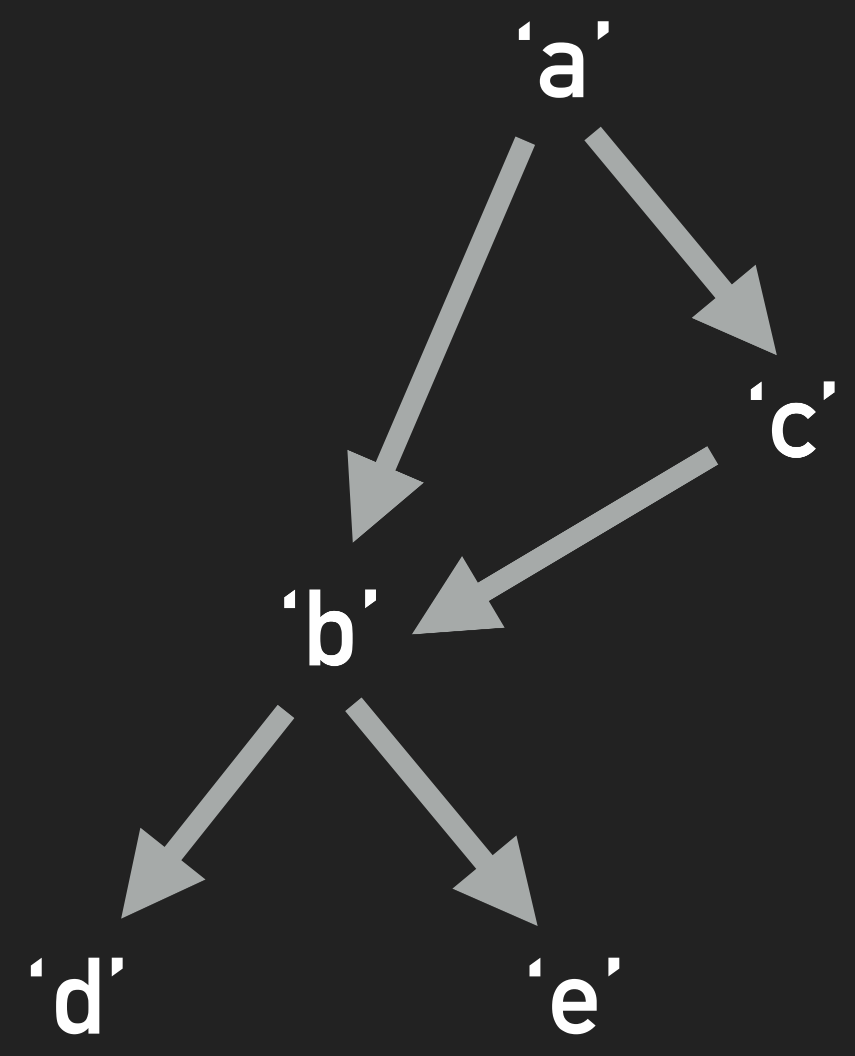
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)

(‘b’, ‘d’)

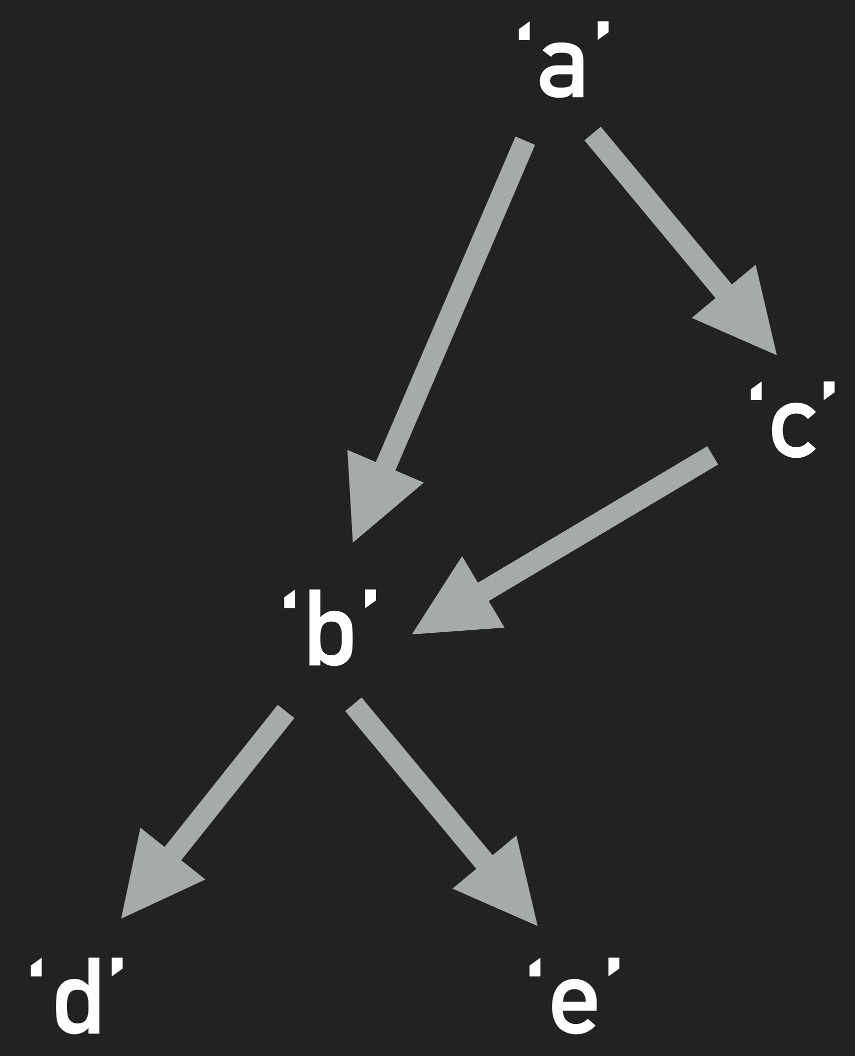
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)

(‘b’, ‘d’)
(‘b’, ‘e’)

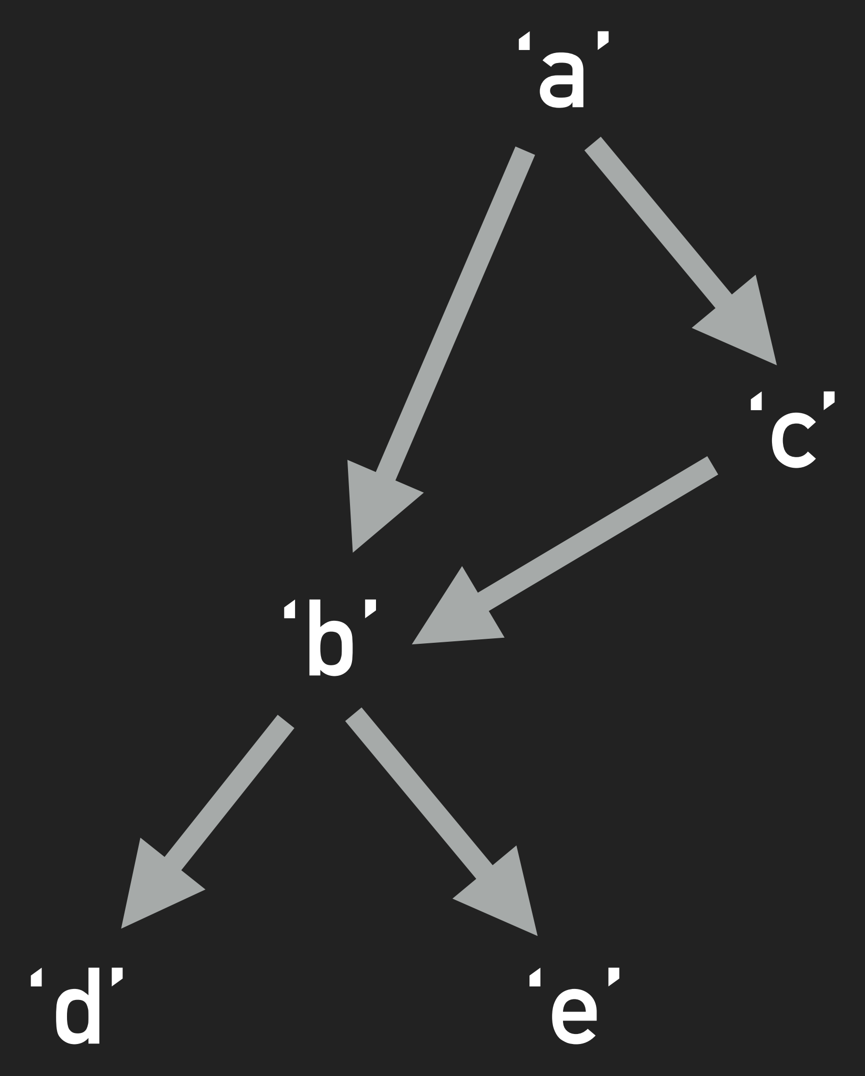
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)   (‘a’, ‘c’)

(‘b’, ‘d’)
(‘b’, ‘e’)

ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)

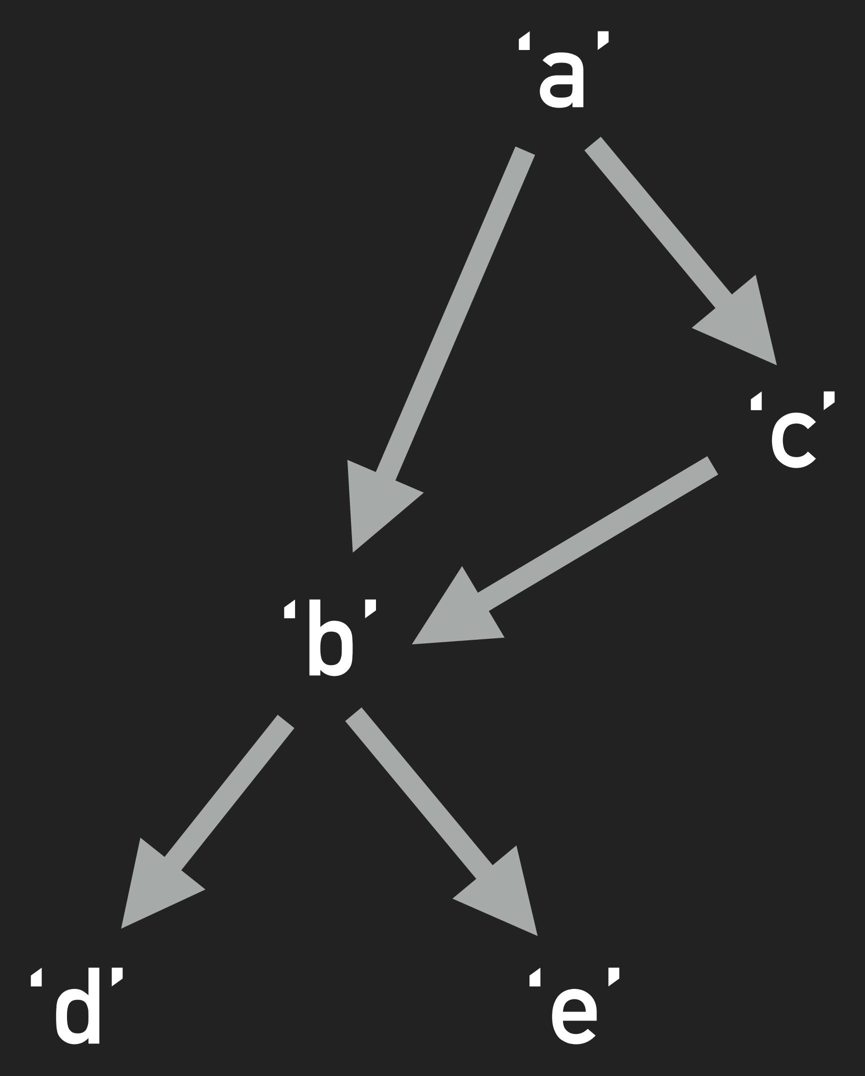
(‘a’, ‘c’)

(‘c’, ‘b’)

(‘b’, ‘d’)

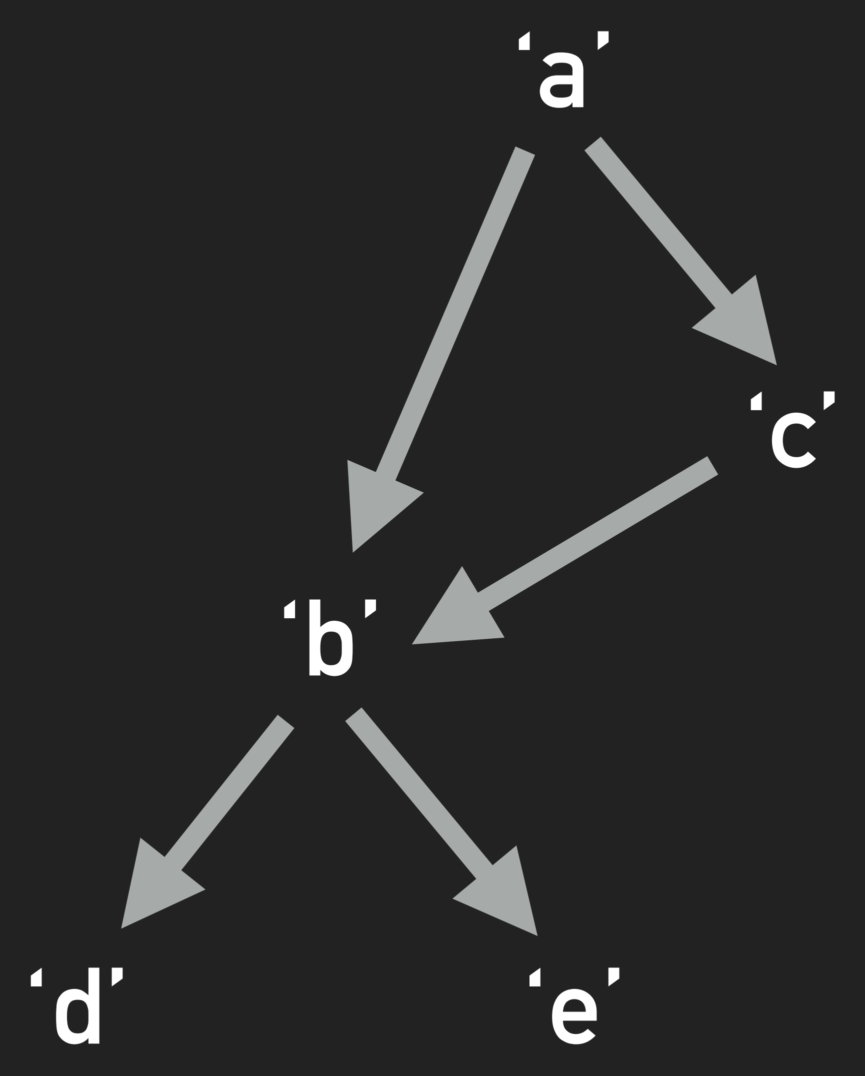
(‘b’, ‘e’)

ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



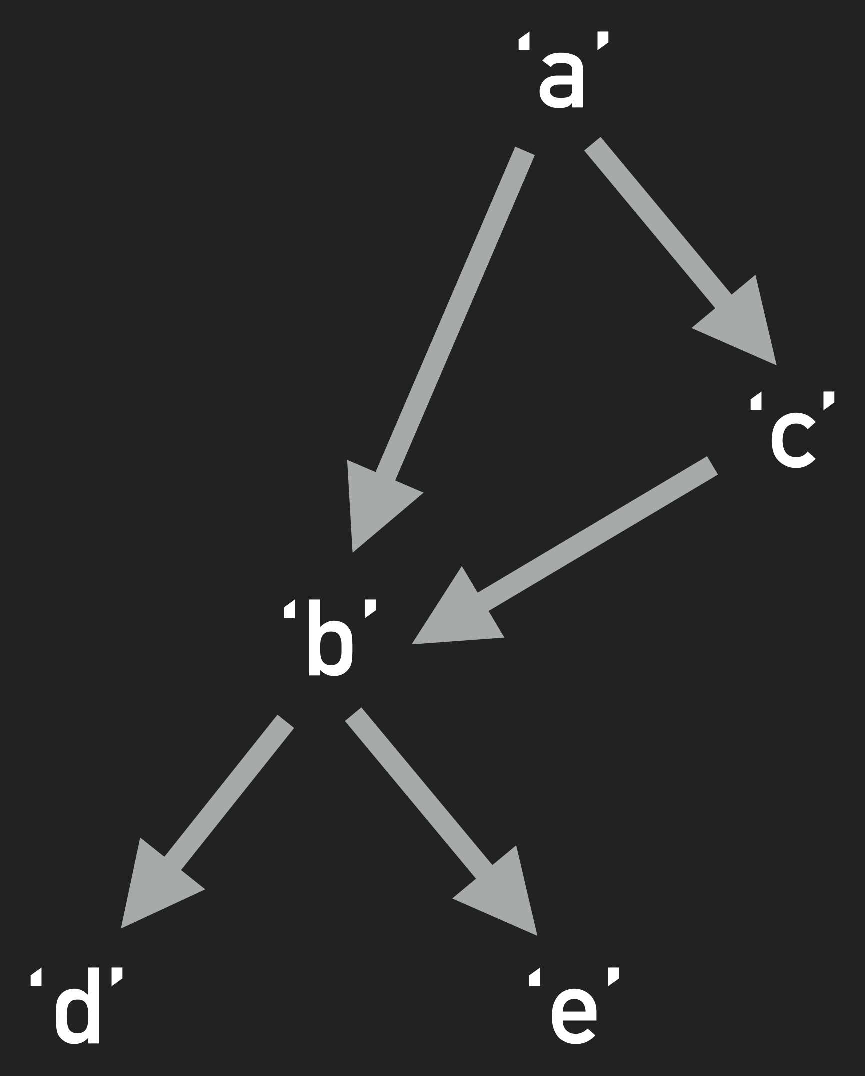
('a', 'b')	('a', 'c')
	('c', 'b')
('b', 'd')	('b', 'd')
('b', 'e')	

ITERATIVE GRAPH COMPUTATION IN DATAFLOW.

