CELLULAR AUTOMATA

Pseudo Random Number Generators and Their Resistance to Asynchrony

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CA AS PRNG

t=0

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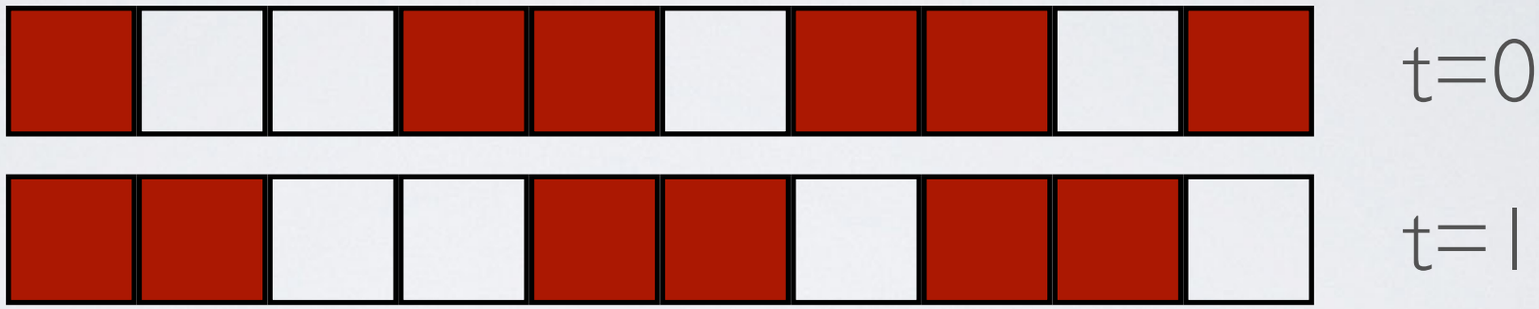

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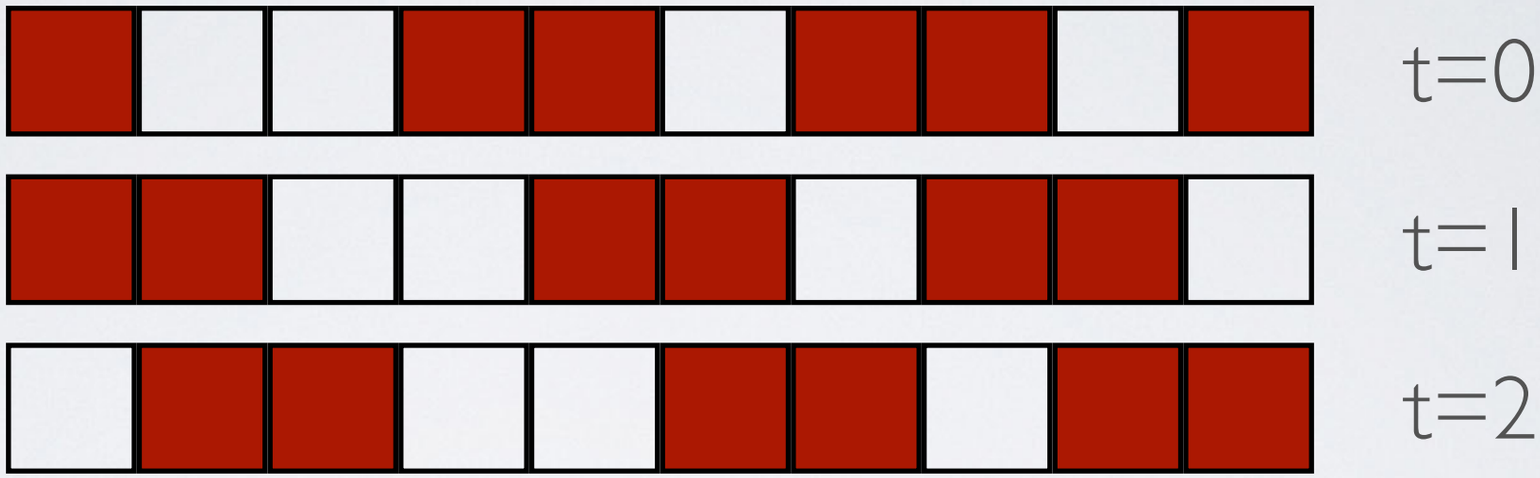

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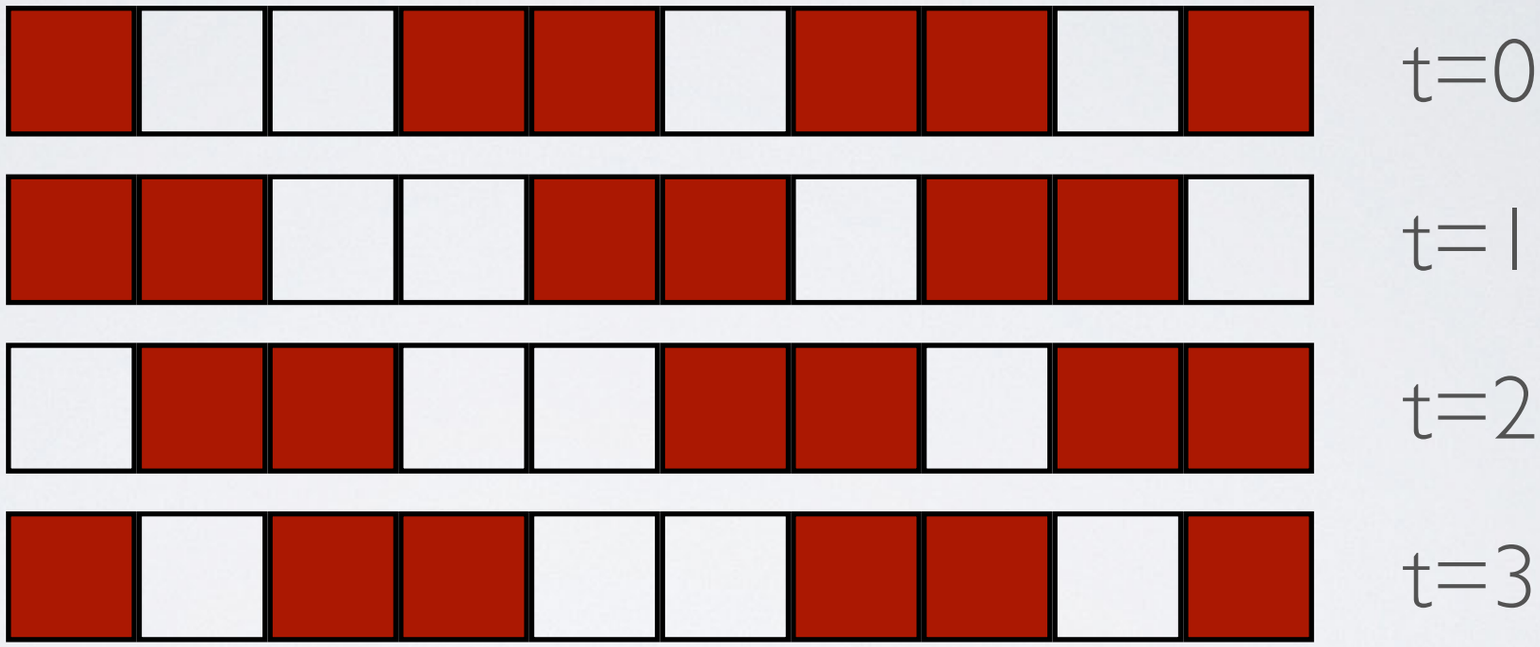