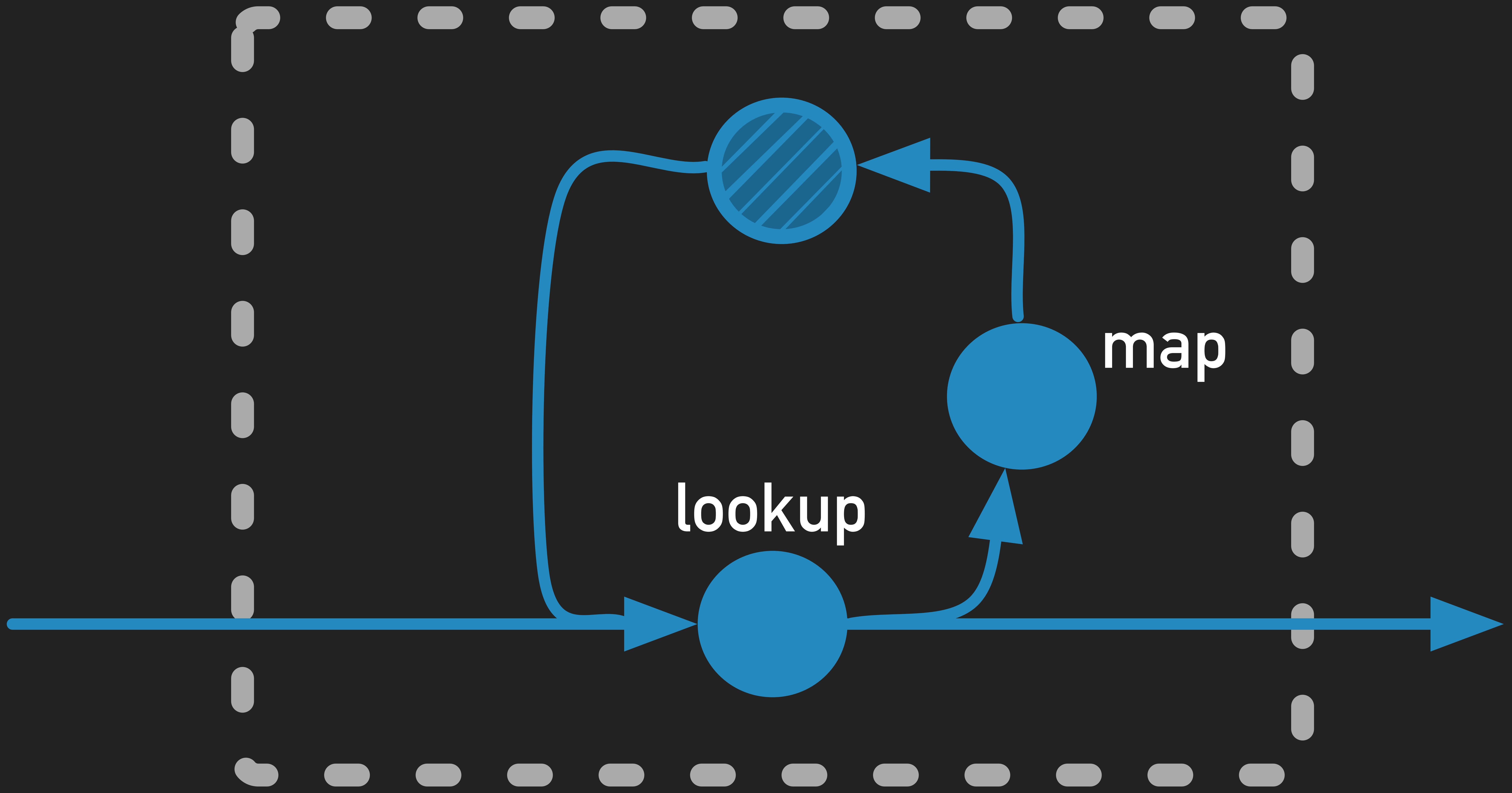


(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)

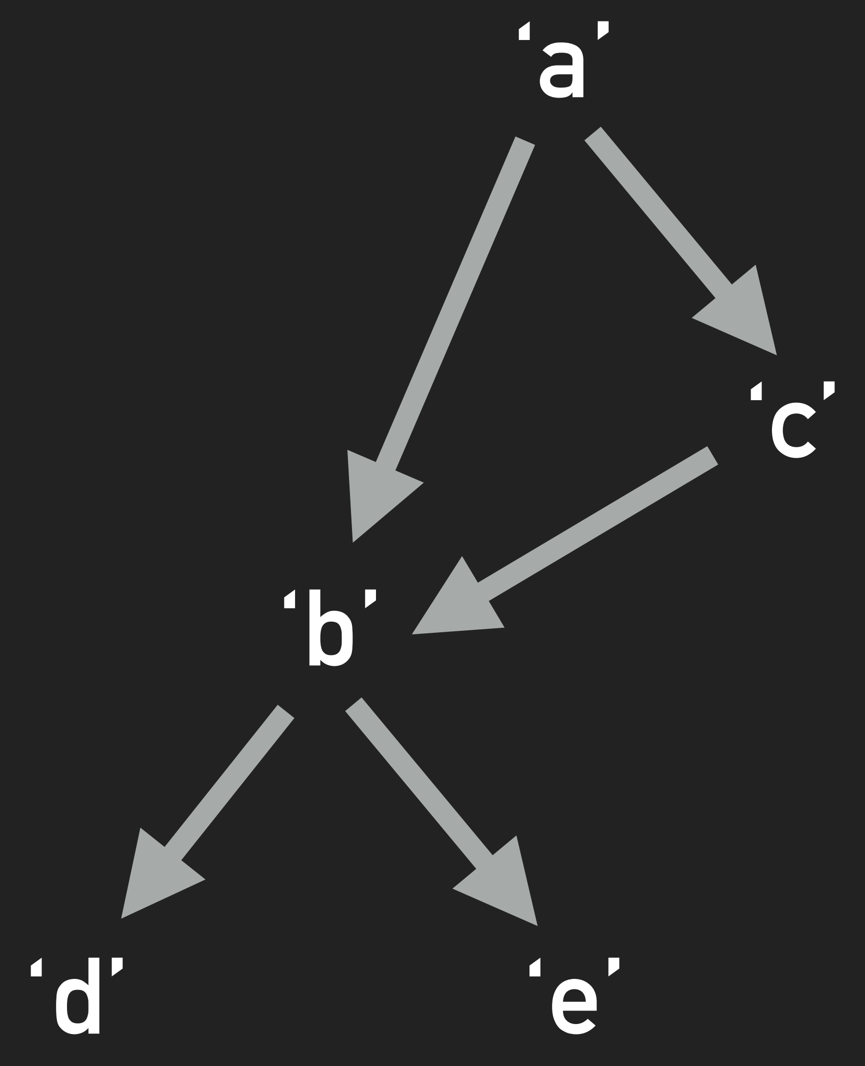
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



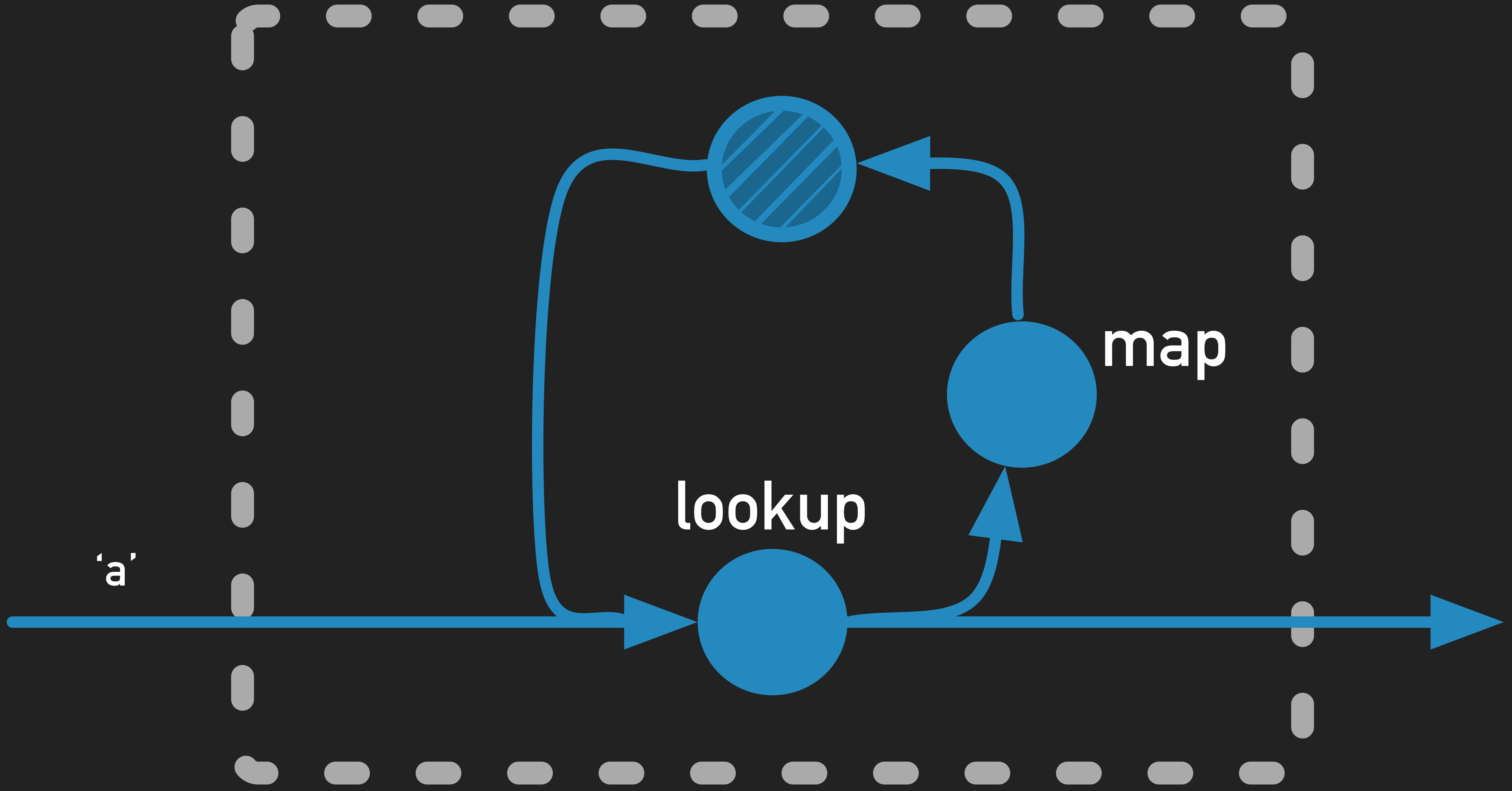
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



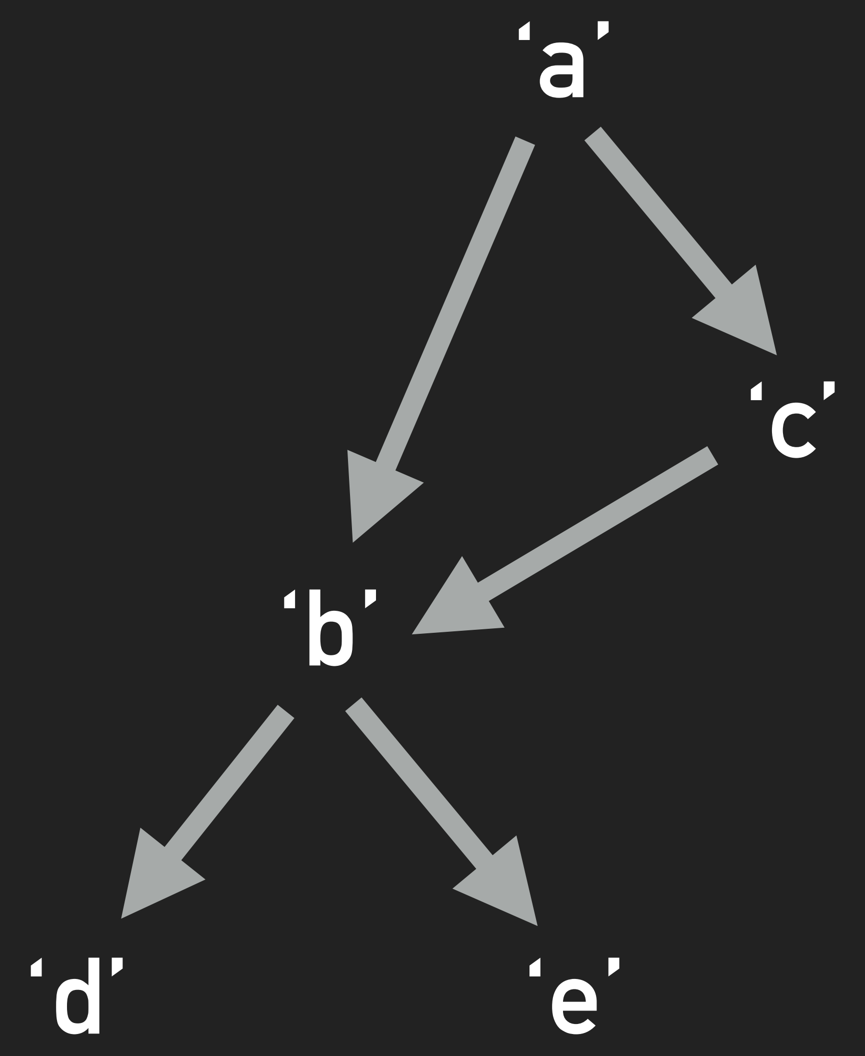
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



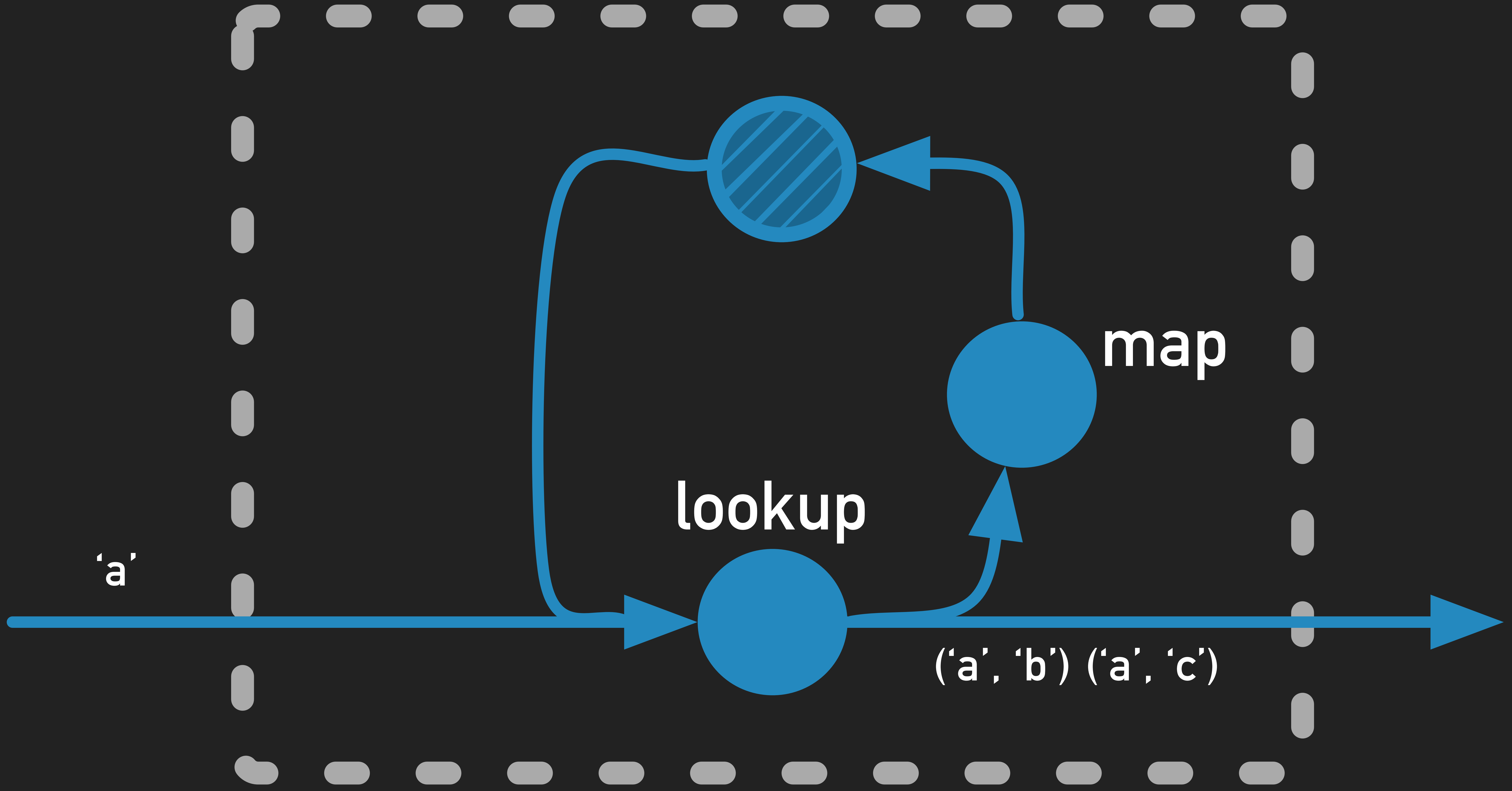
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



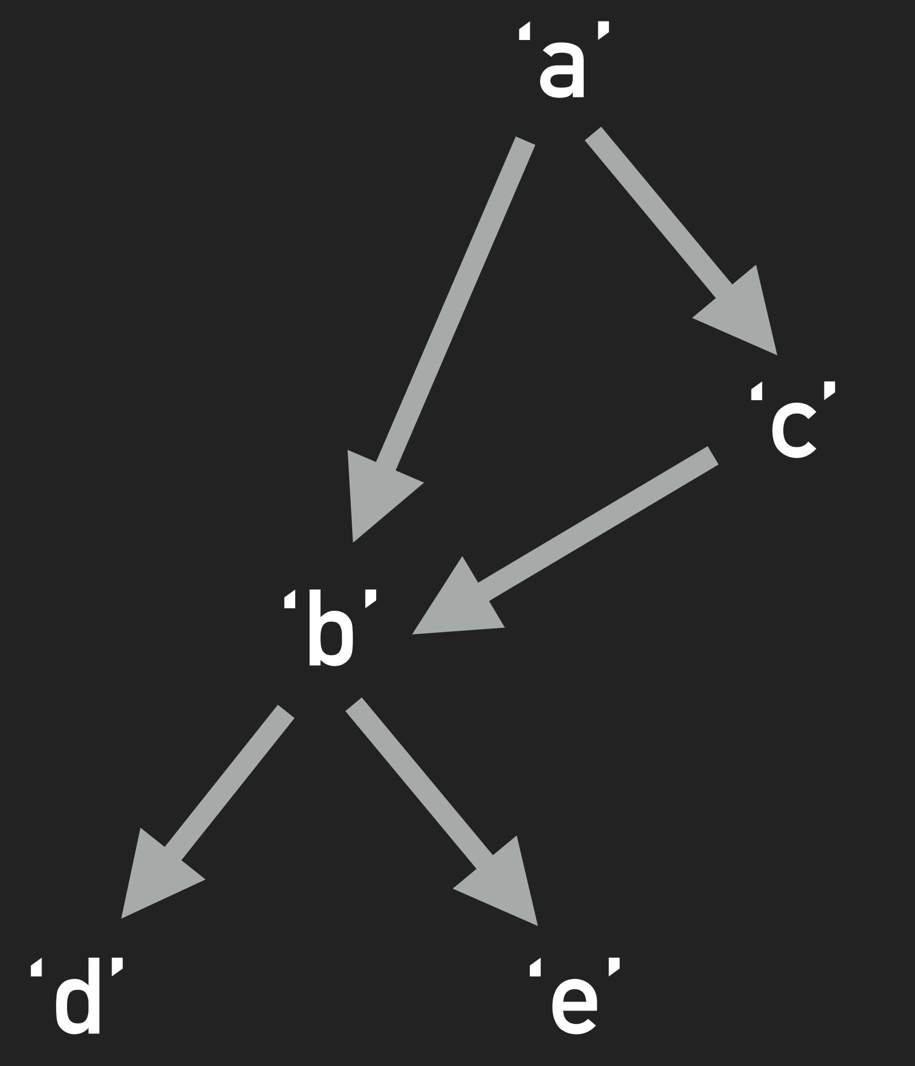
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