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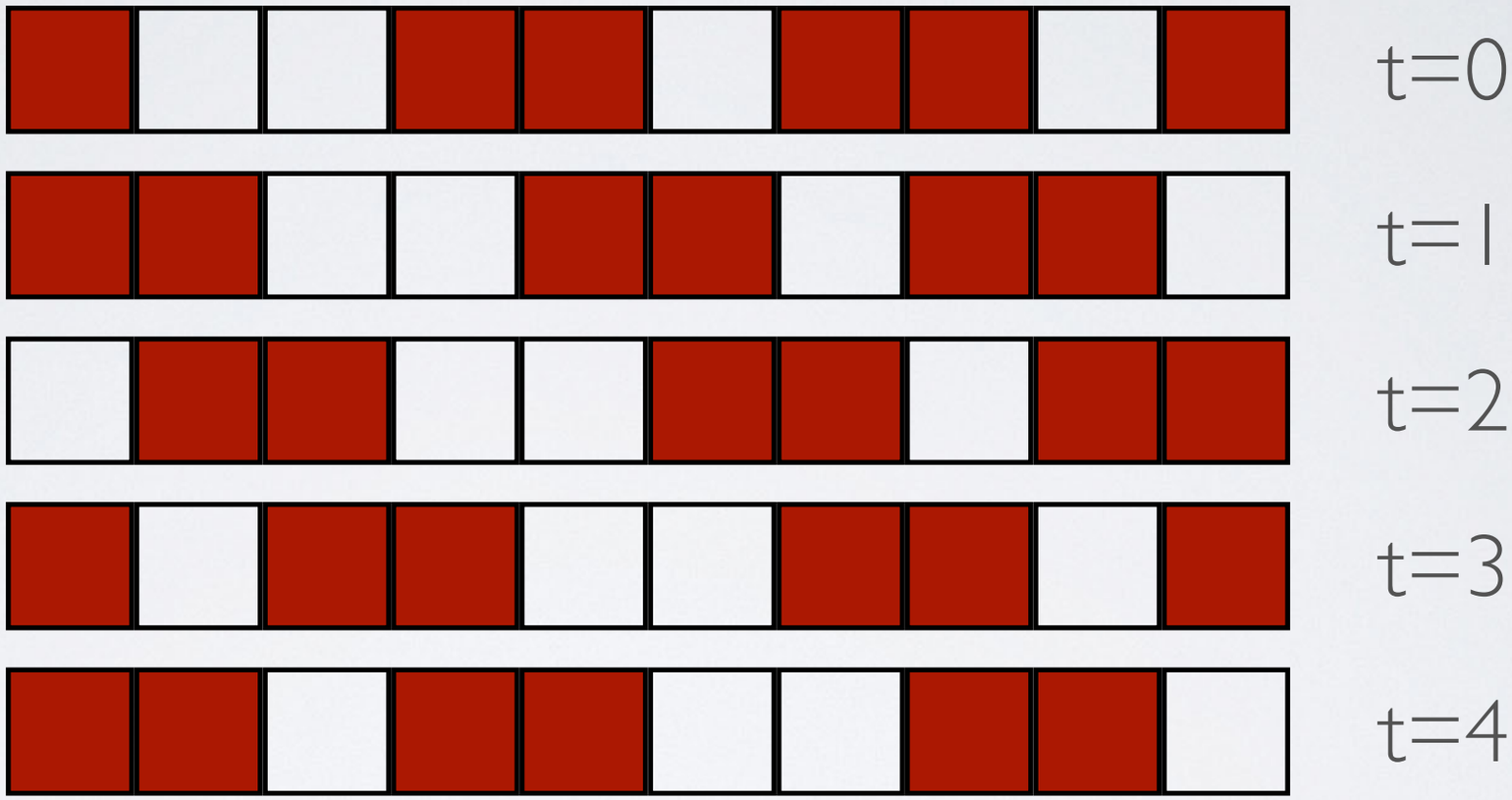

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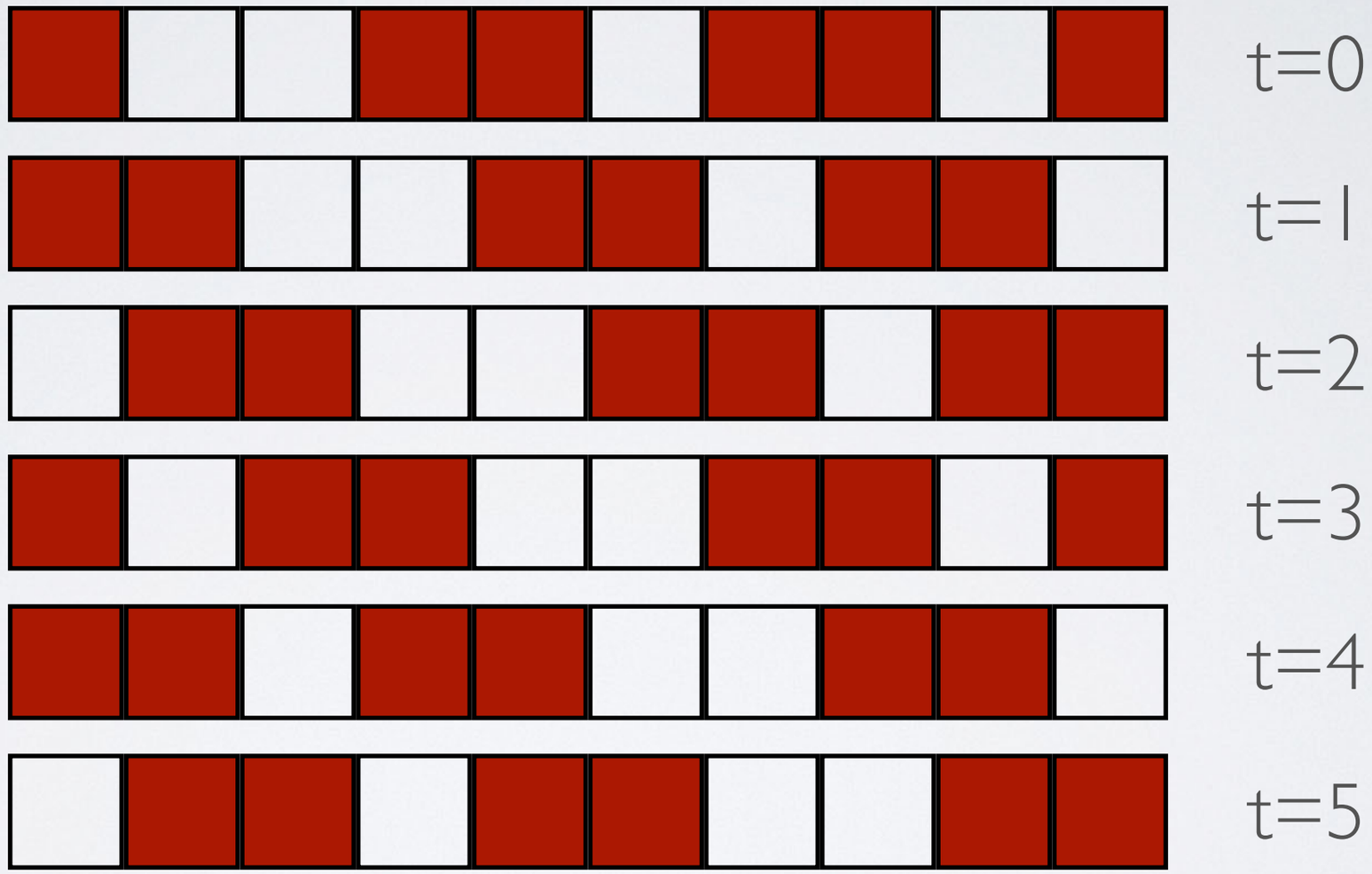

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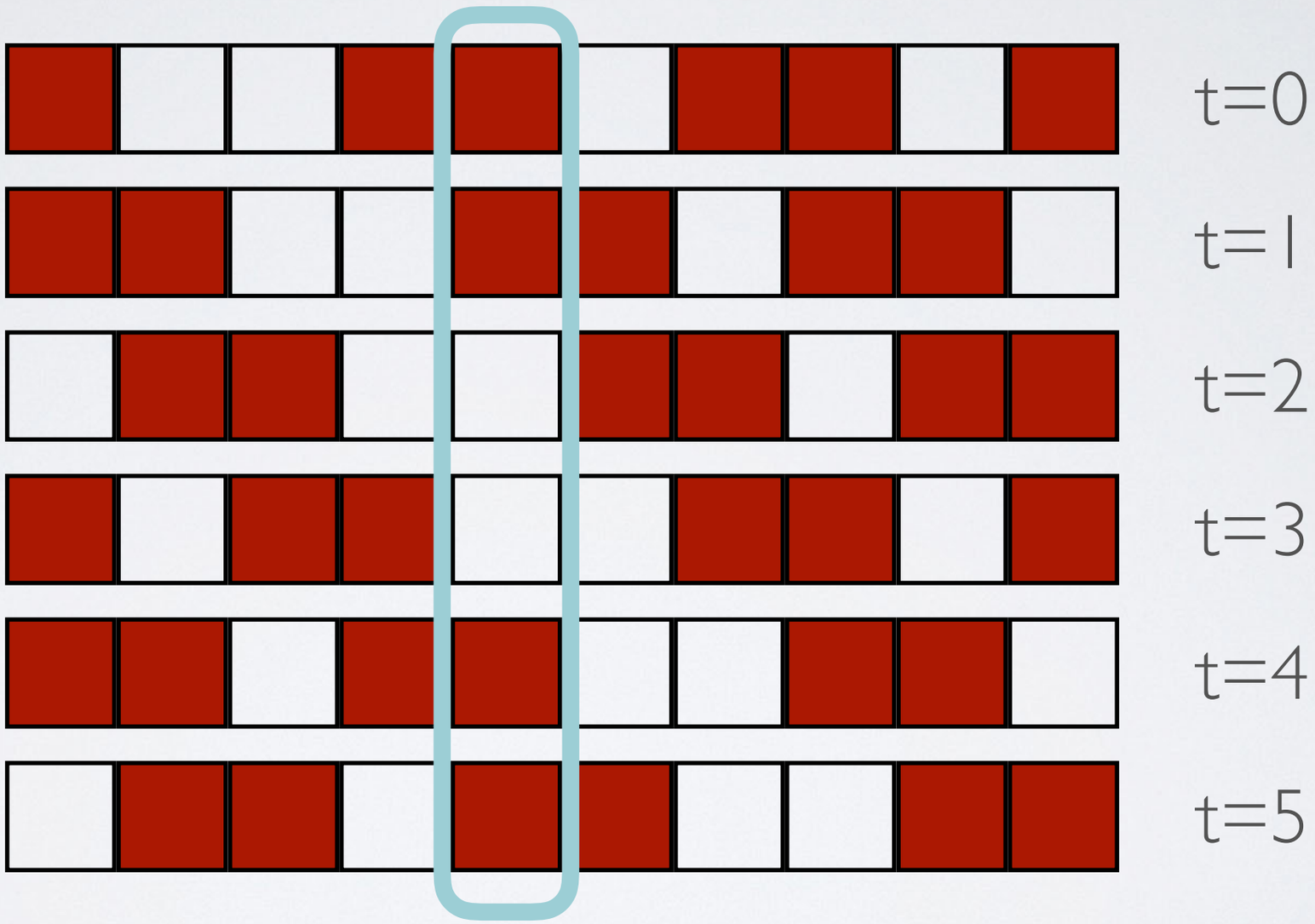

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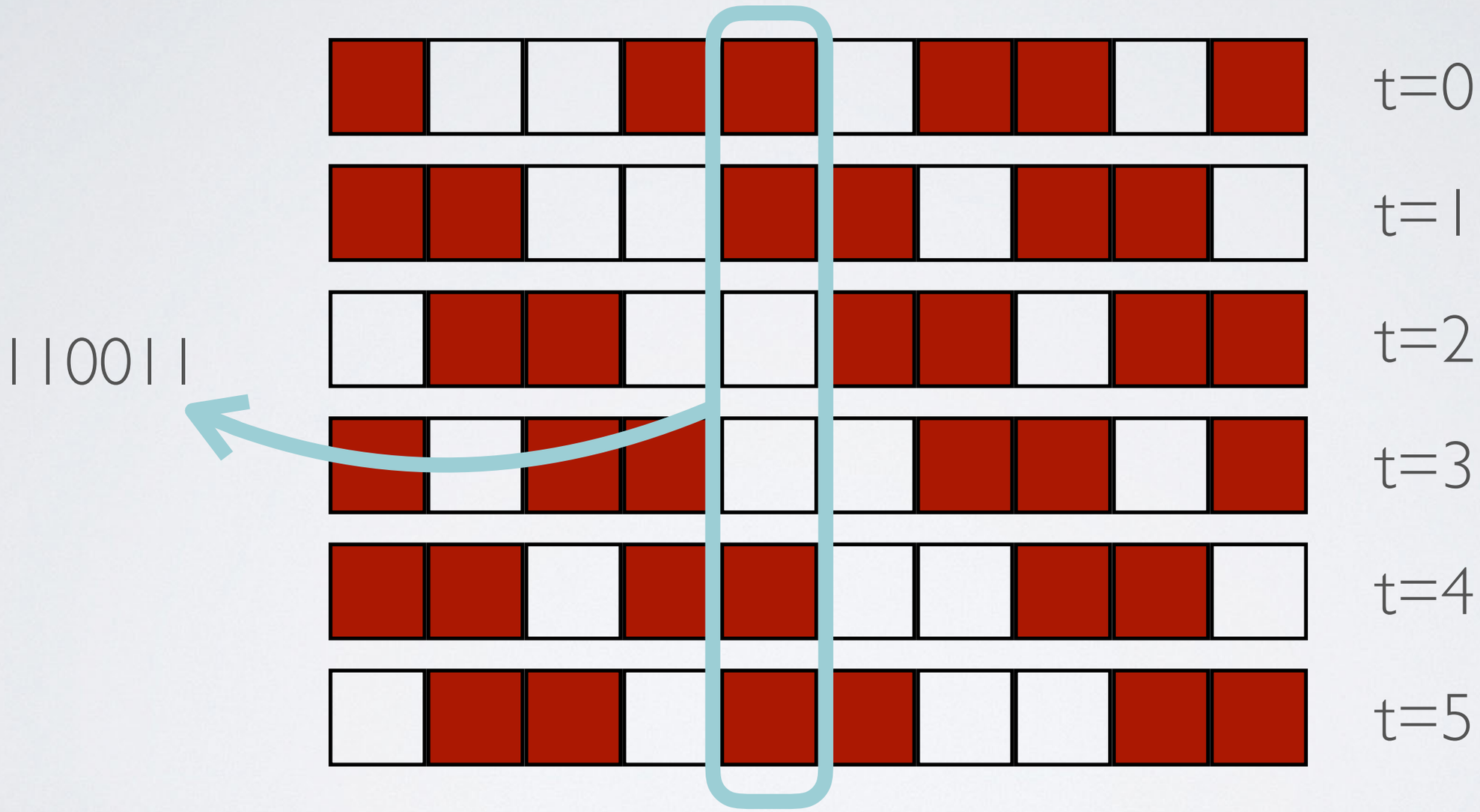

WHY ARE THEY USEFUL?

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- PRNG are essential cryptographic primitives
- CA can be fast!
- But, how can they be attacked?

GOOD RULES FOR PRNG

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- Balanced

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- Balanced
- Non-linear

GOOD RULES FOR PRNG

- Balanced
- Non-linear
- First order correlation immune

SCENARIO

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CA-based PRNG

SCENARIO

CA-based PRNG

Encrypted Message

SCENARIO

CA-based PRNG

Encrypted Message

SCENARIO

I find your lack of asynchrony disturbing

CA-based PRNG

Encrypted Message

SCENARIO

I find your lack of asynchrony disturbing

ACA-based PRNG

~~CA-based PRNG~~

Encrypted Message

ASYNCHRONY

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- Not all cells update at the same time

ASYNCHRONY

- Not all cells update at the same time
- Many kinds of asynchronous CA

ASYNCHRONY

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- Many kinds of asynchronous CA
- Here: "block" asynchrony

BLOCK ASYNCHRONY

k=2

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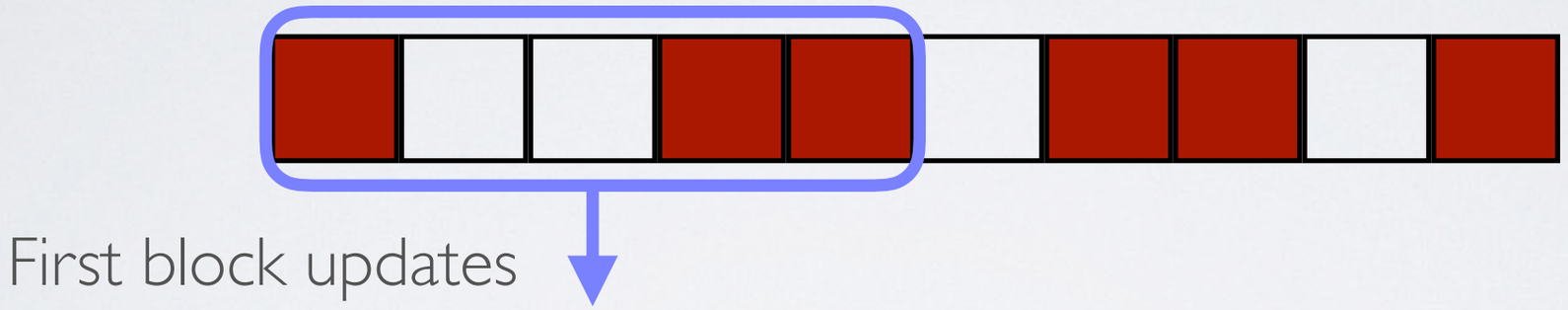

First block updates

BLOCK ASYNCHRONY

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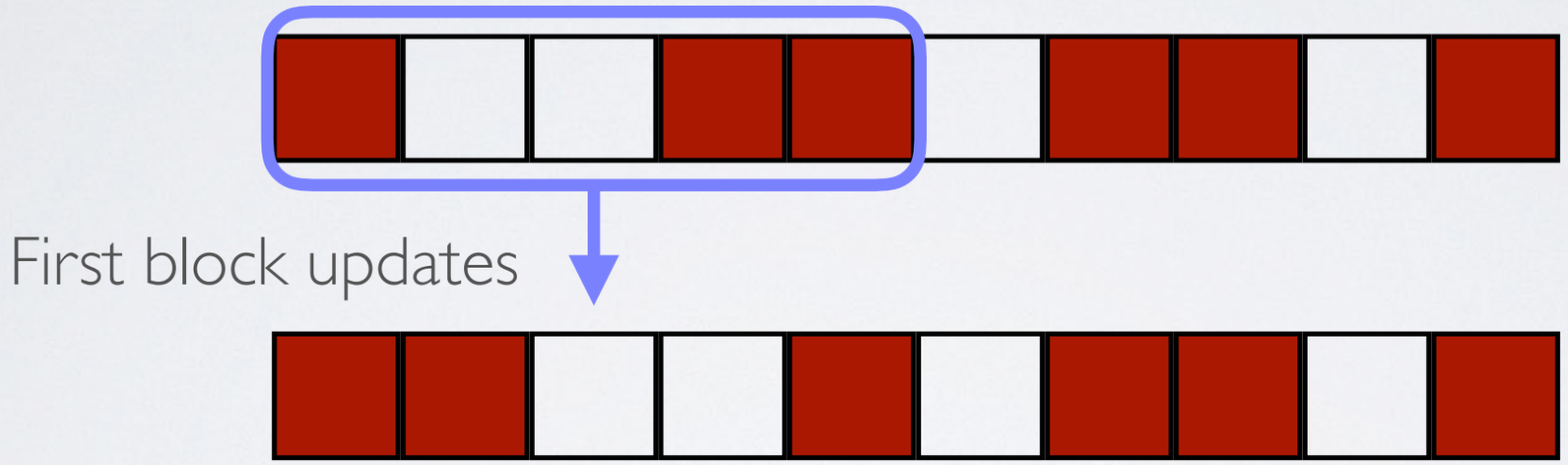