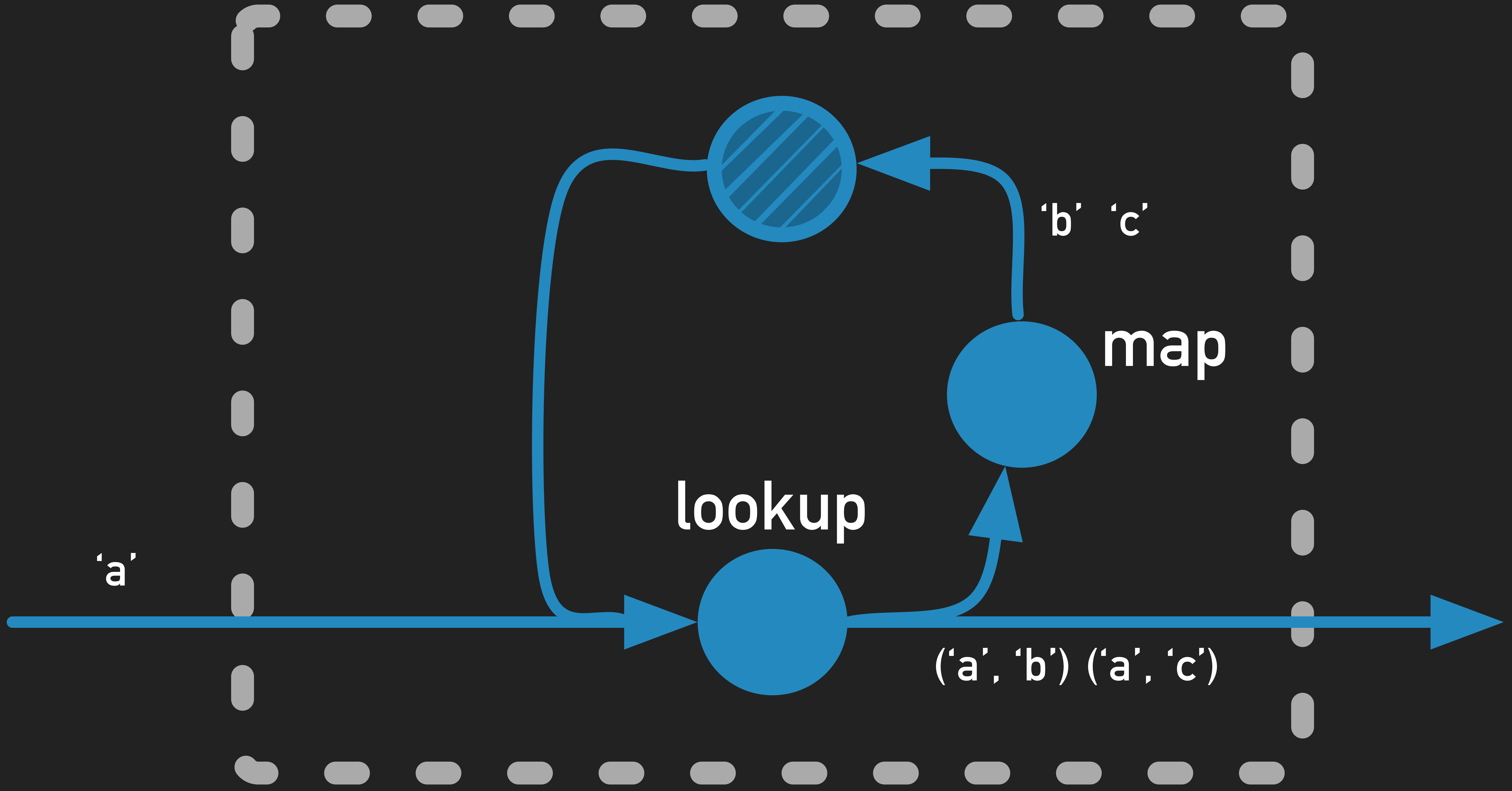
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



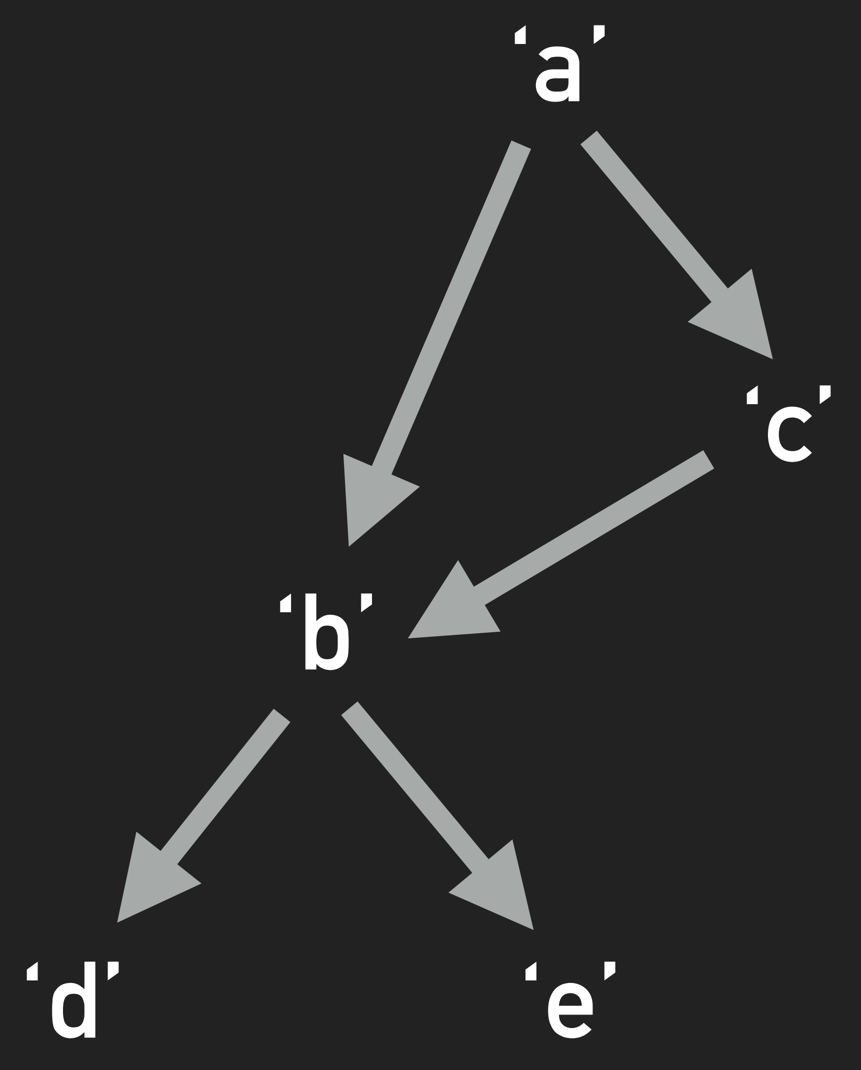
(‘a’, ‘b’)

(‘b’, ‘d’)
(‘b’, ‘e’)

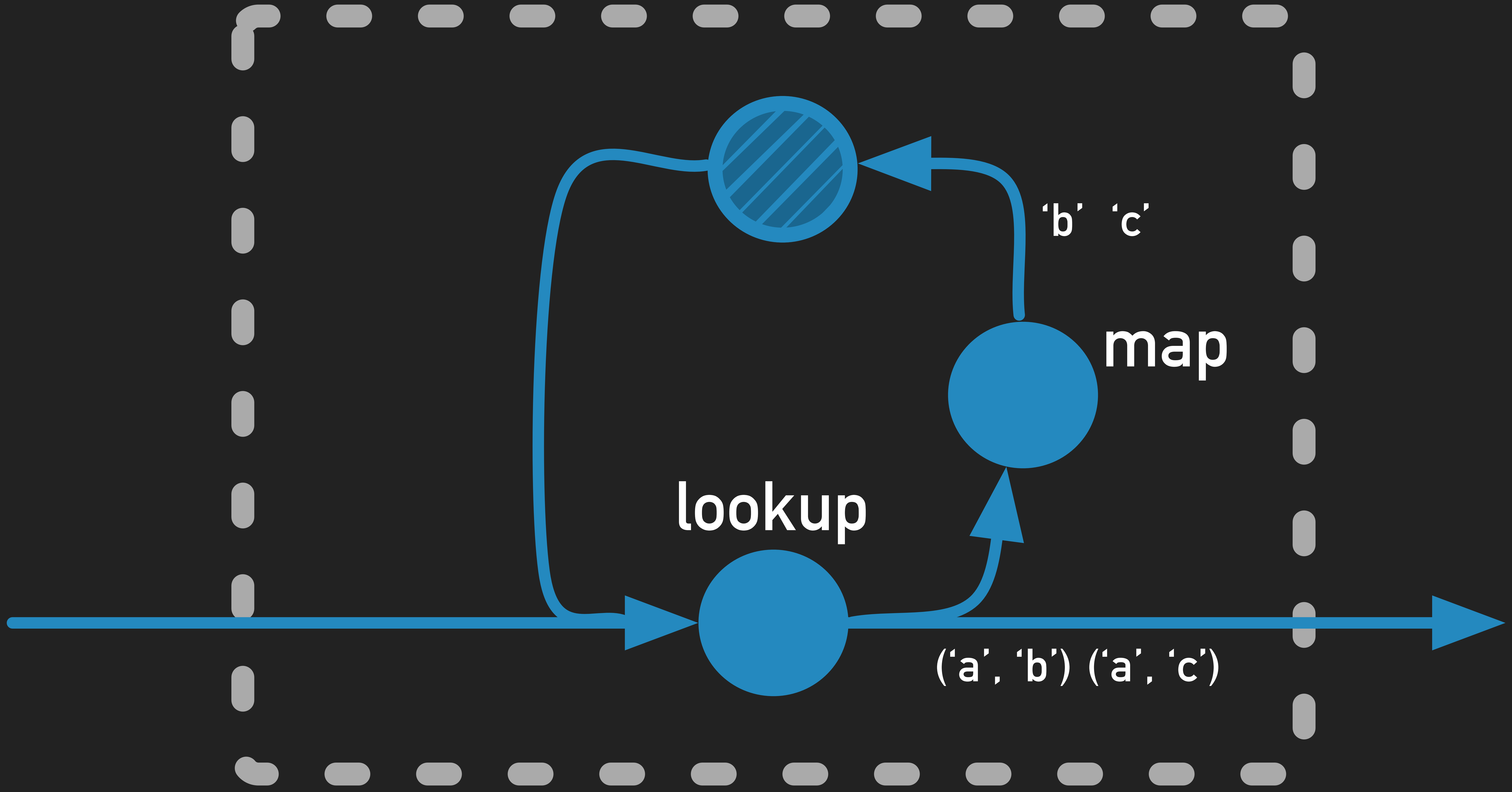
(‘a’, ‘c’)
(‘c’, ‘b’)
(‘b’, ‘d’)
(‘b’, ‘e’)



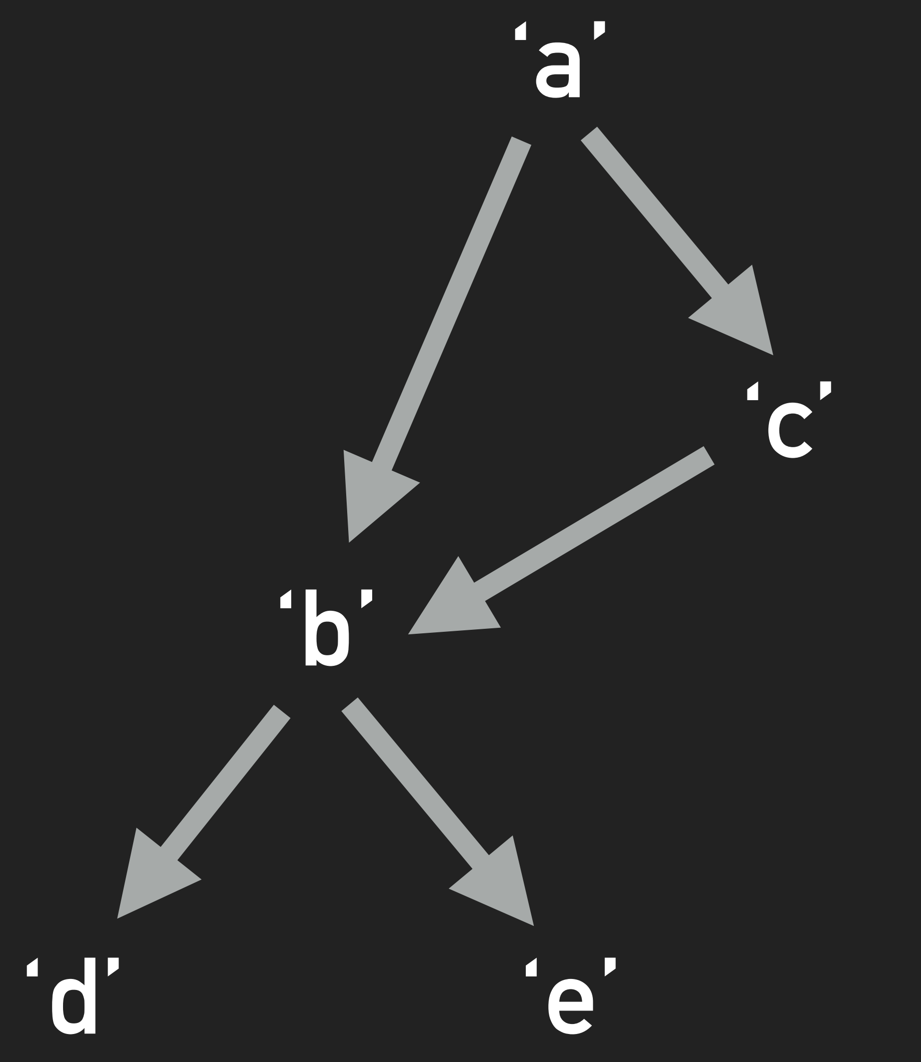
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



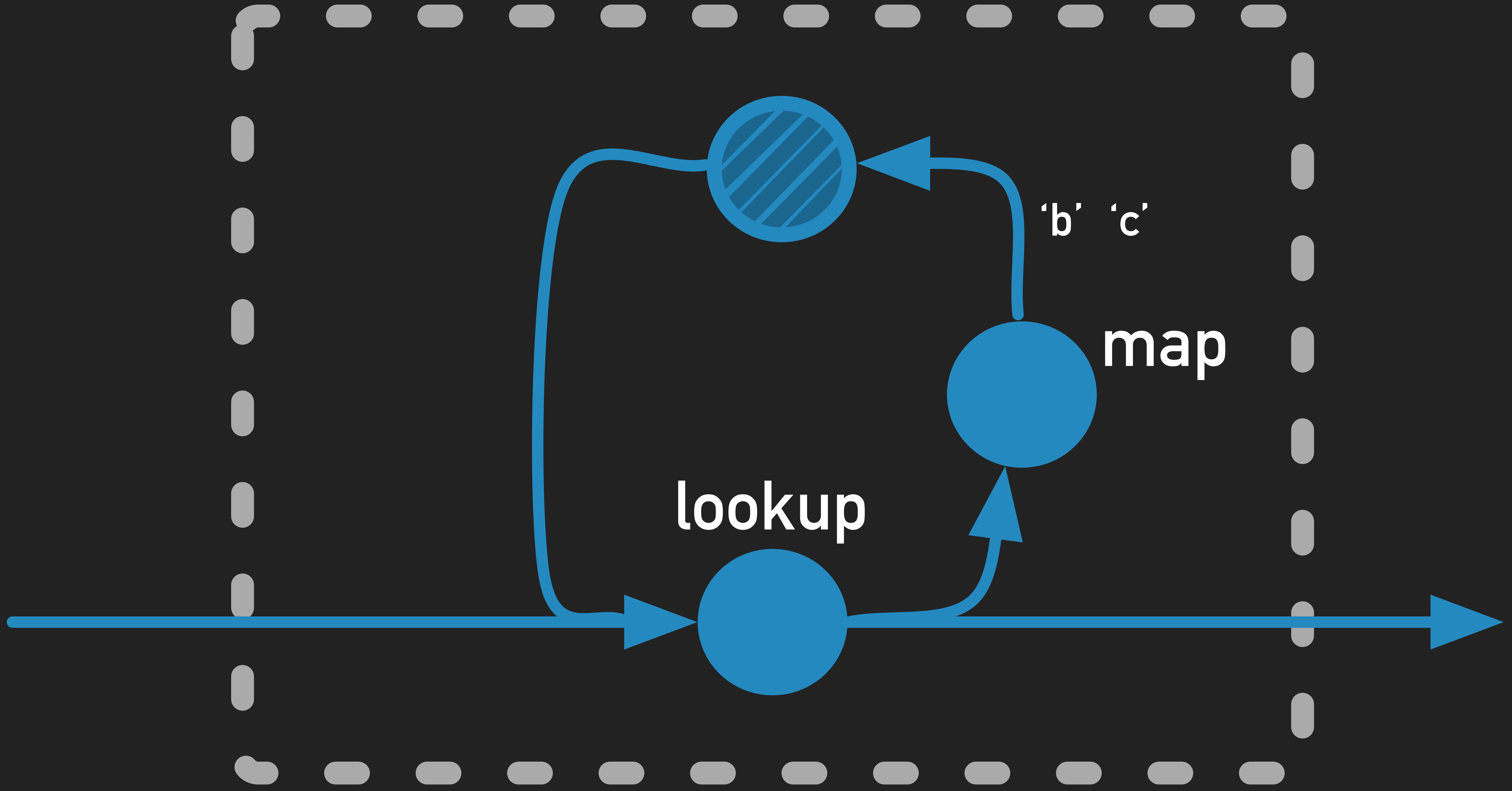
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)

(‘b’, ‘d’)
(‘b’, ‘e’)

(‘a’, ‘c’)
(‘c’, ‘b’)
(‘b’, ‘d’)
(‘b’, ‘e’)