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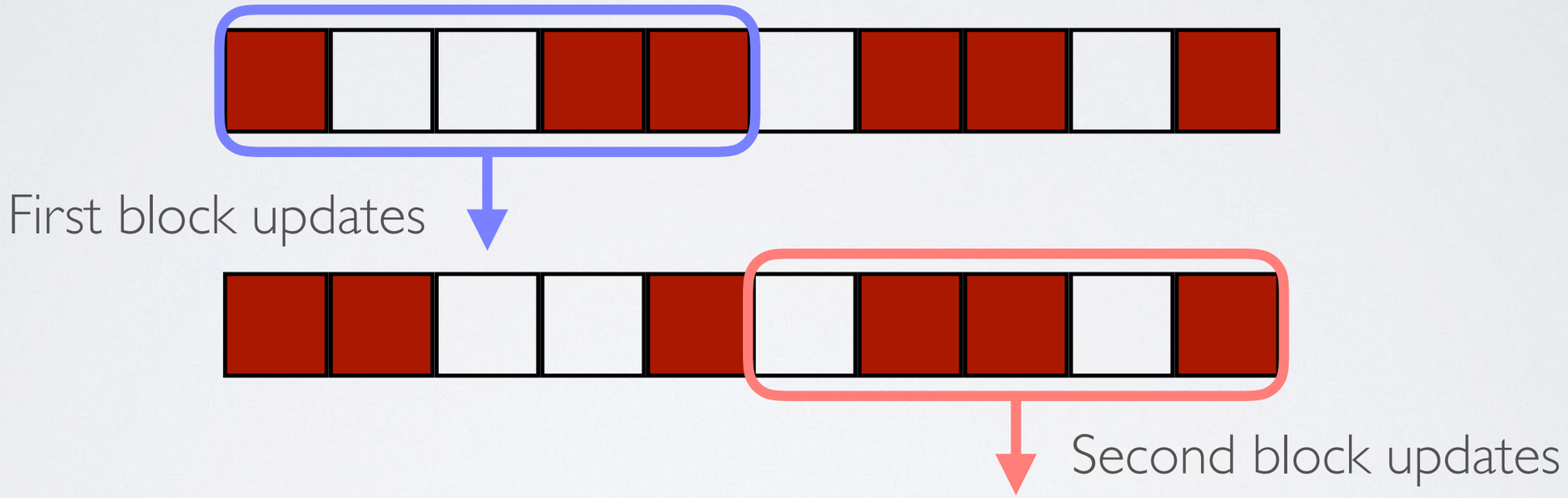

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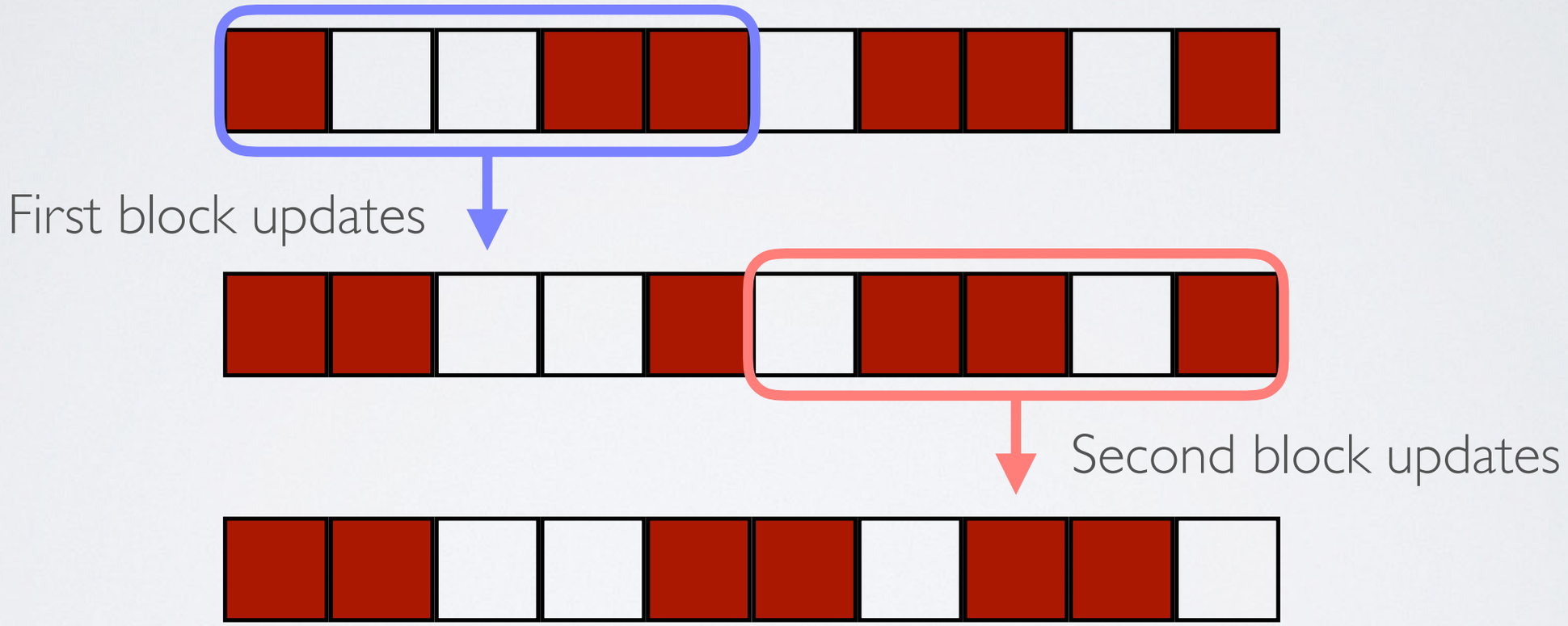

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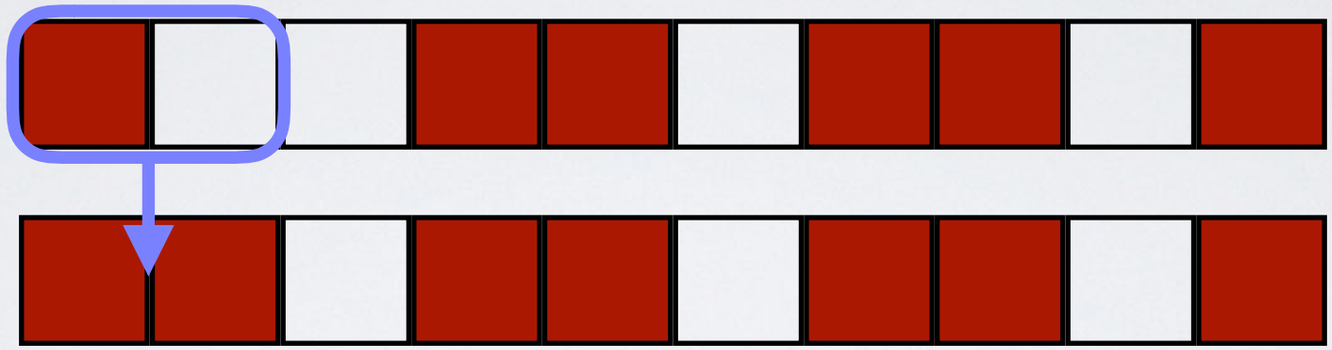

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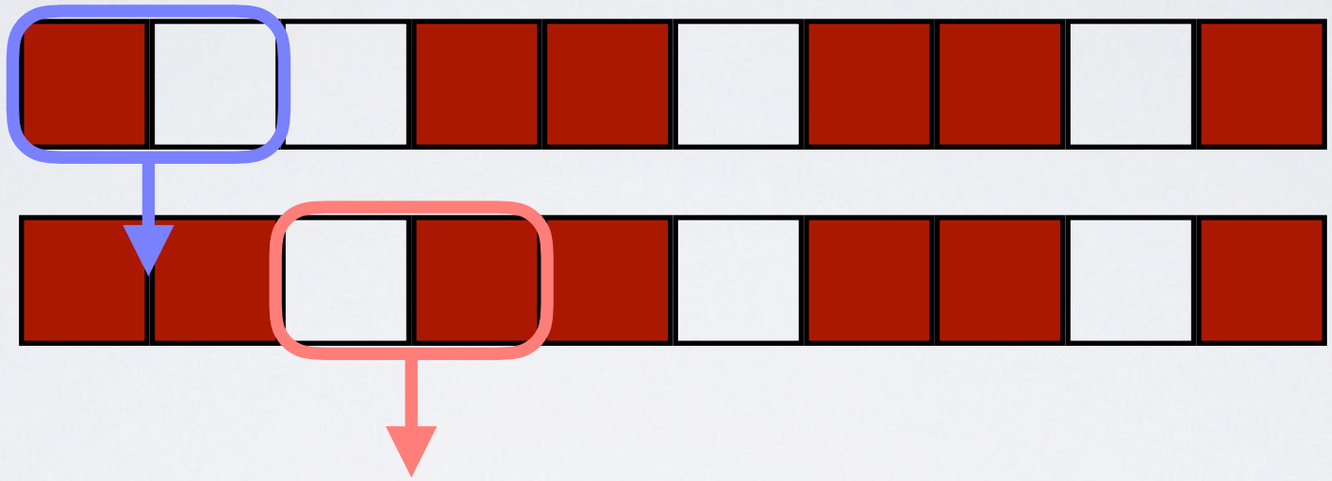