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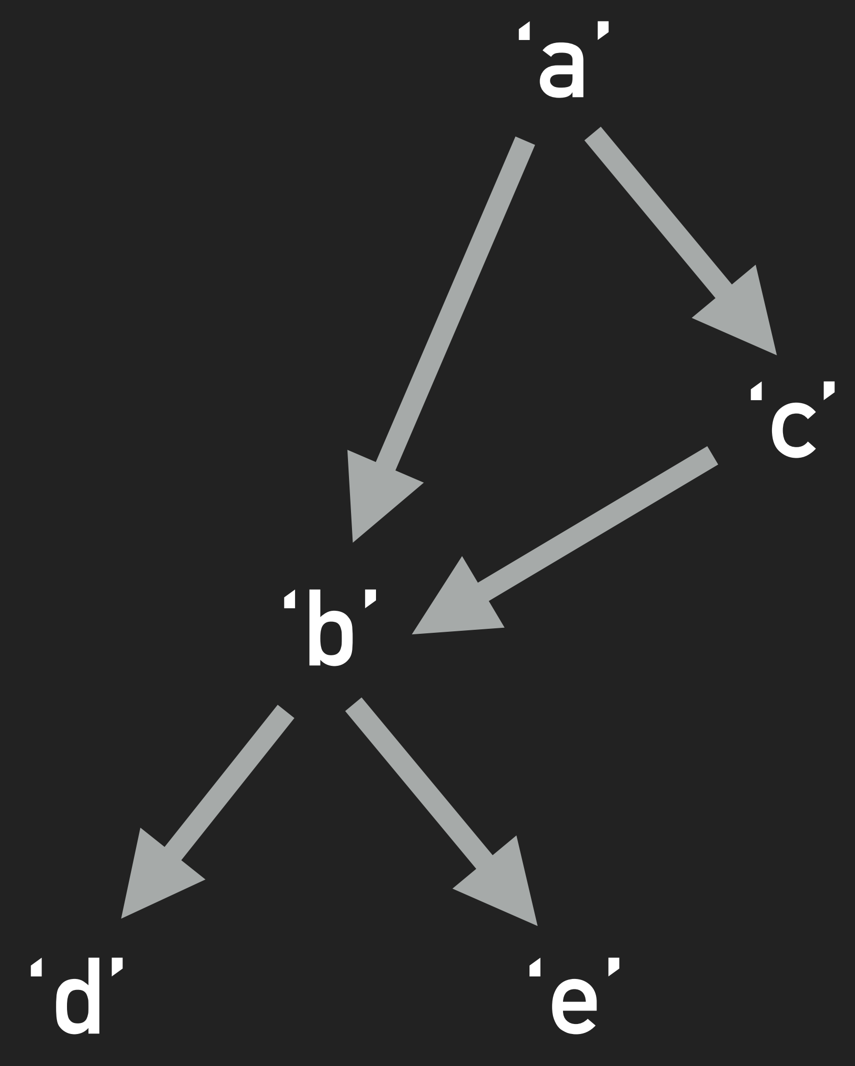
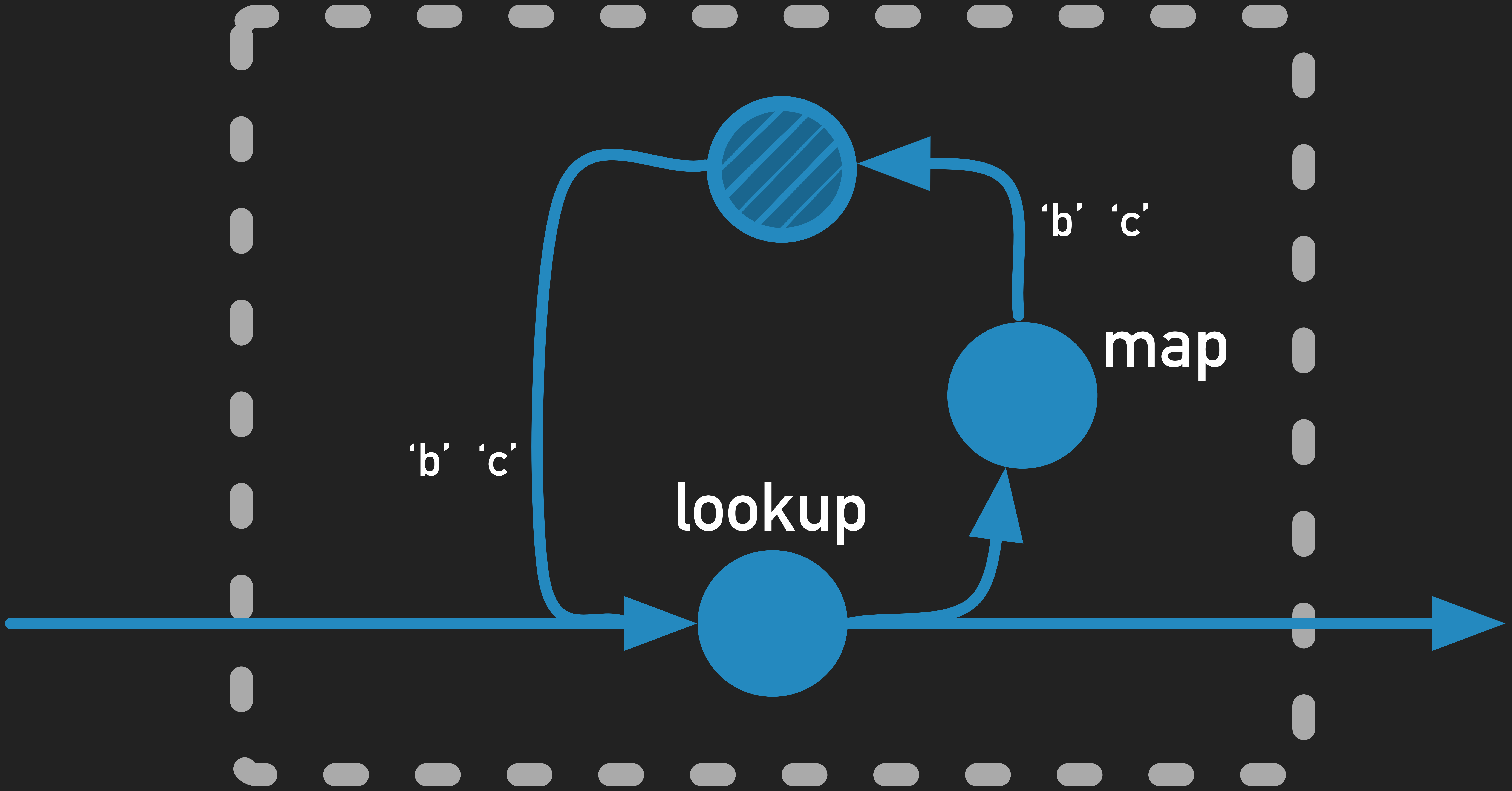
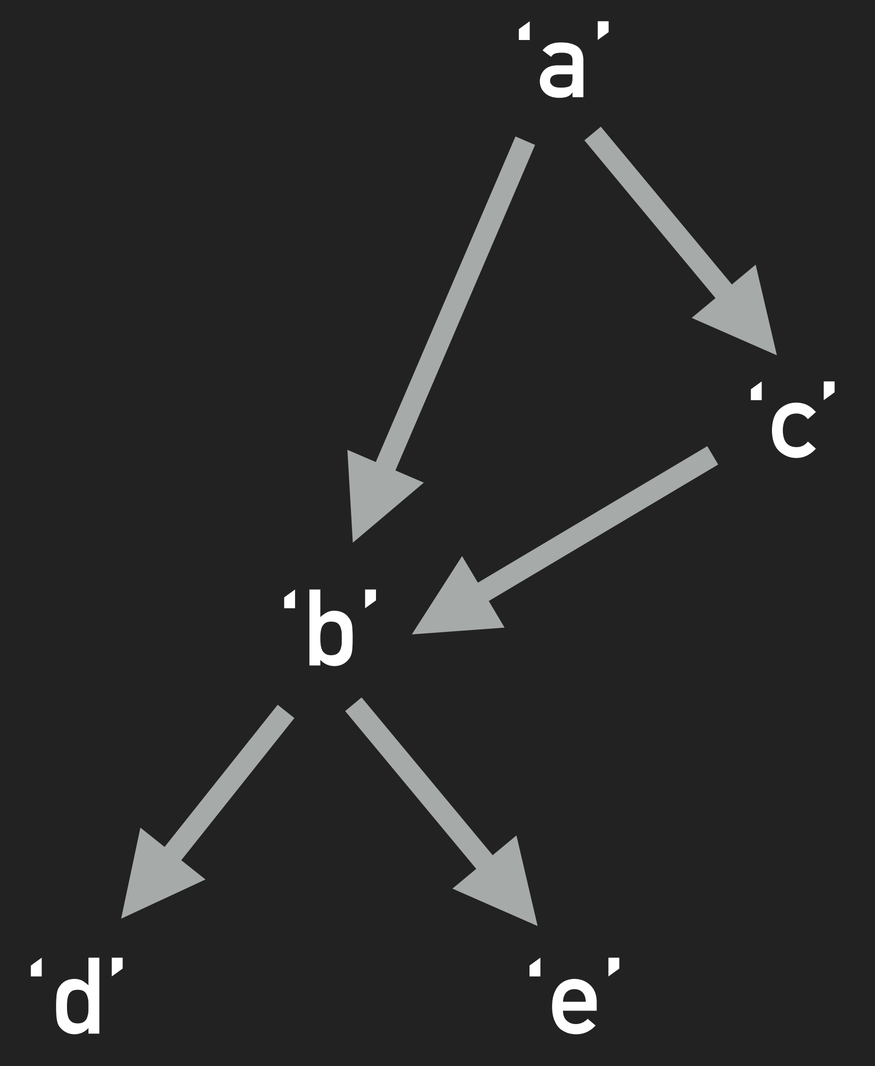


(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



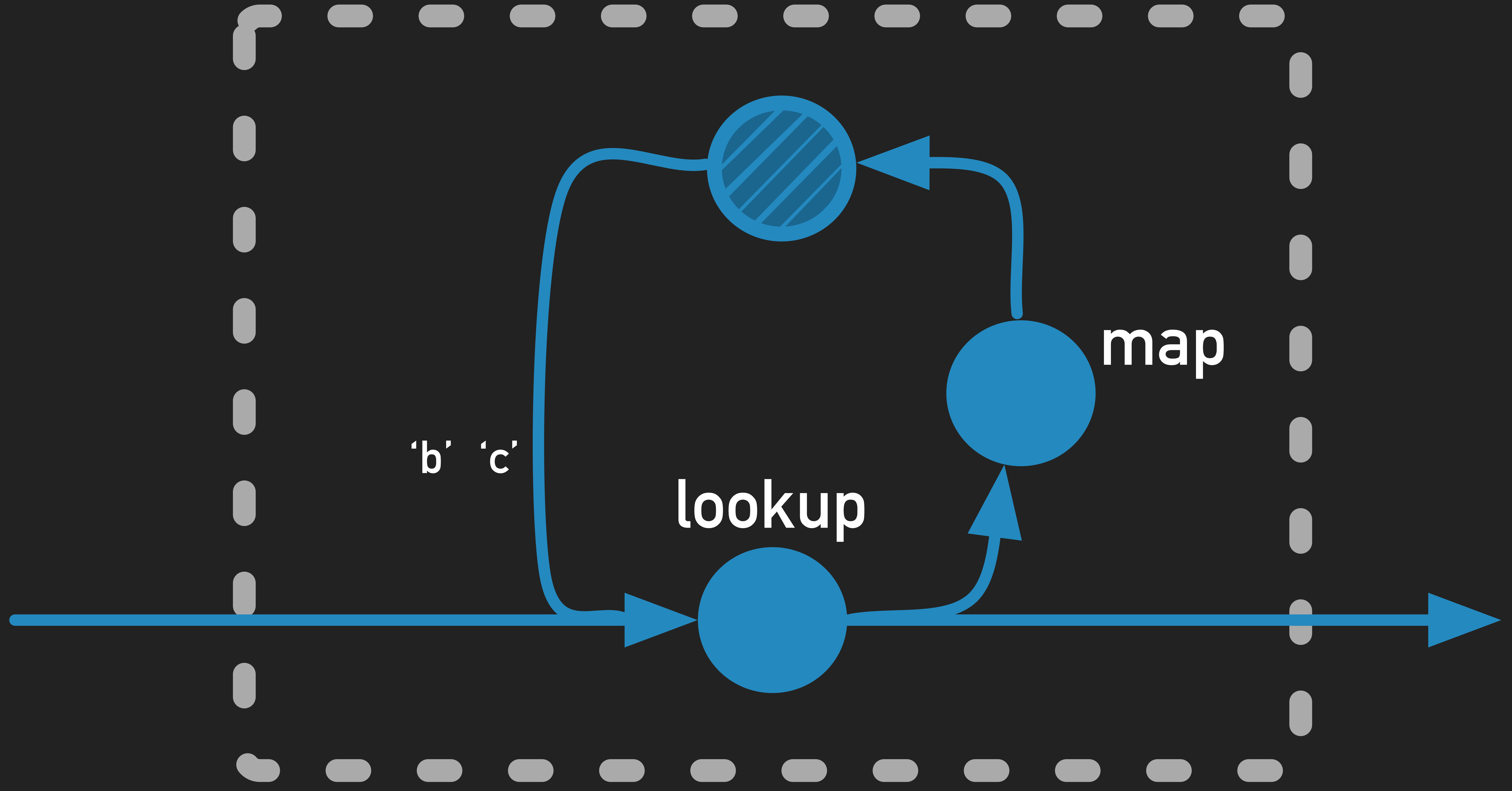
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



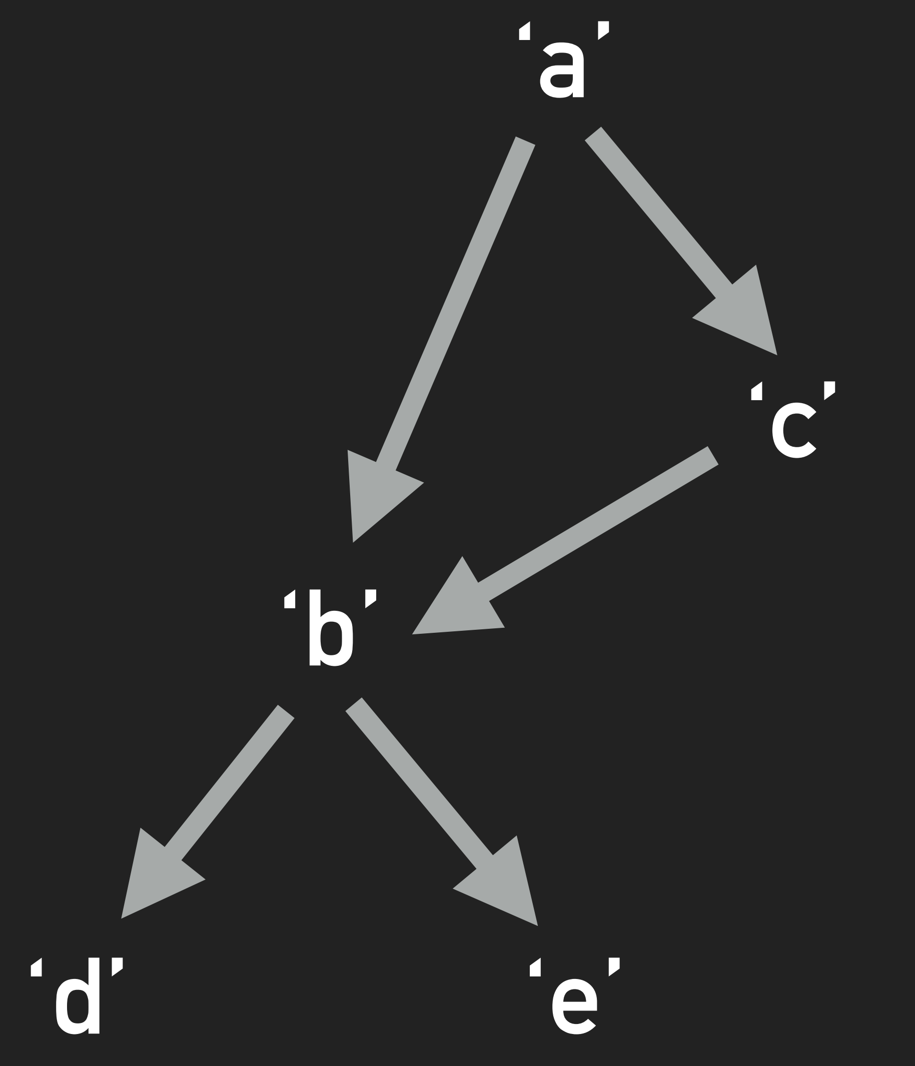
('a', 'b')

('b', 'd')
('b', 'e')

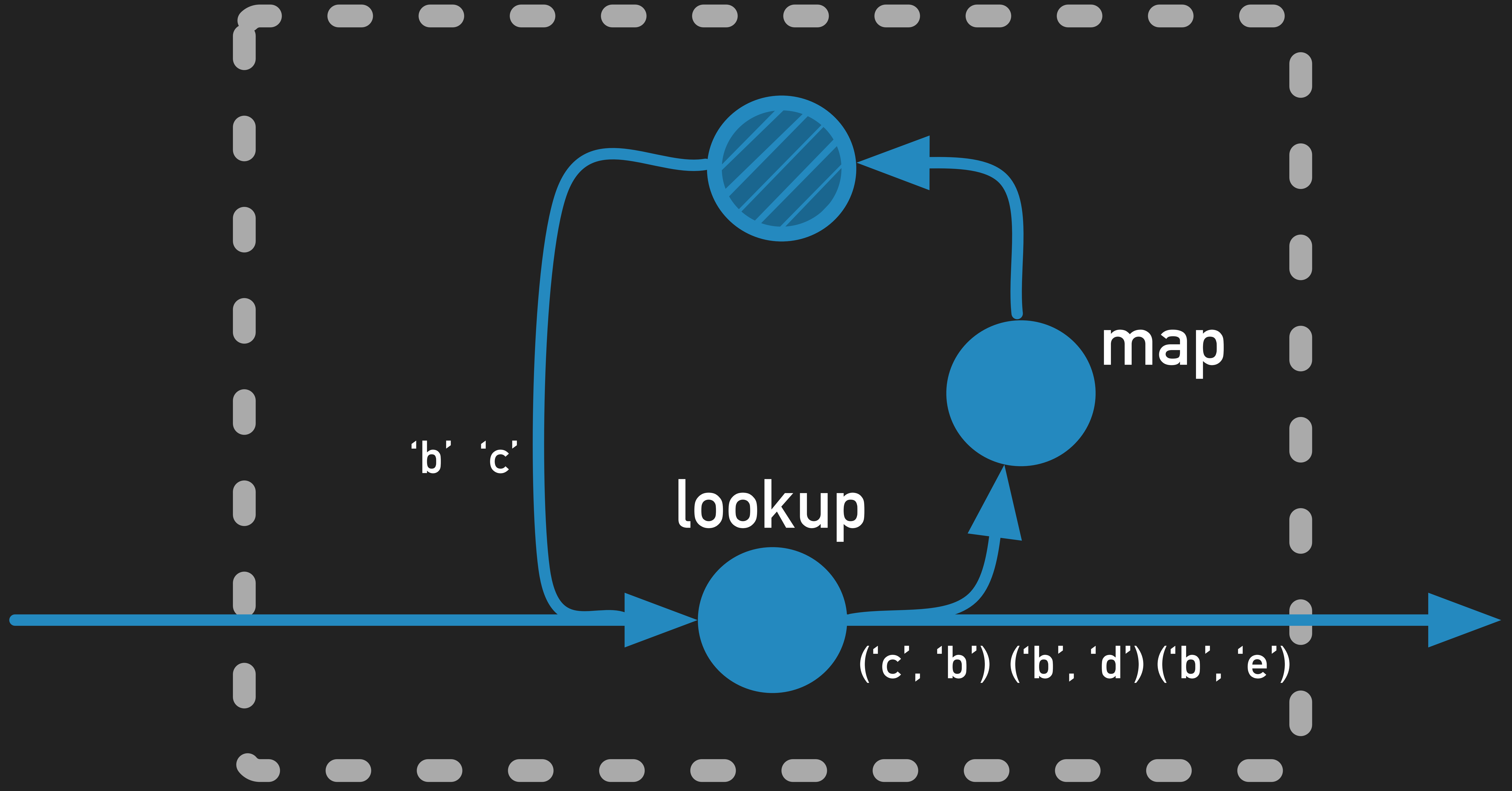
('a', 'c')
('c', 'b')
('b', 'd')
('b', 'e')



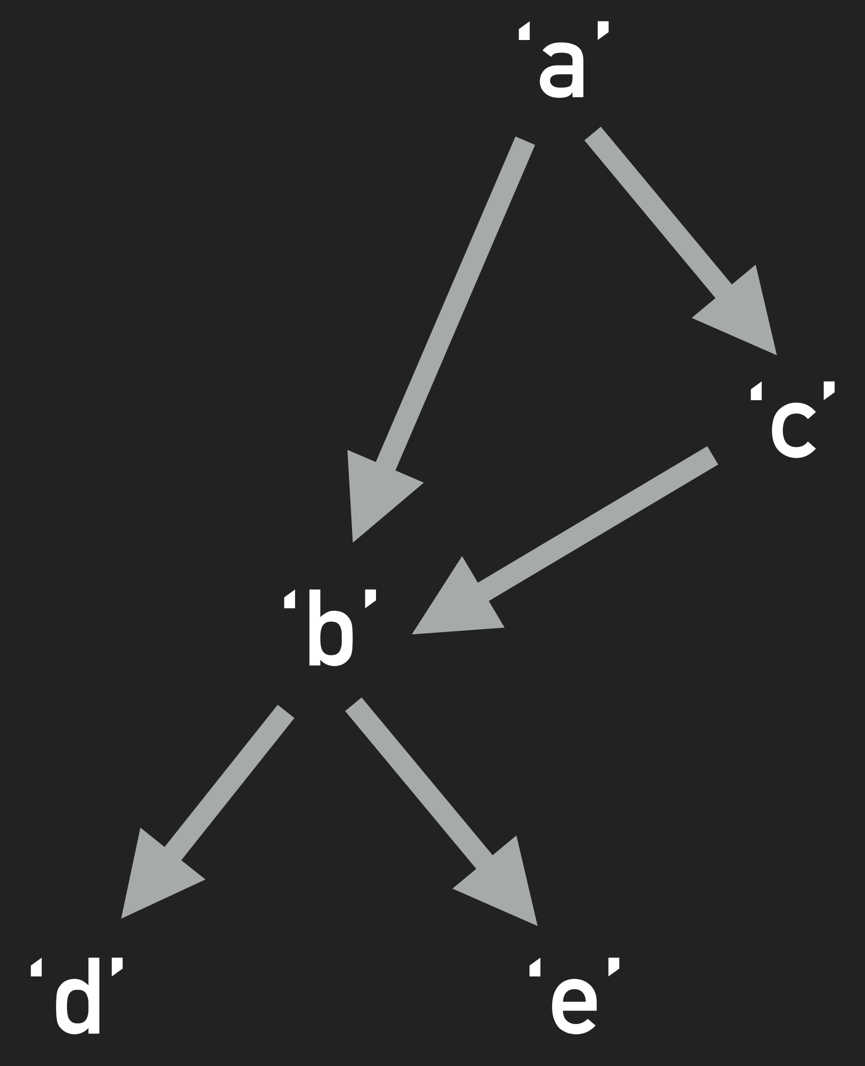
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



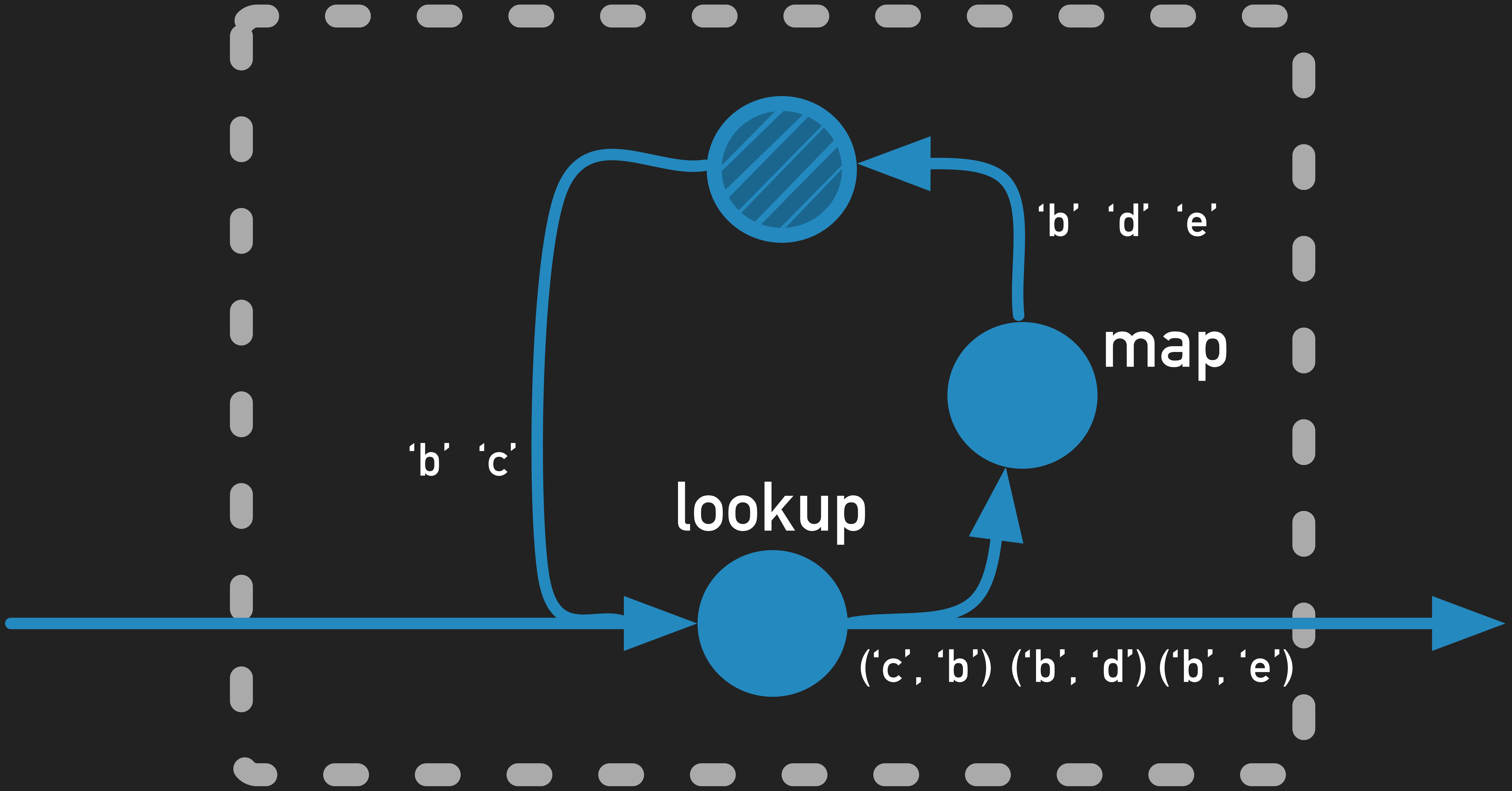
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



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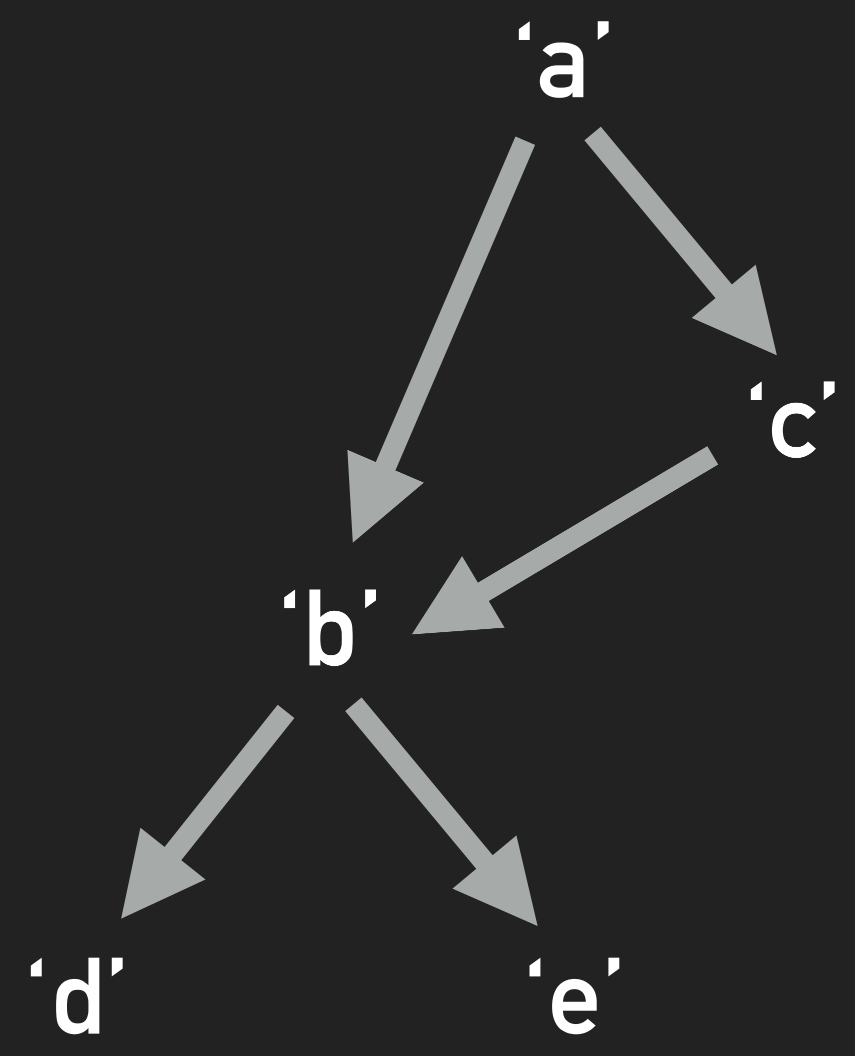
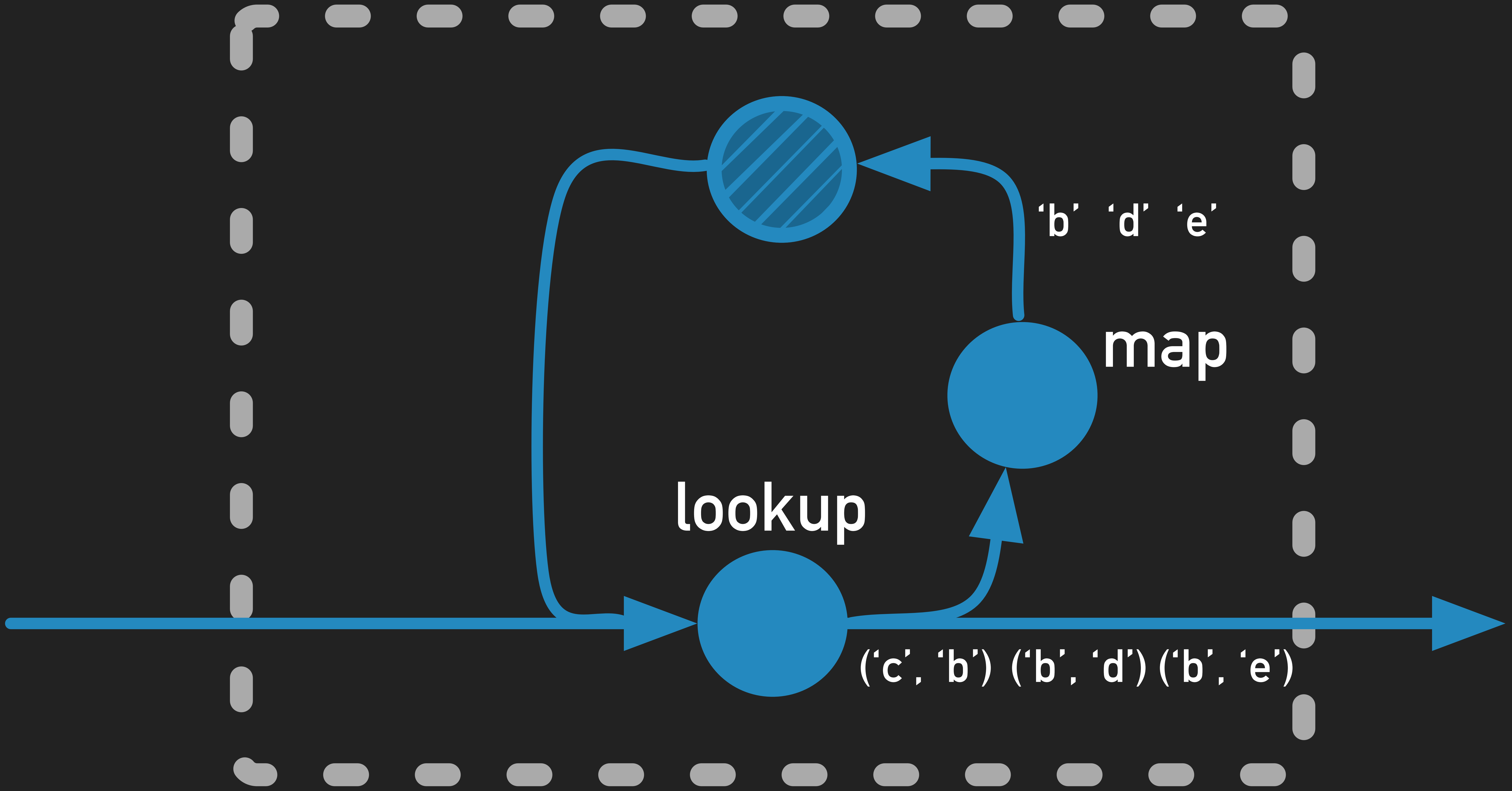


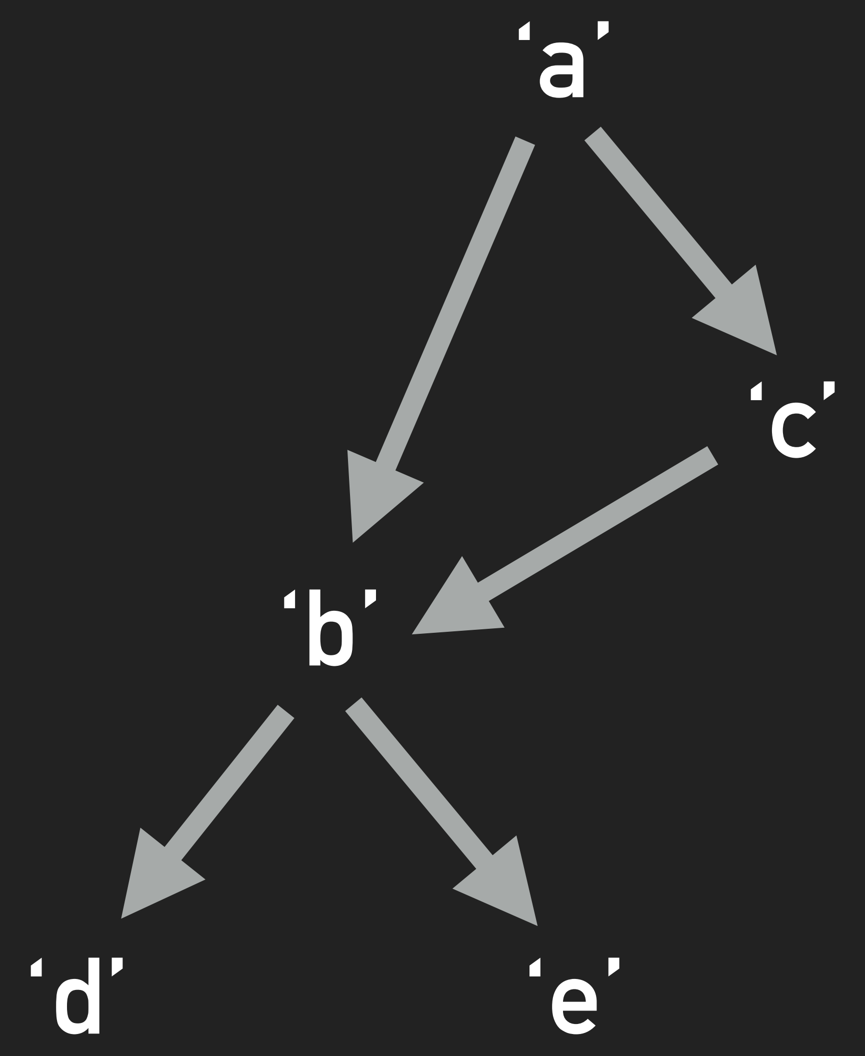
(‘a’, ‘b’)

(‘b’, ‘d’)
(‘b’, ‘e’)

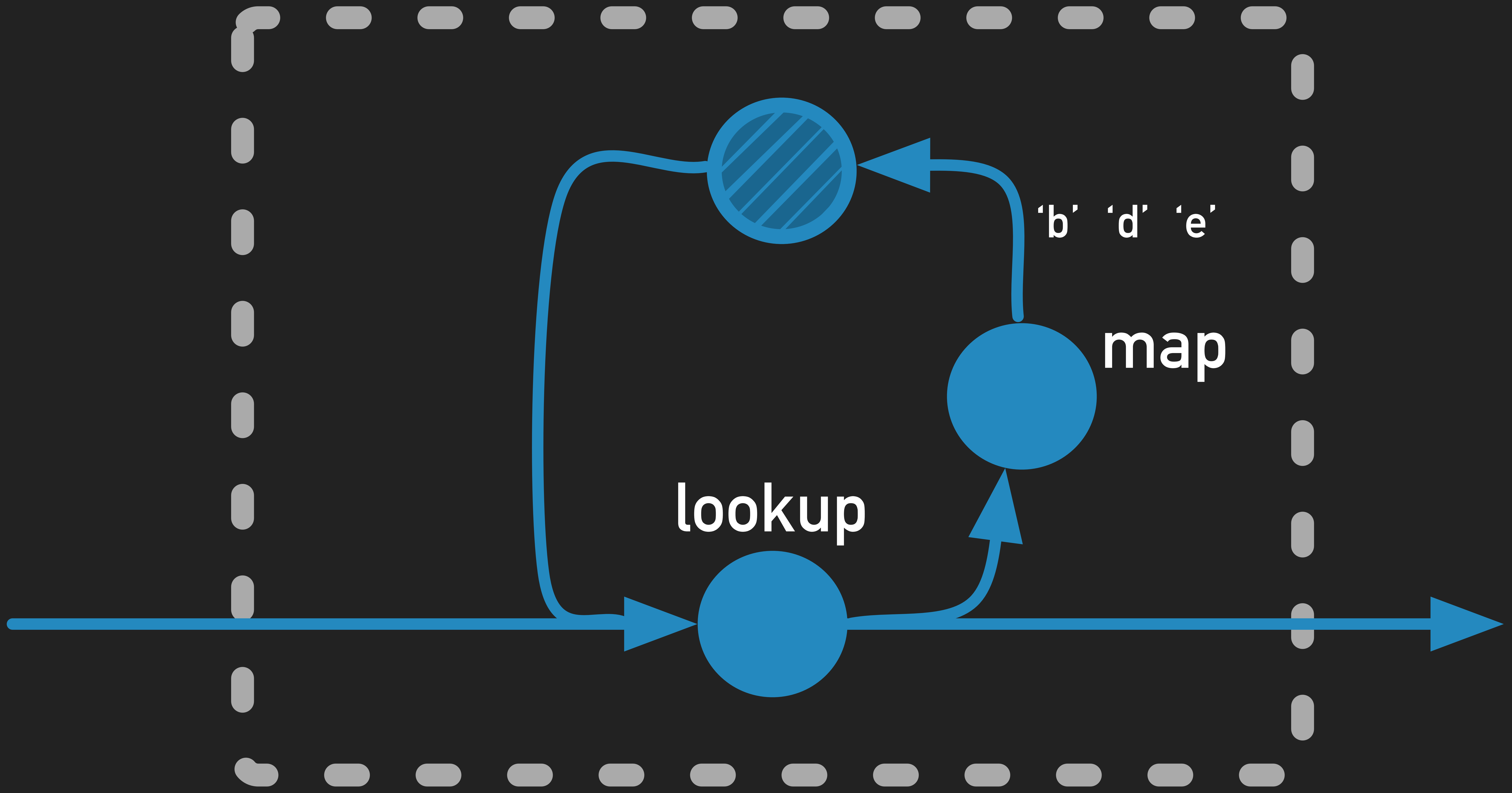
(‘a’, ‘c’)
(‘c’, ‘b’)
(‘b’, ‘d’)
(‘b’, ‘e’)