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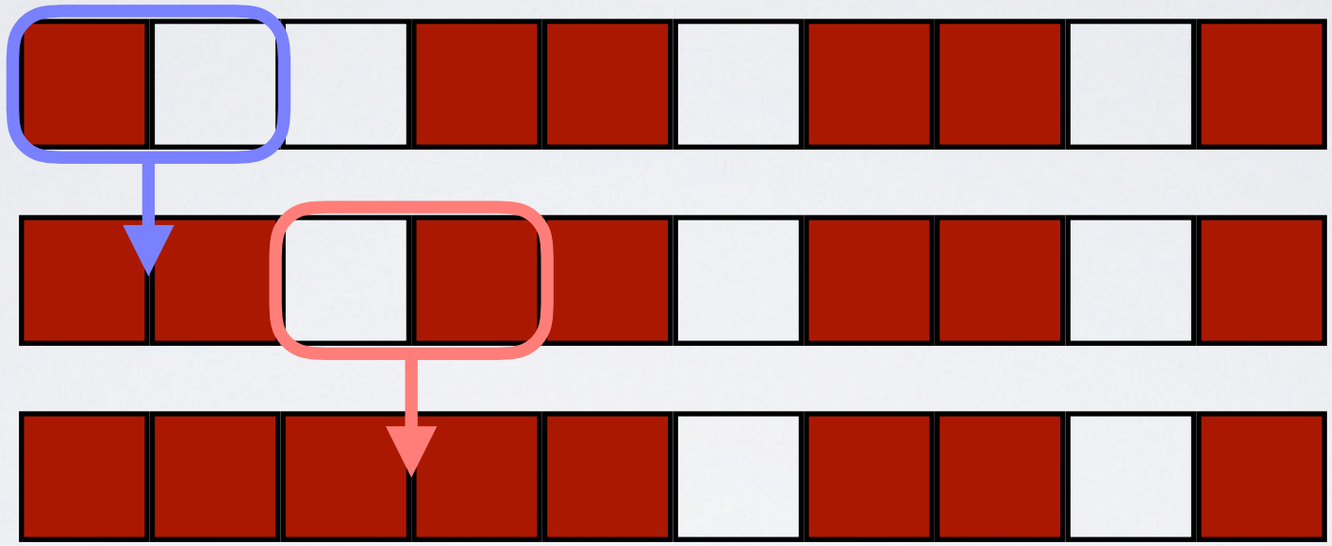

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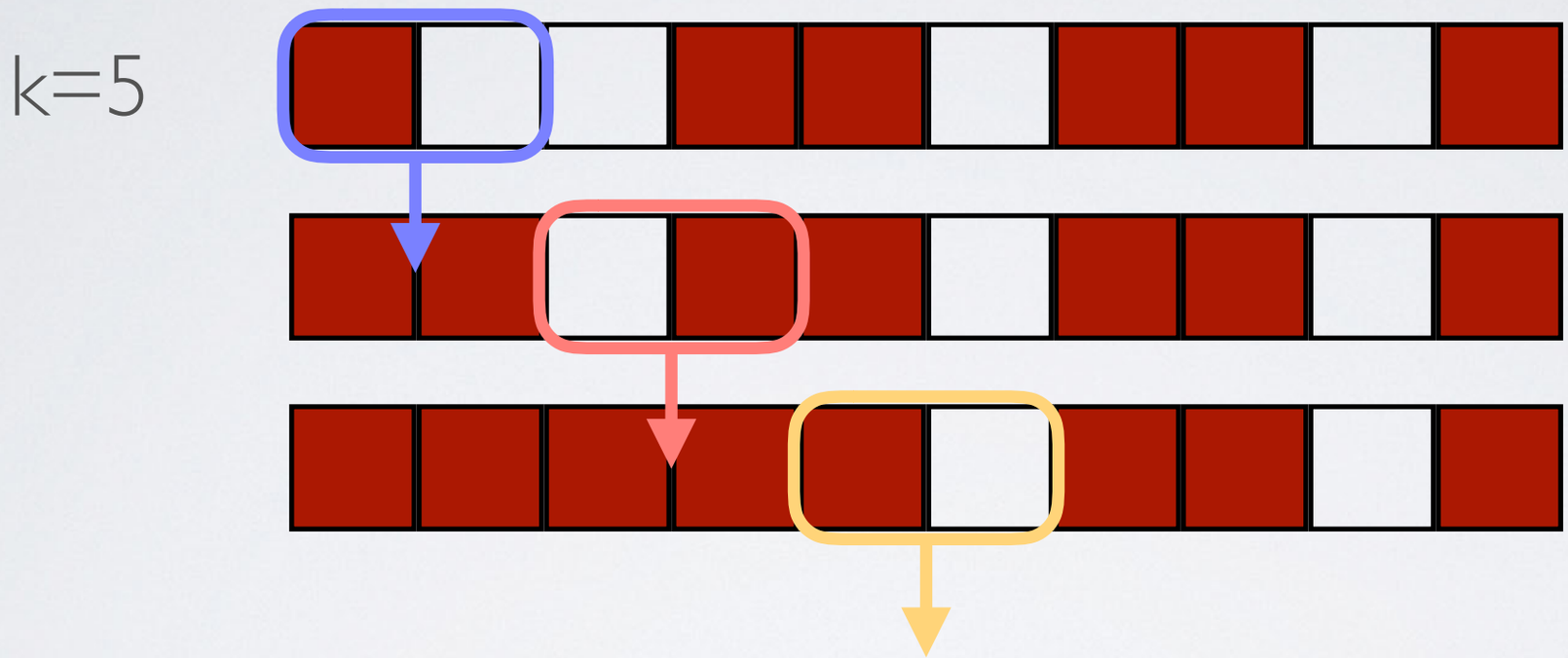

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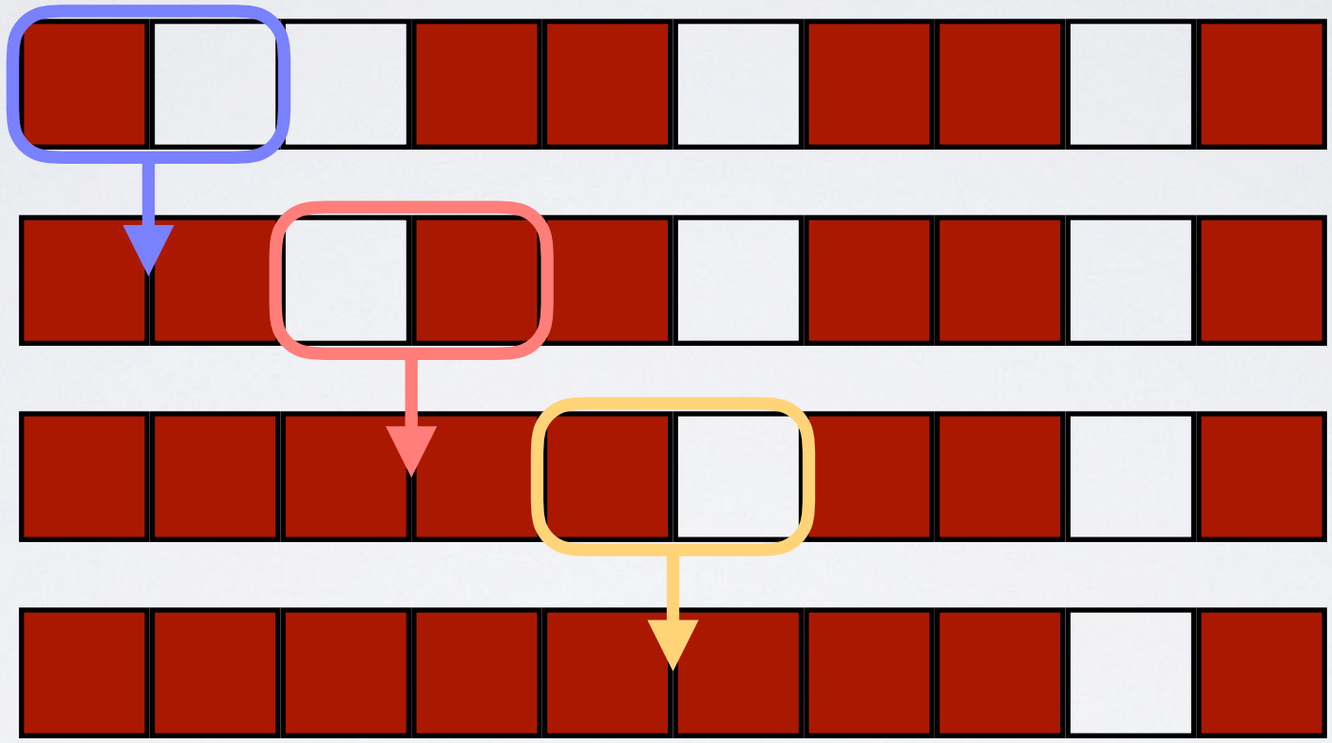