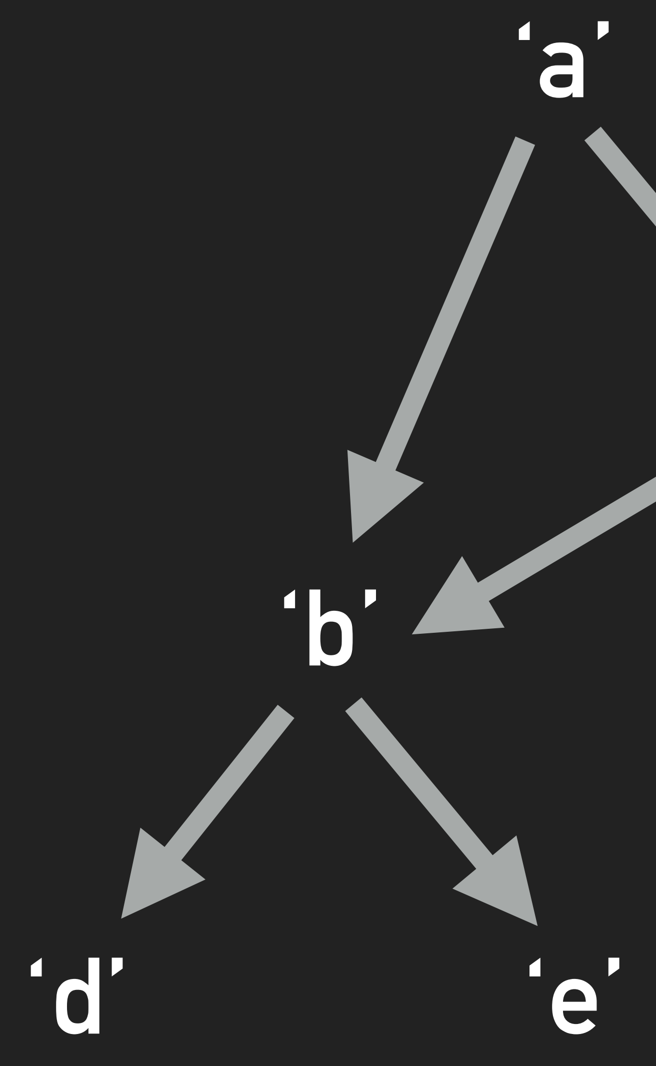
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



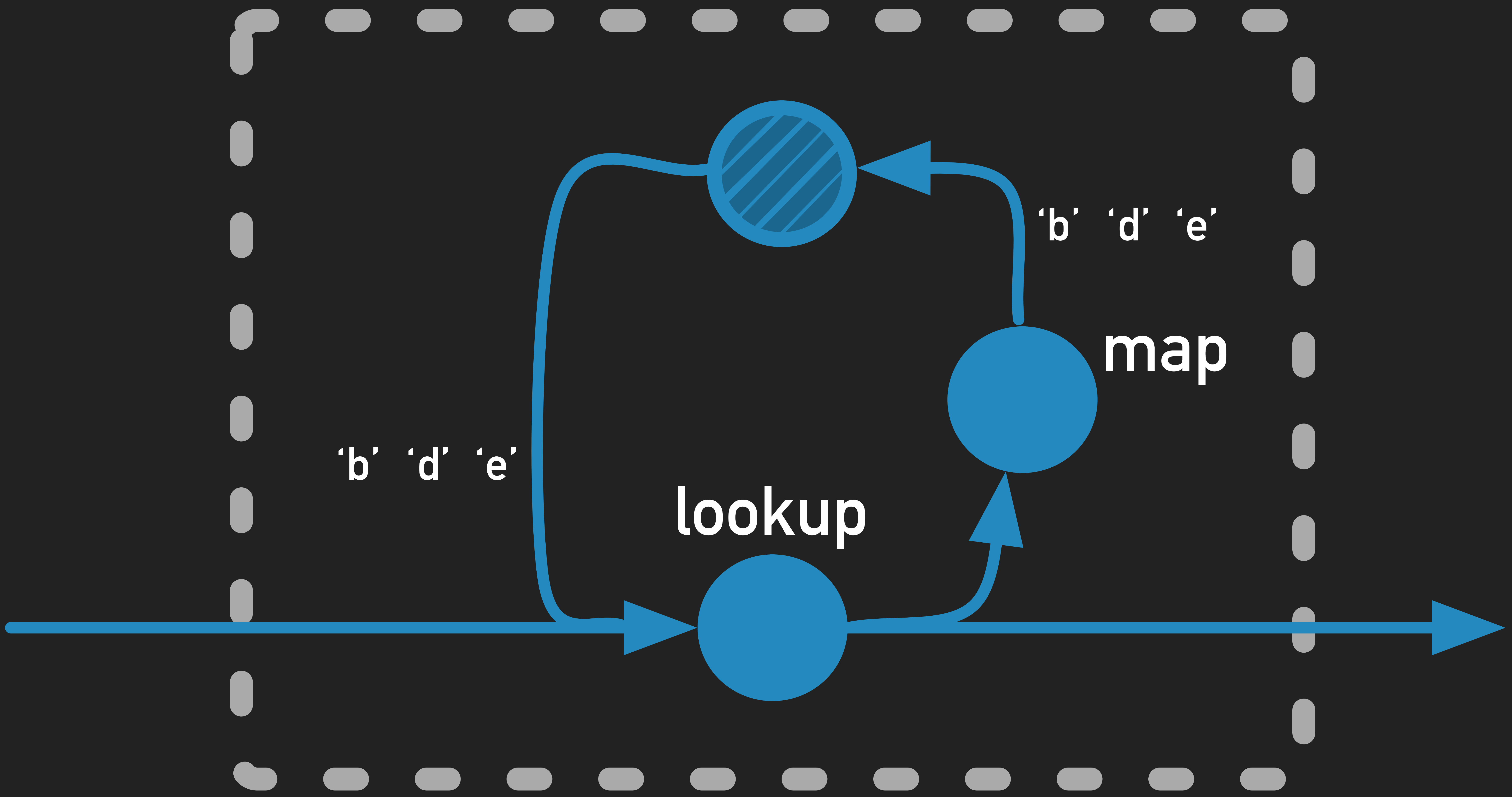
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



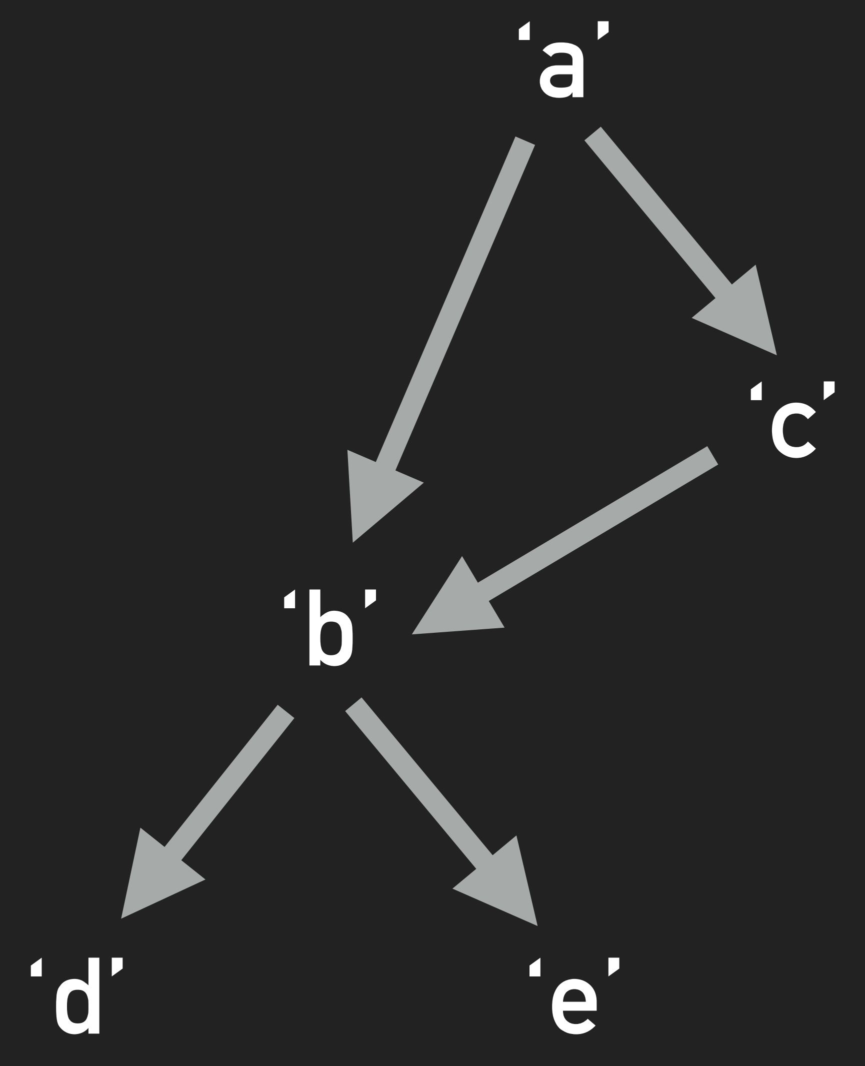
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



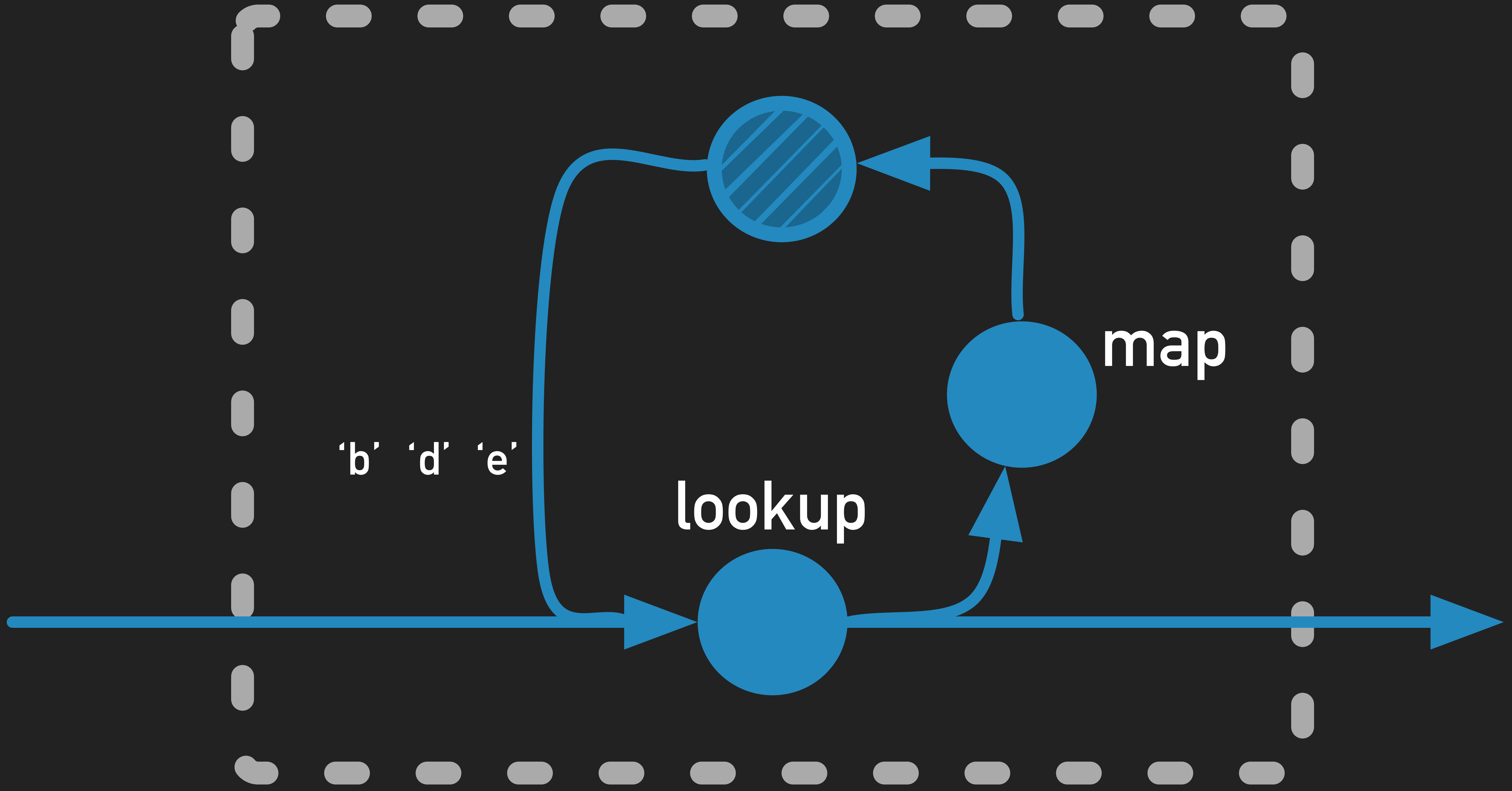
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



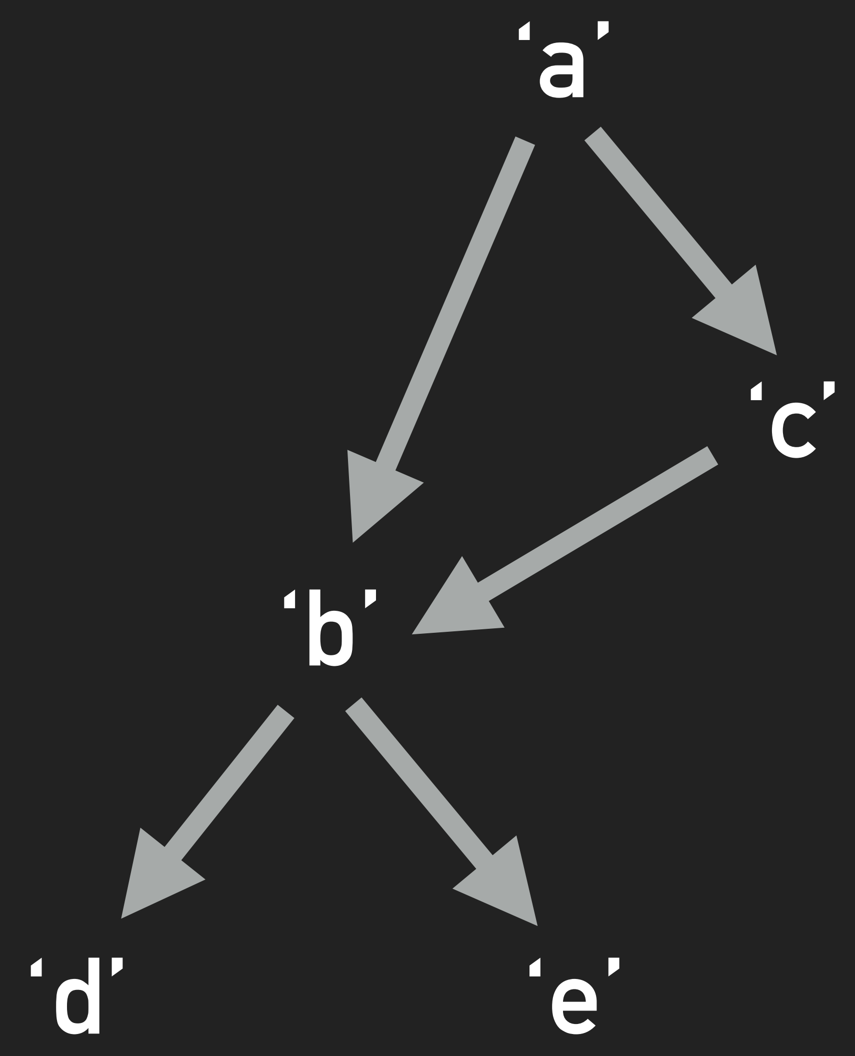
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



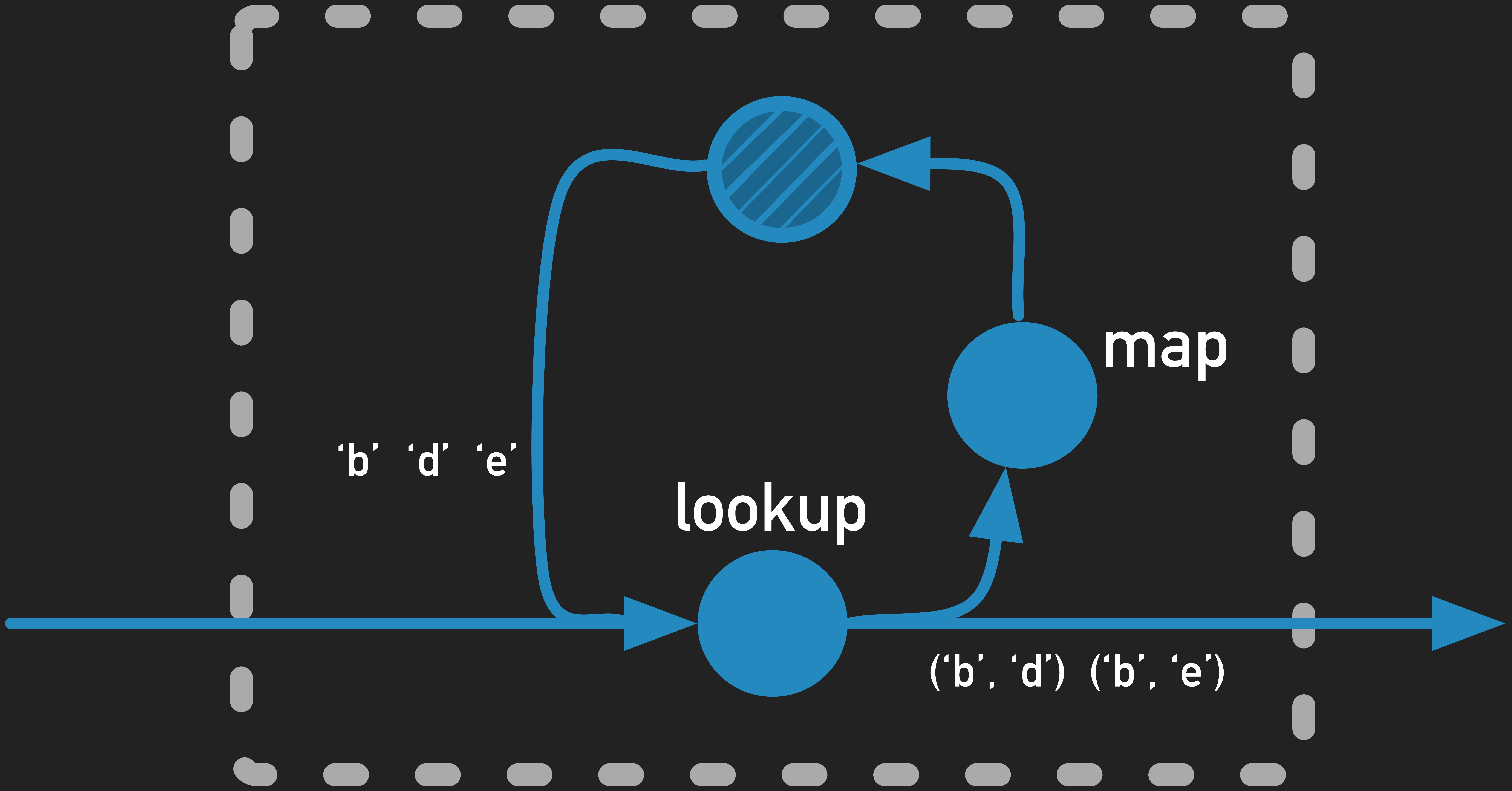
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



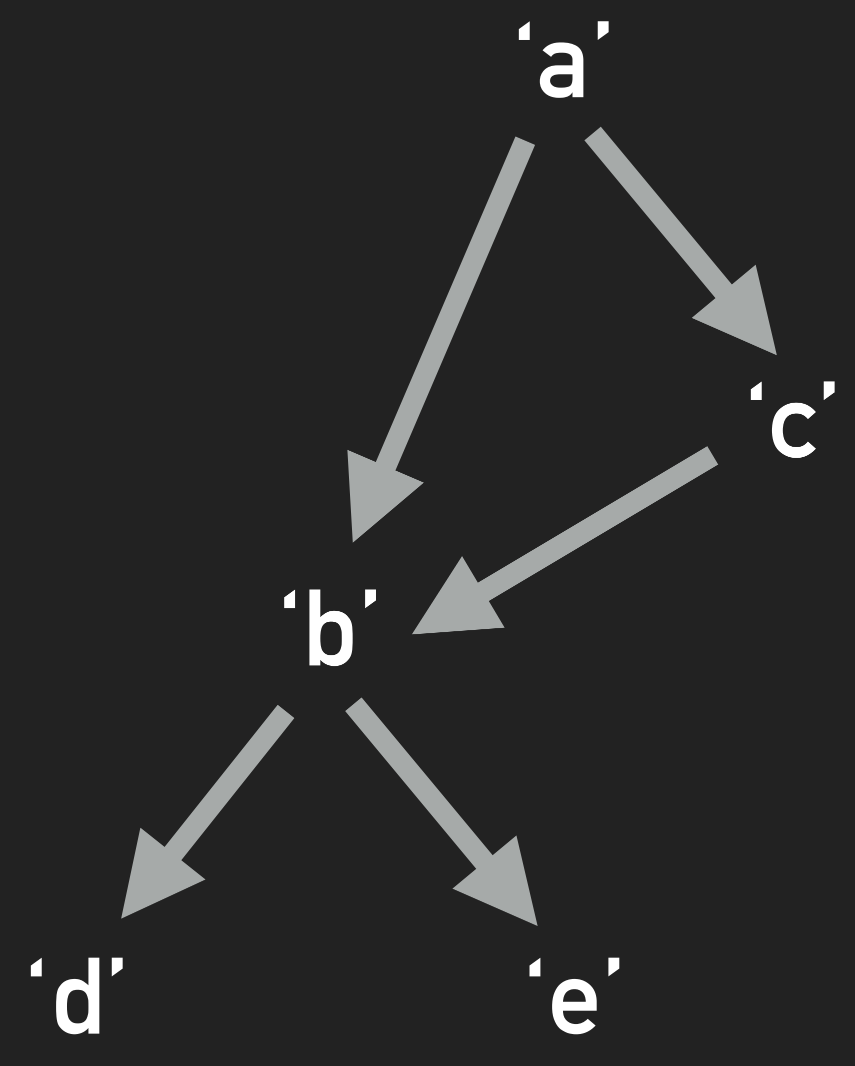
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



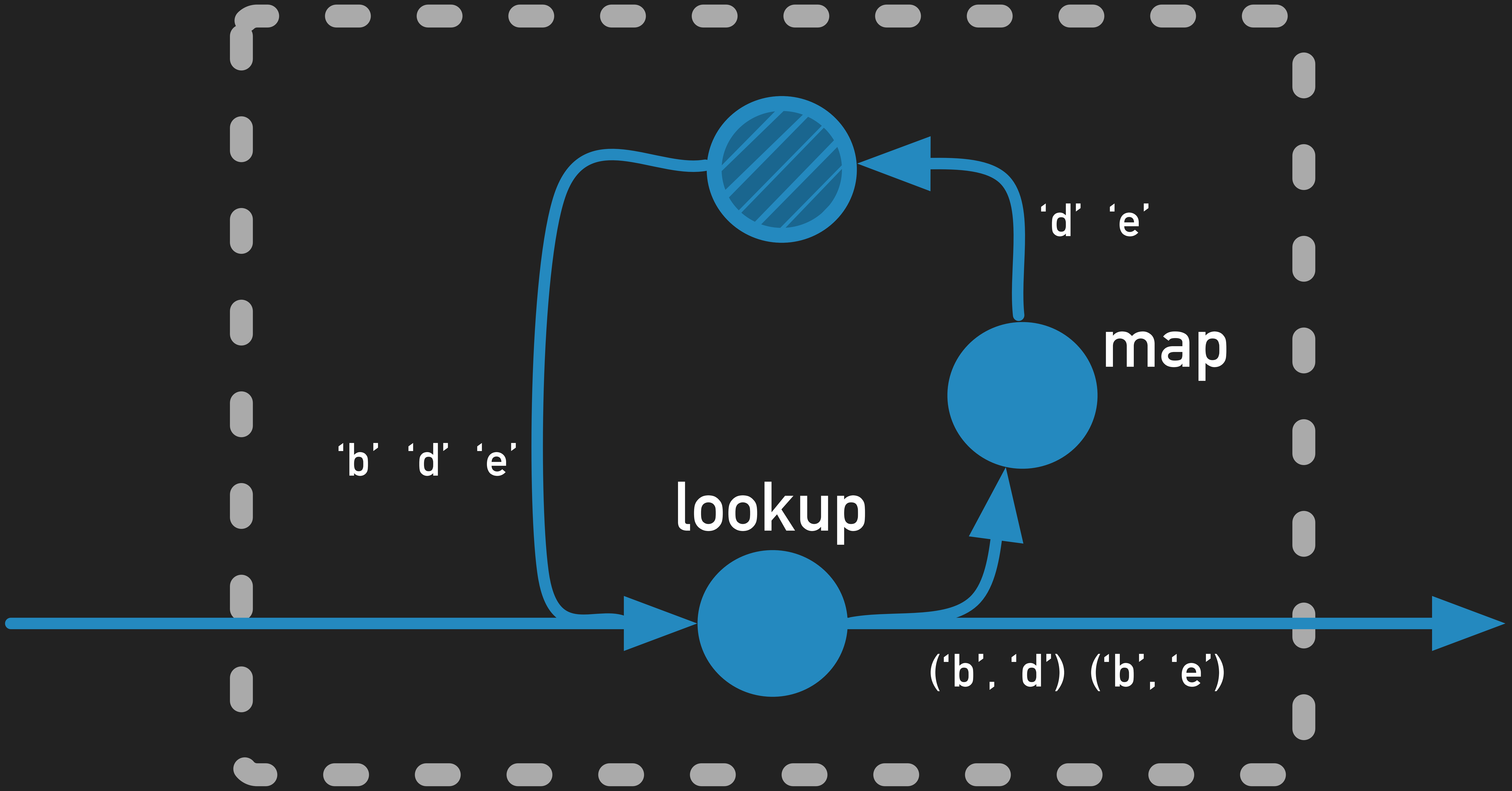
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



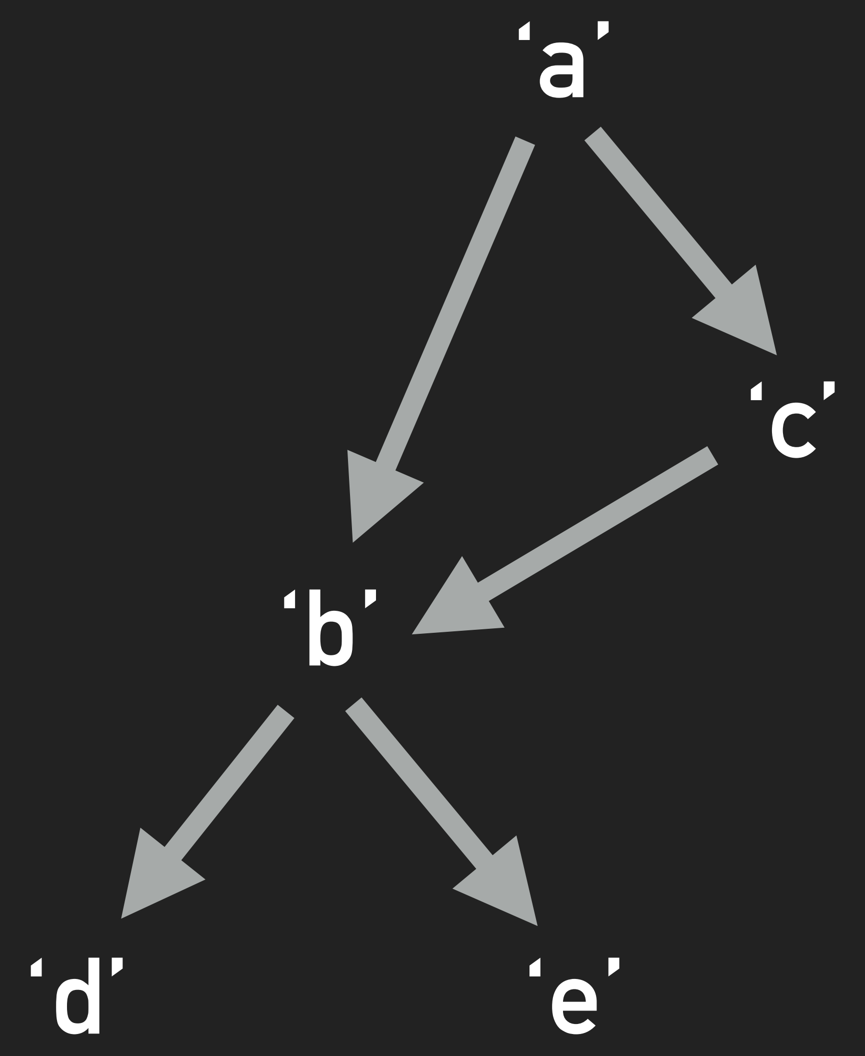
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



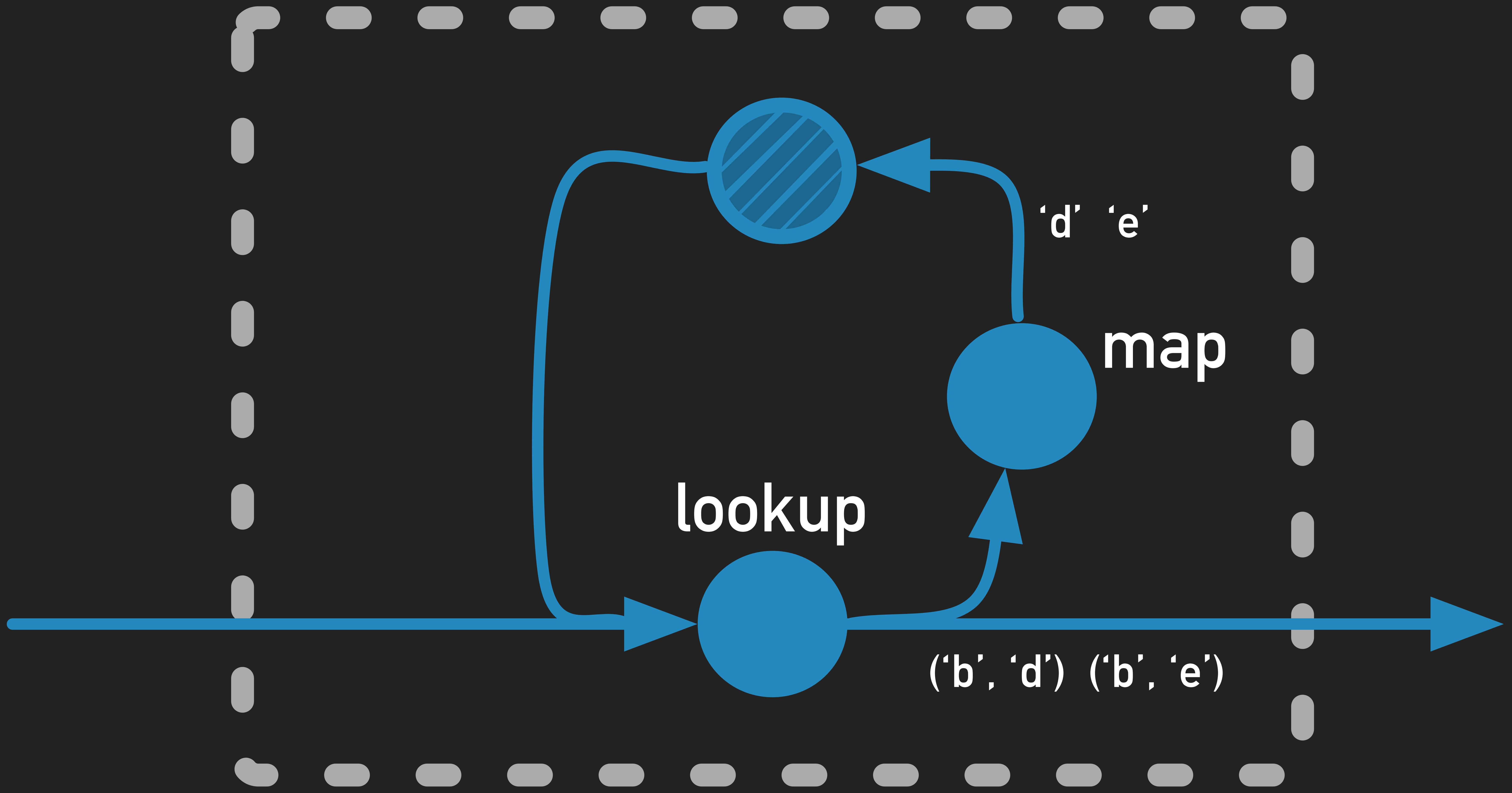
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



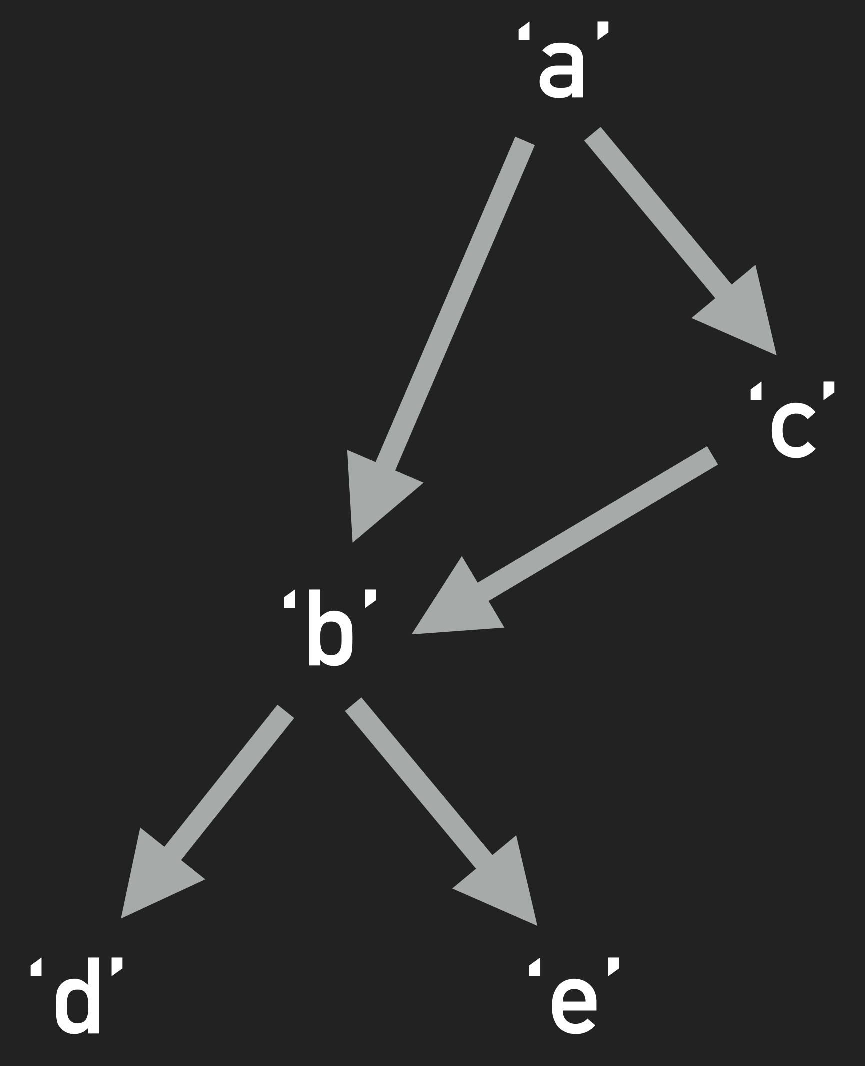
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