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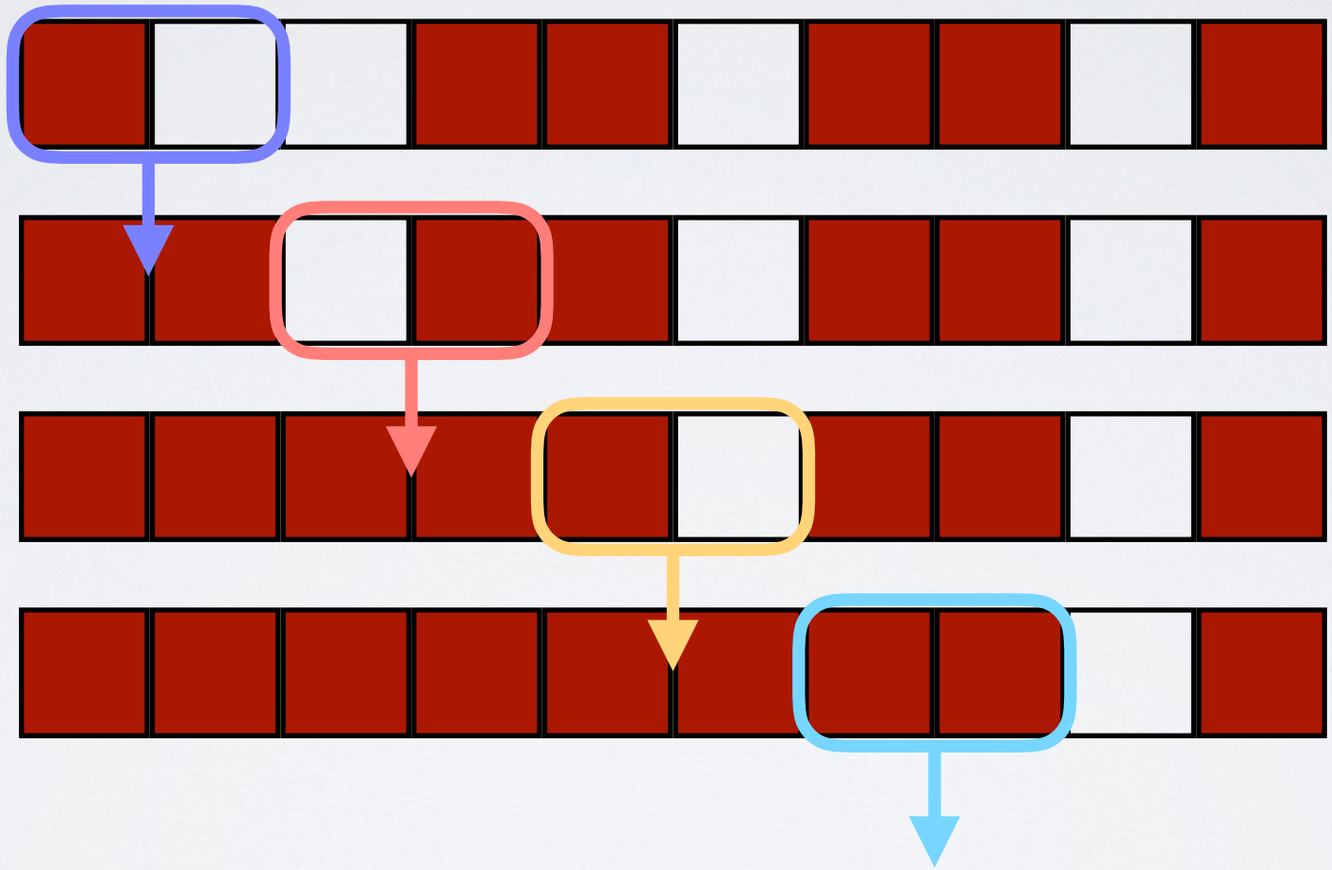

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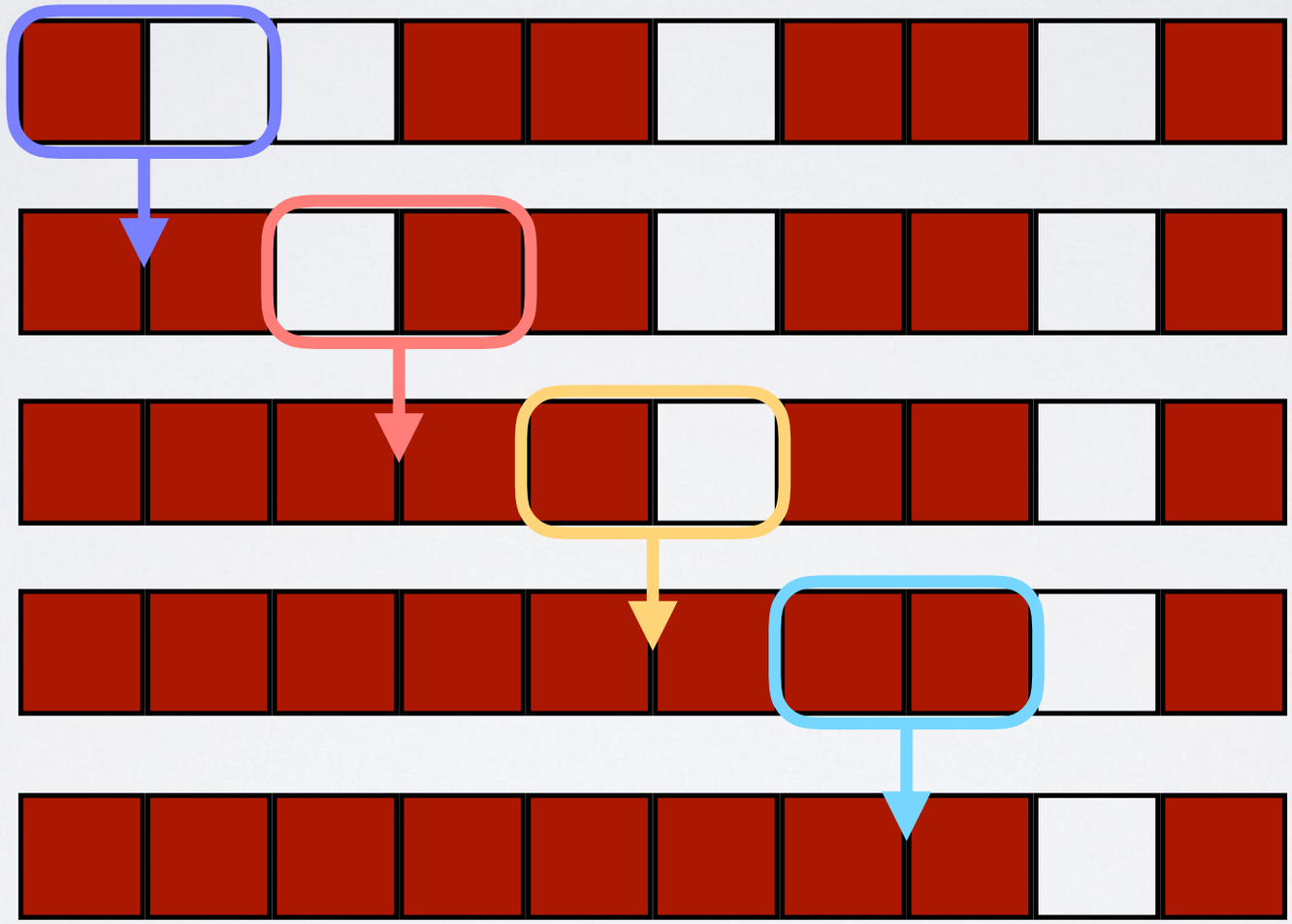

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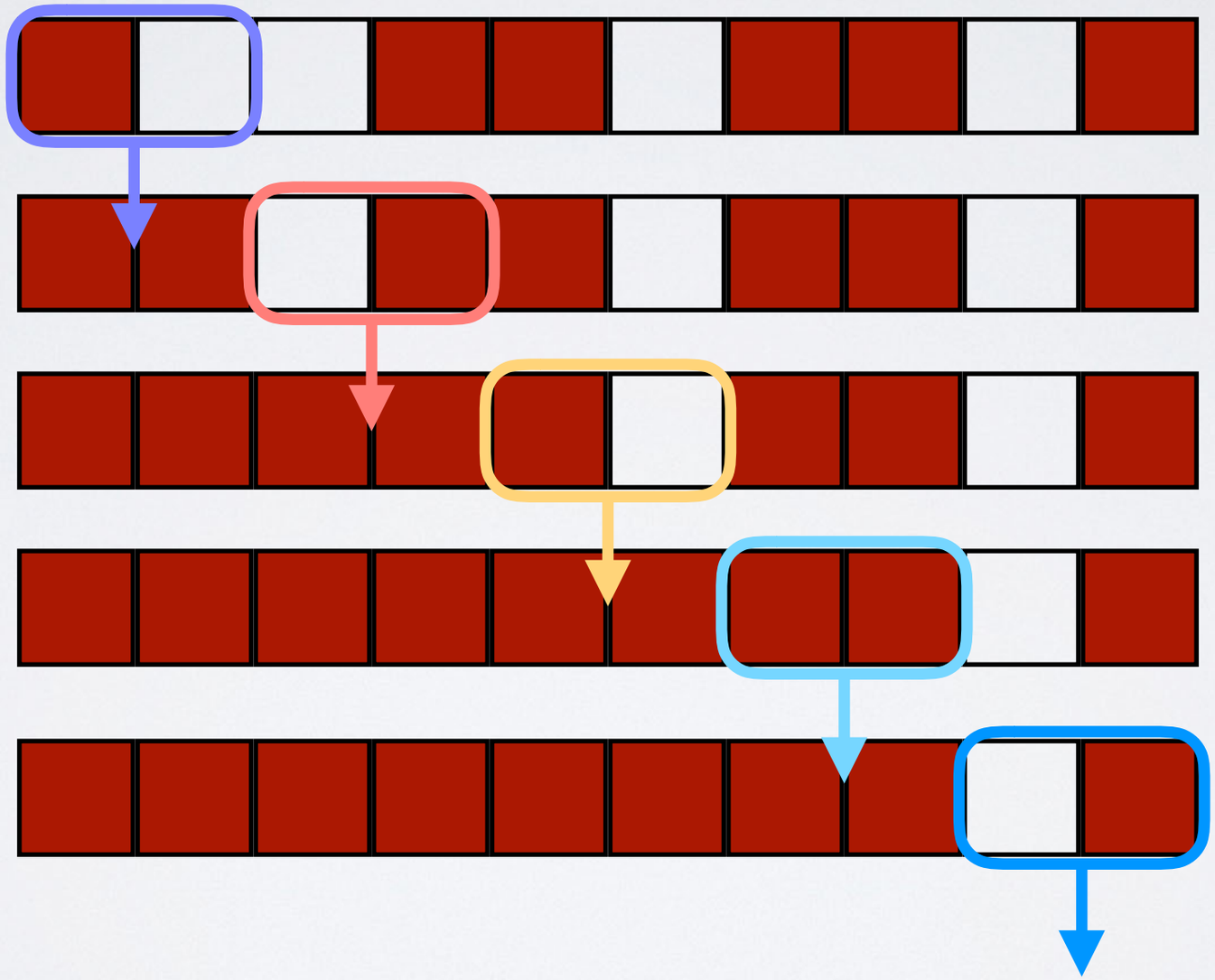