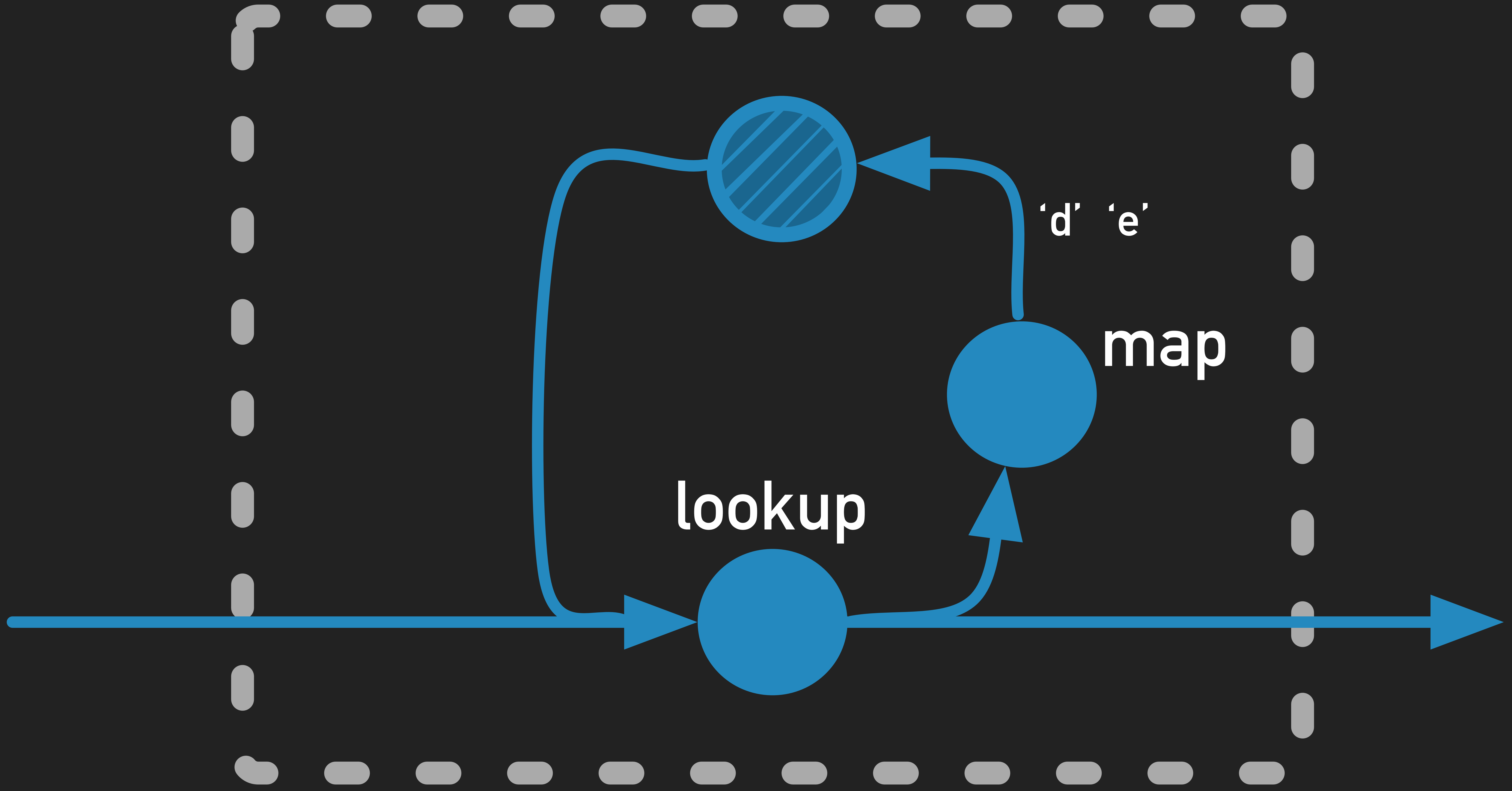
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



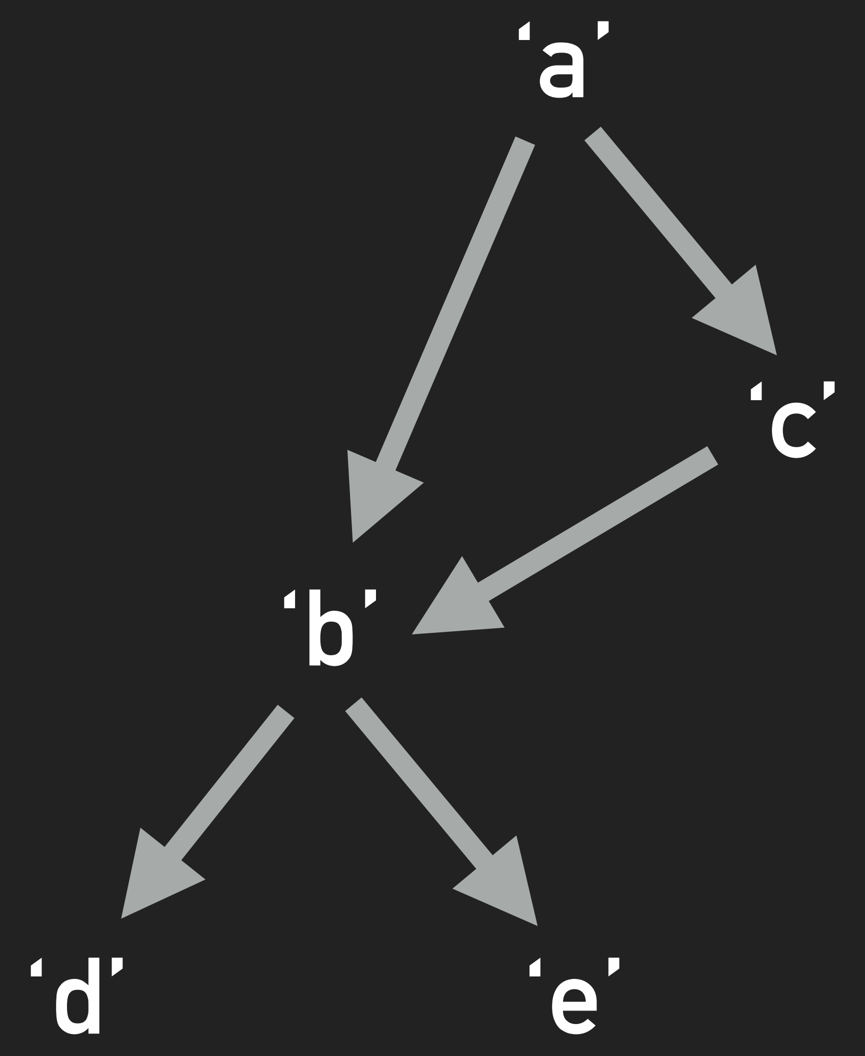
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



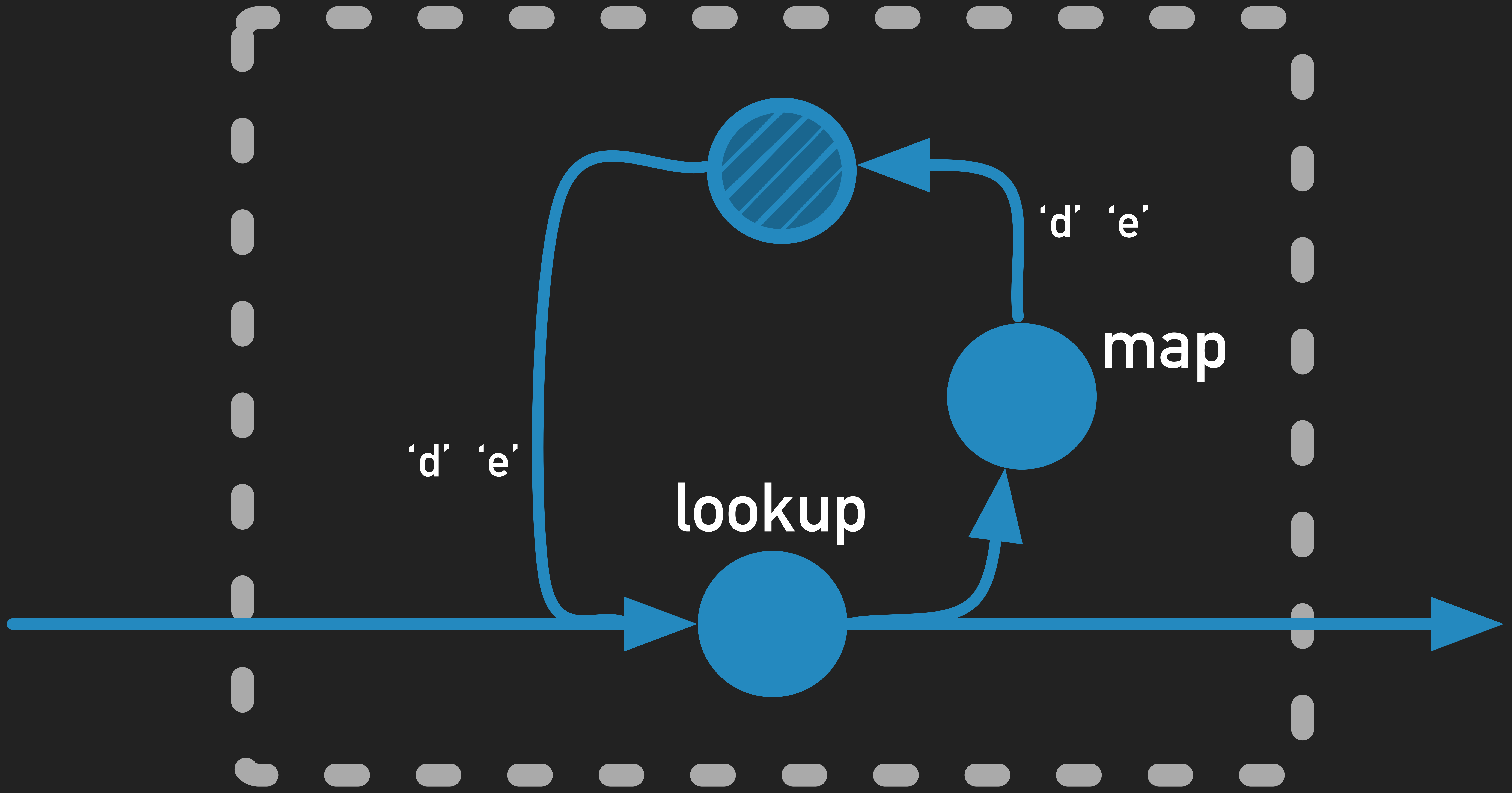
(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



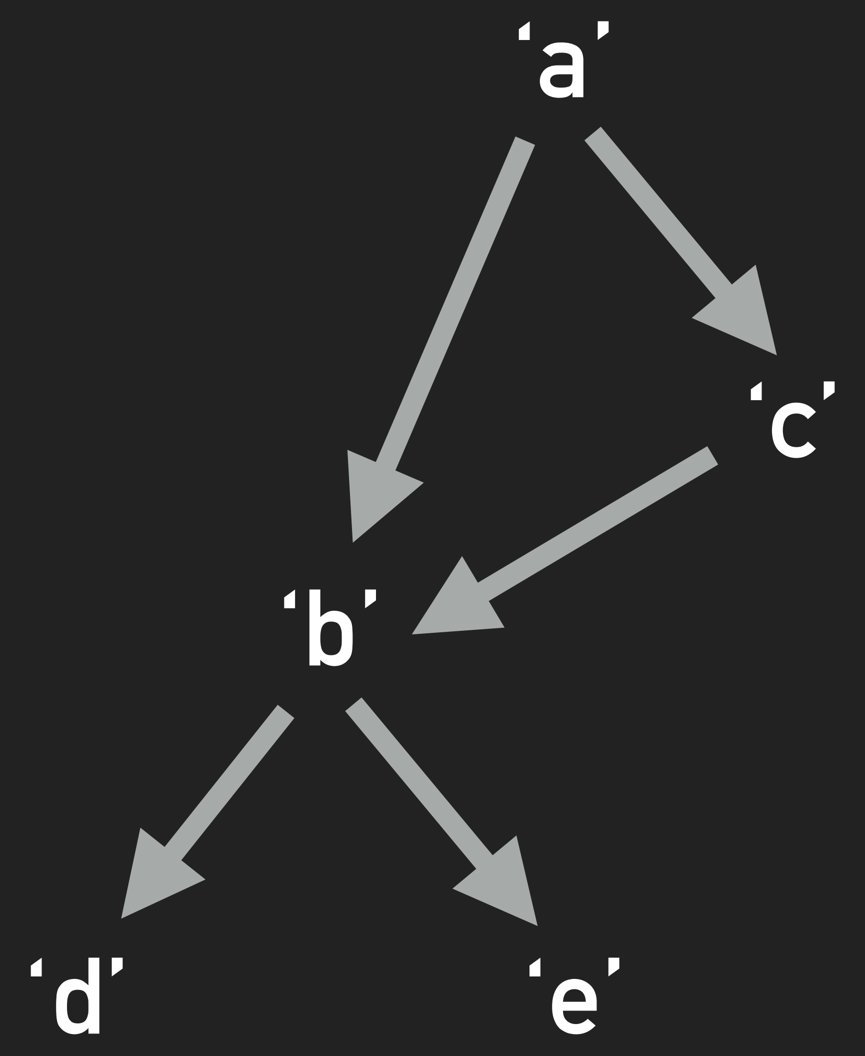
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)



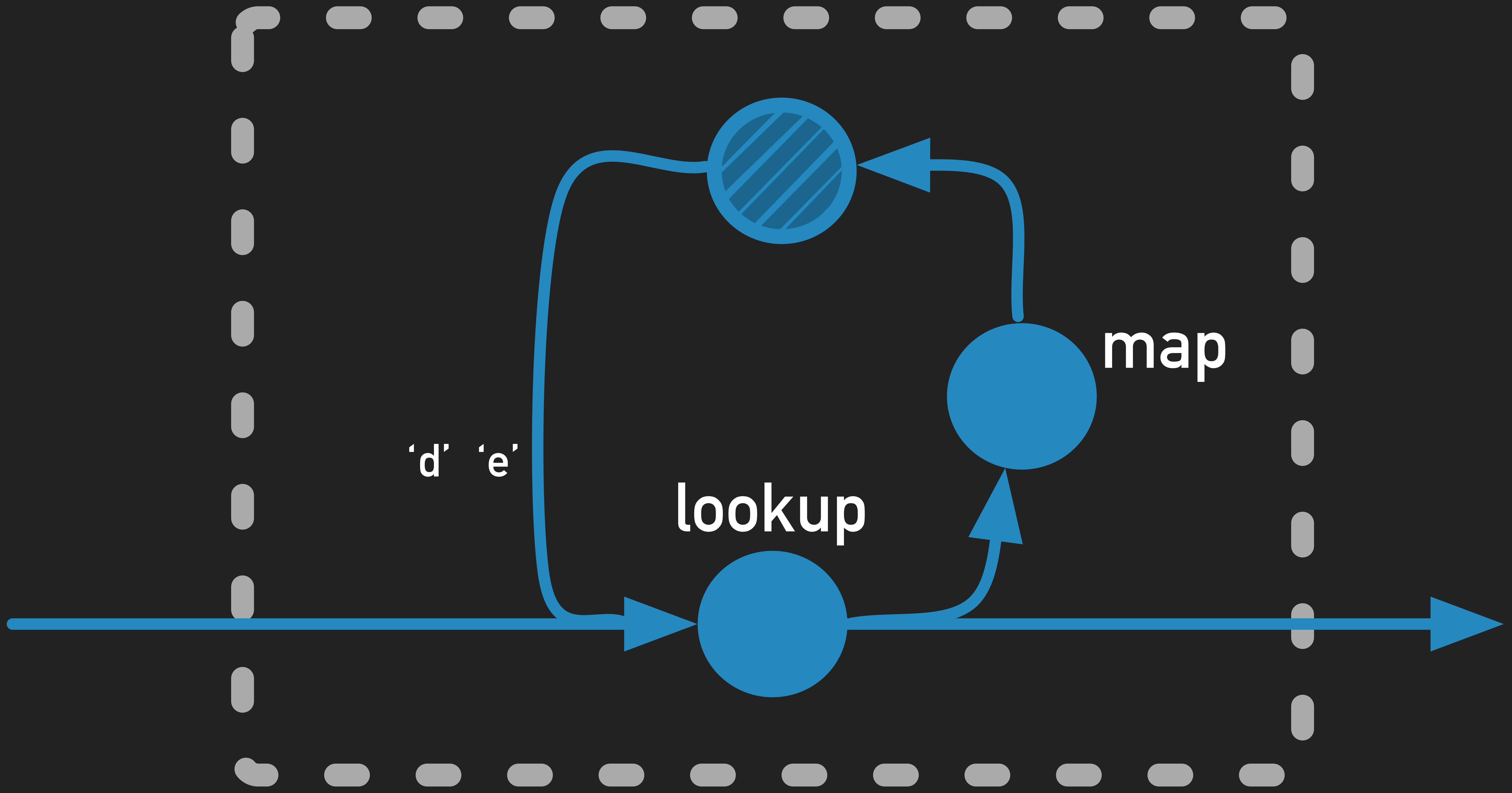
ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



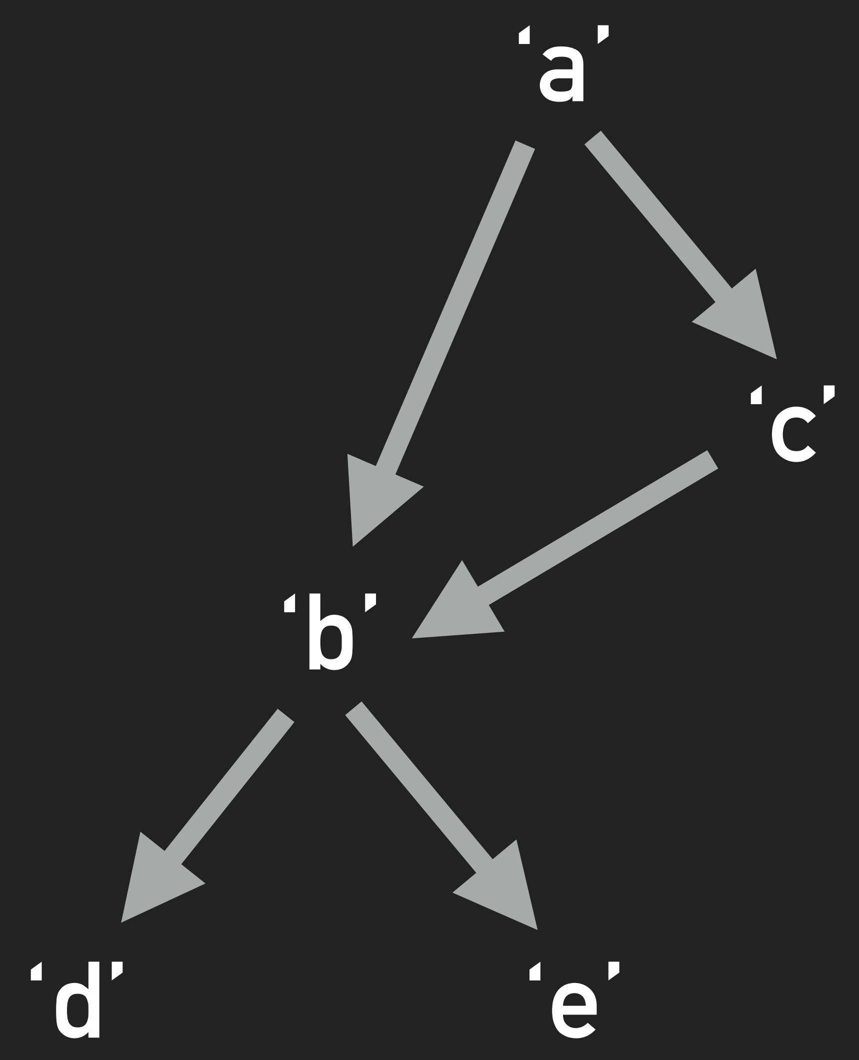
(‘a’, ‘b’)

(‘b’, ‘d’)
(‘b’, ‘e’)

(‘a’, ‘c’)
(‘c’, ‘b’)
(‘b’, ‘d’)
(‘b’, ‘e’)



ITERATIVE GRAPH COMPUTATION IN DATAFLOW.



(‘a’, ‘b’)	(‘a’, ‘c’)
	(‘c’, ‘b’)
(‘b’, ‘d’)	(‘b’, ‘d’)
(‘b’, ‘e’)	(‘b’, ‘e’)