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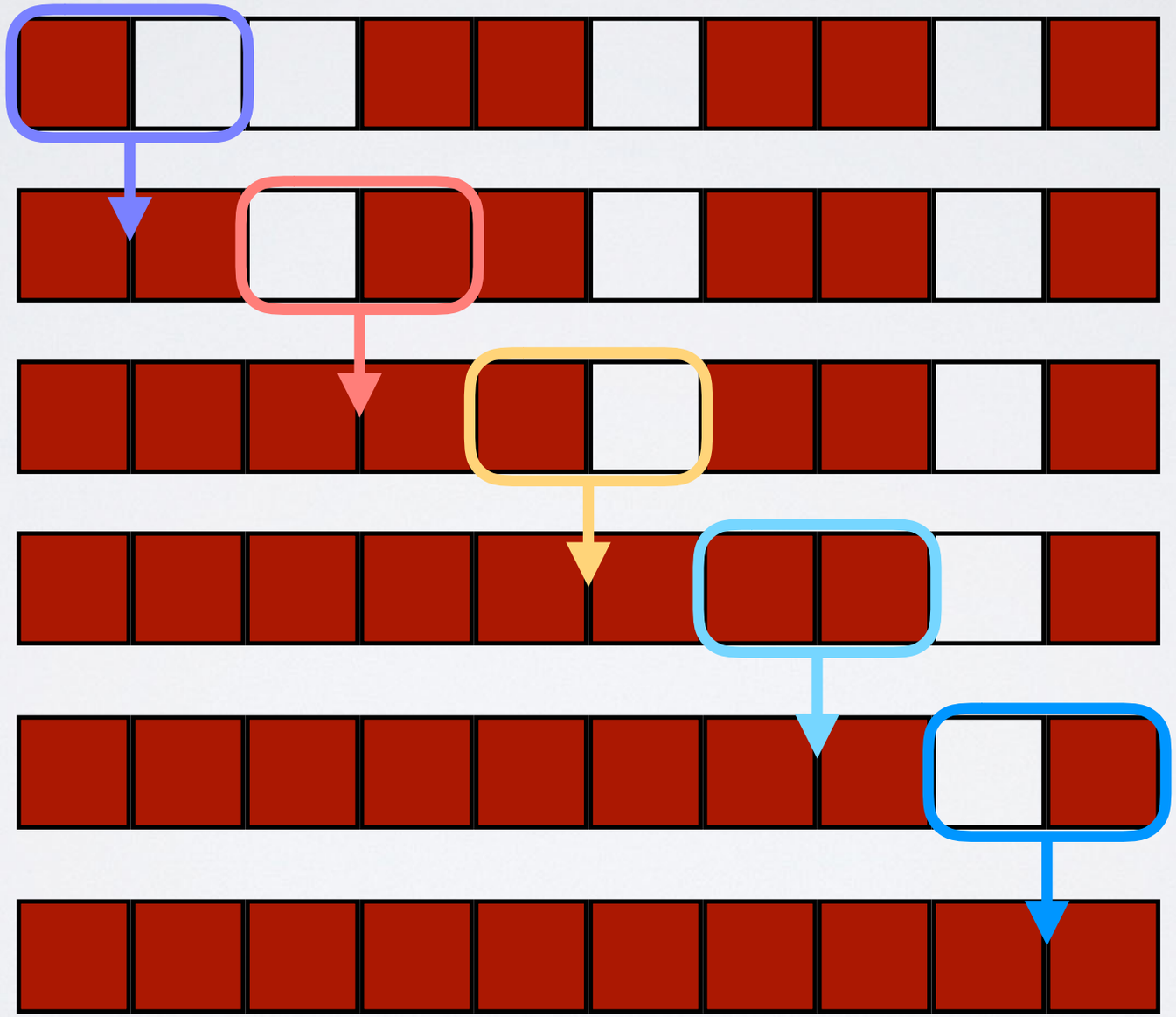

THE QUESTIONS

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- How asynchrony influences the PRNG strength?

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- Which CA are resistant to asynchrony?

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- Which CA are resistant to asynchrony?
- Can asynchrony increase PRNG strength?

EXPERIMENTS

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- Balanced elementary rules
- Initial configuration: 64 bits
- 10^3 repetitions each producing 10^6 bits
- Asynchrony k=1, 2, 4, 8, 16, 32, 64

THREE TYPES

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THREE TYPES

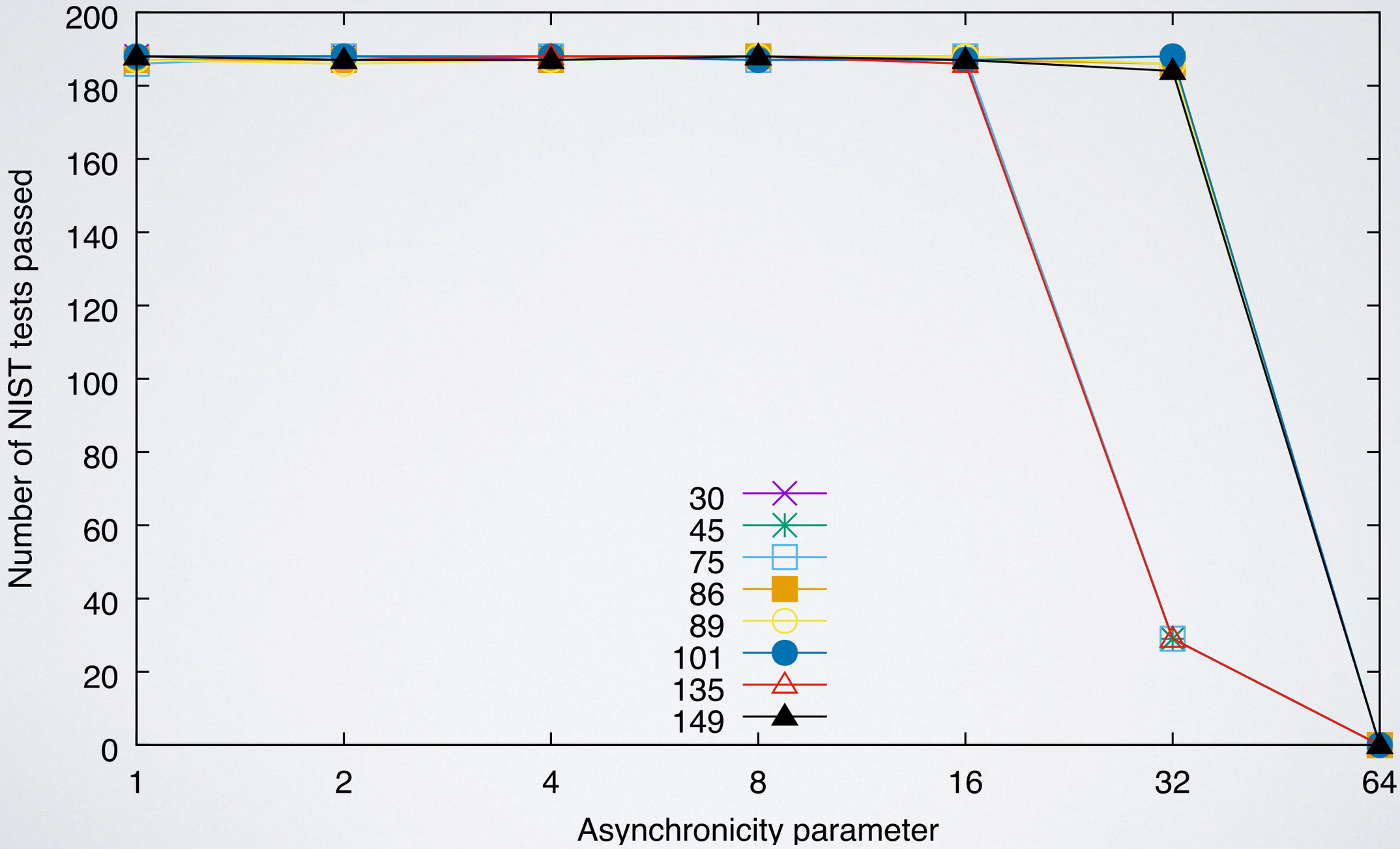
- **Plateau**: remains strong
- **Hill**: from strong to stronger
- **Mountain**: from weak to strong
- Max asynchrony = weak PRNG in all cases

THREE TYPES

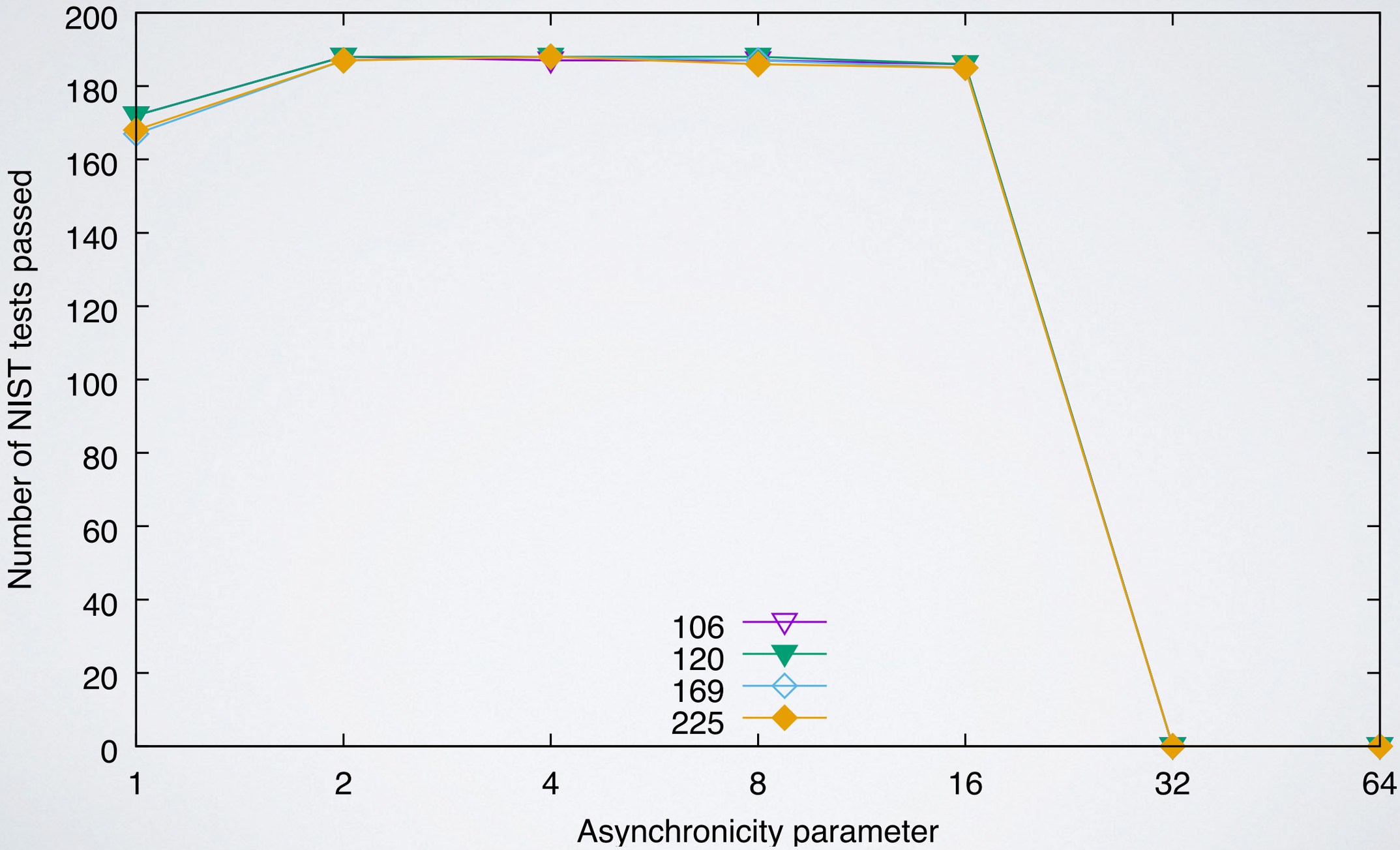
Type 1	Type 2	Type 3
30, 45, 75, 86, 89, 101, 135, 149	106, 120, 169, 225	60, 90, 105, 150, 154, 165, 166, 180, 195, 210

Every other rule is alway weak as a PRNG

TYPE I


Number of NIST tests passed
200
180
160
140
120
100
80
60
40
20
0
1
2
4
8
16
32
64
Asynchronicity parameter
30
45
75
86
89
101
135
149

TYPE 2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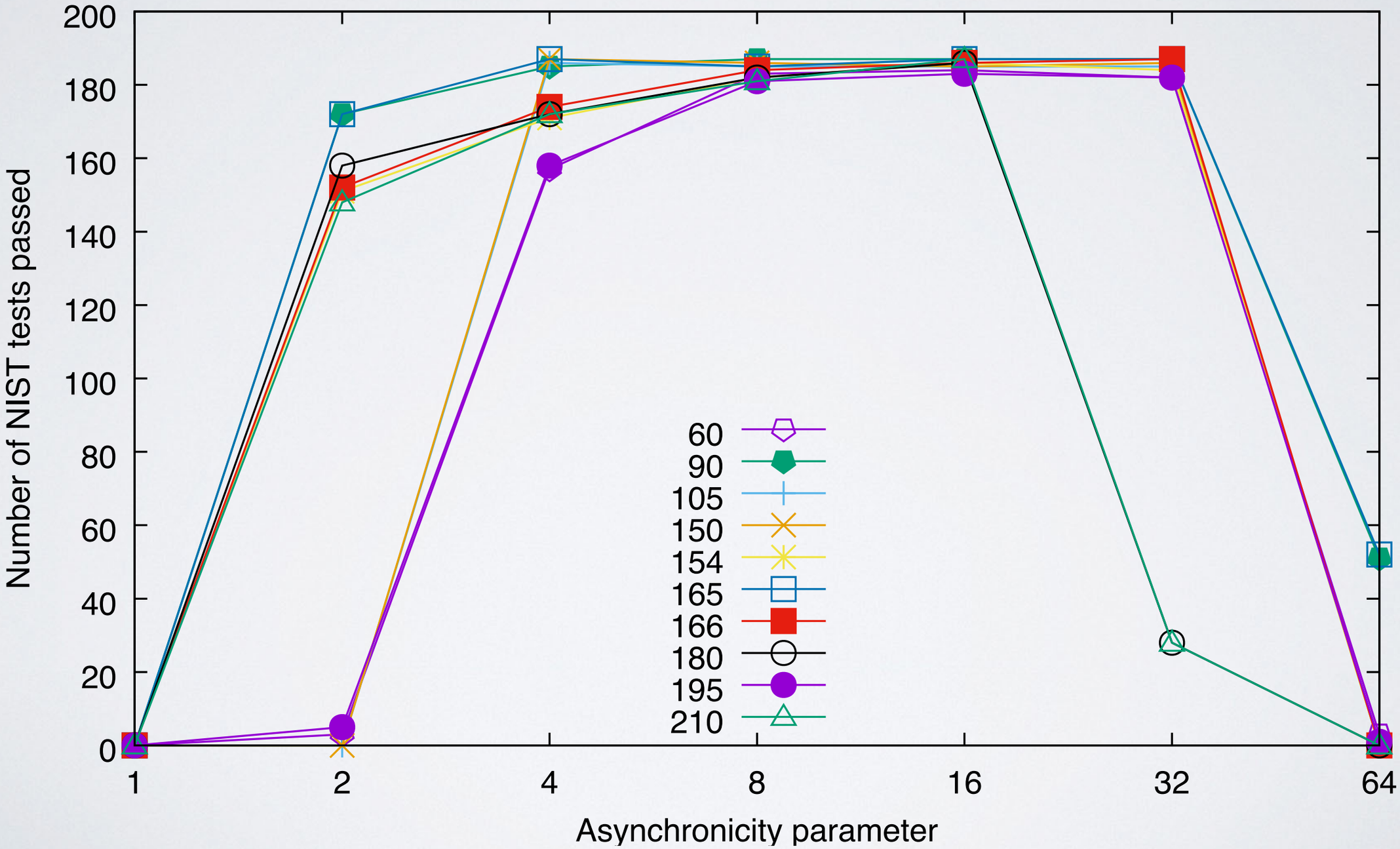
TYPE 3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8
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32
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Asynchronicity parameter
60
90
105
150
154
165
166
180
195
210

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- Always a sudden decrease in strength
- Full asynchrony is destructive for PRNG strength
- Limited asynchrony can be beneficial

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- What about other ways of introducing asynchrony?

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- What happens for CA or radius > 1?
- What about other ways of introducing asynchrony?
- What formal properties of the rules justify their asynchronous behaviour?

THANK YOU

For Your Attention

Questions?