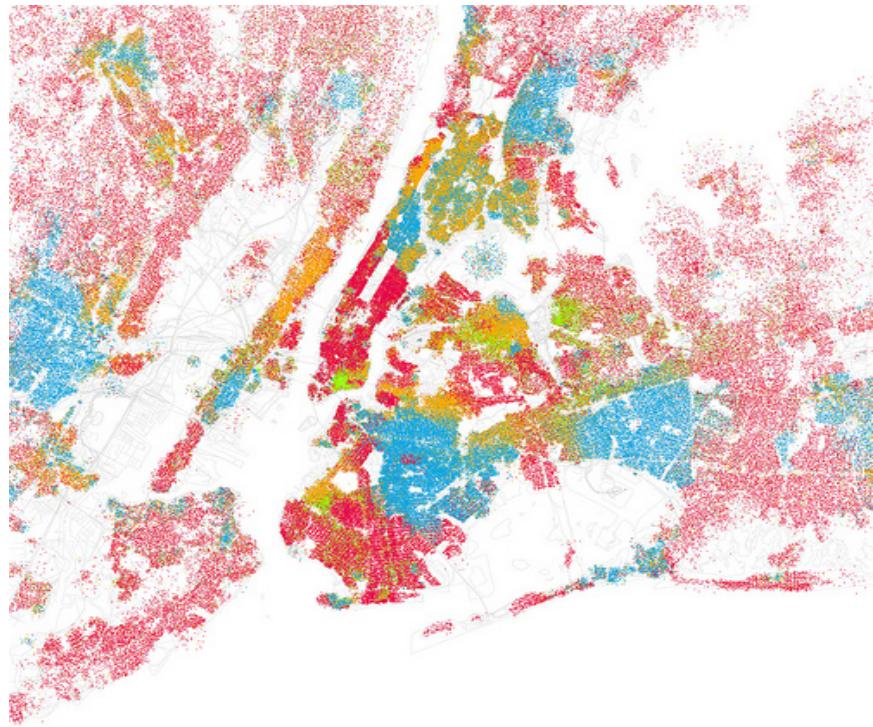


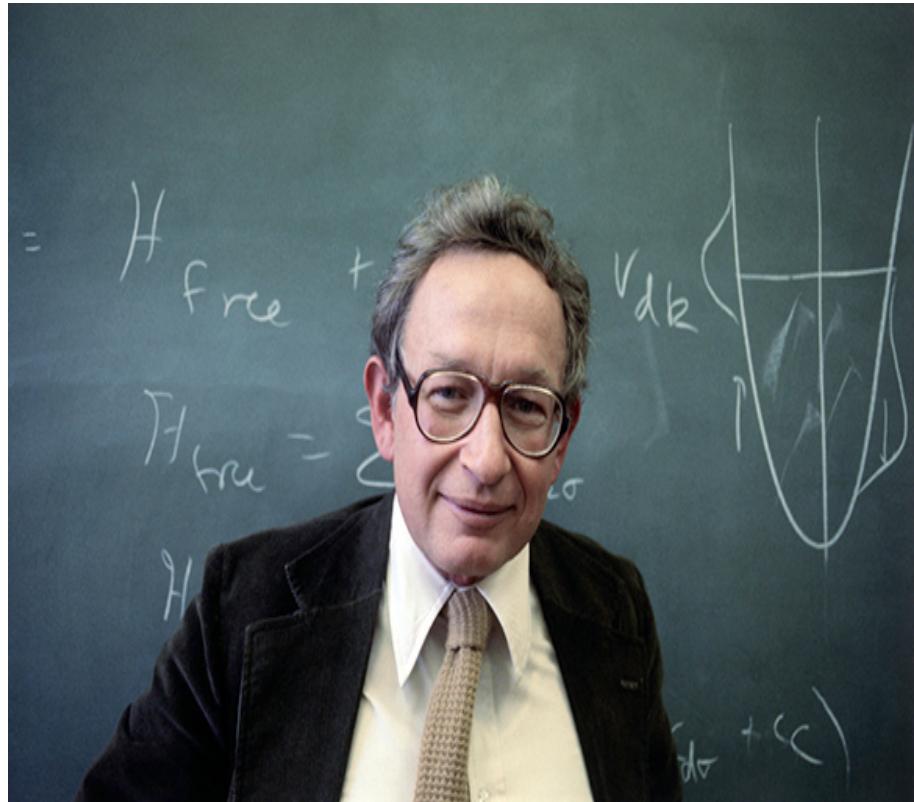
Model Thinking

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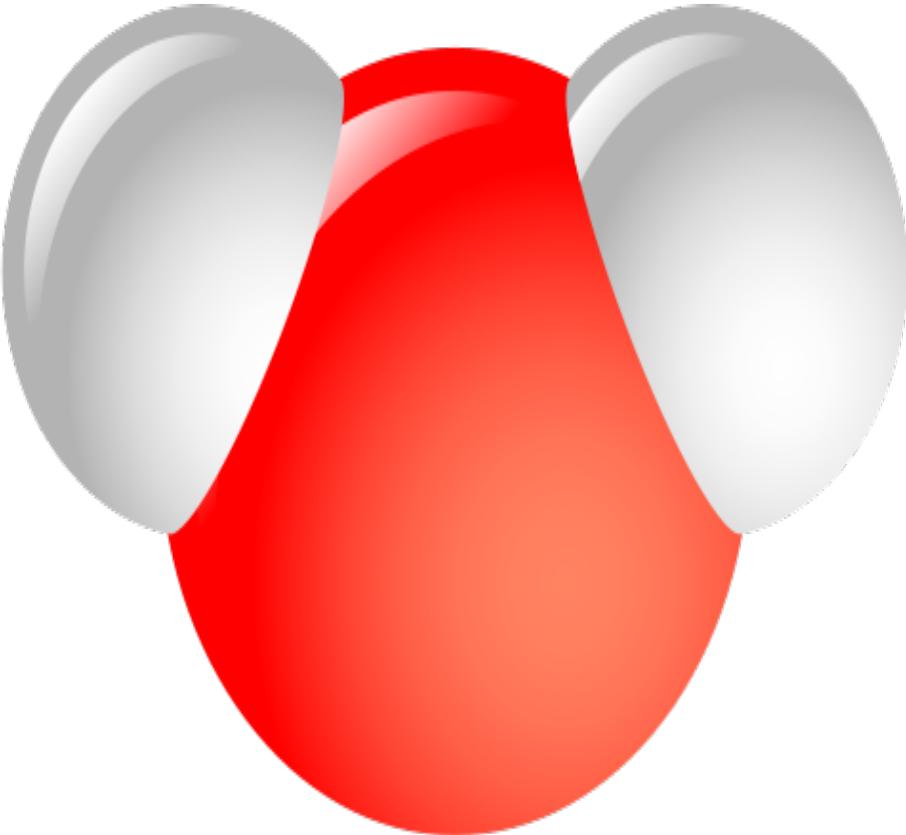
Aggregation



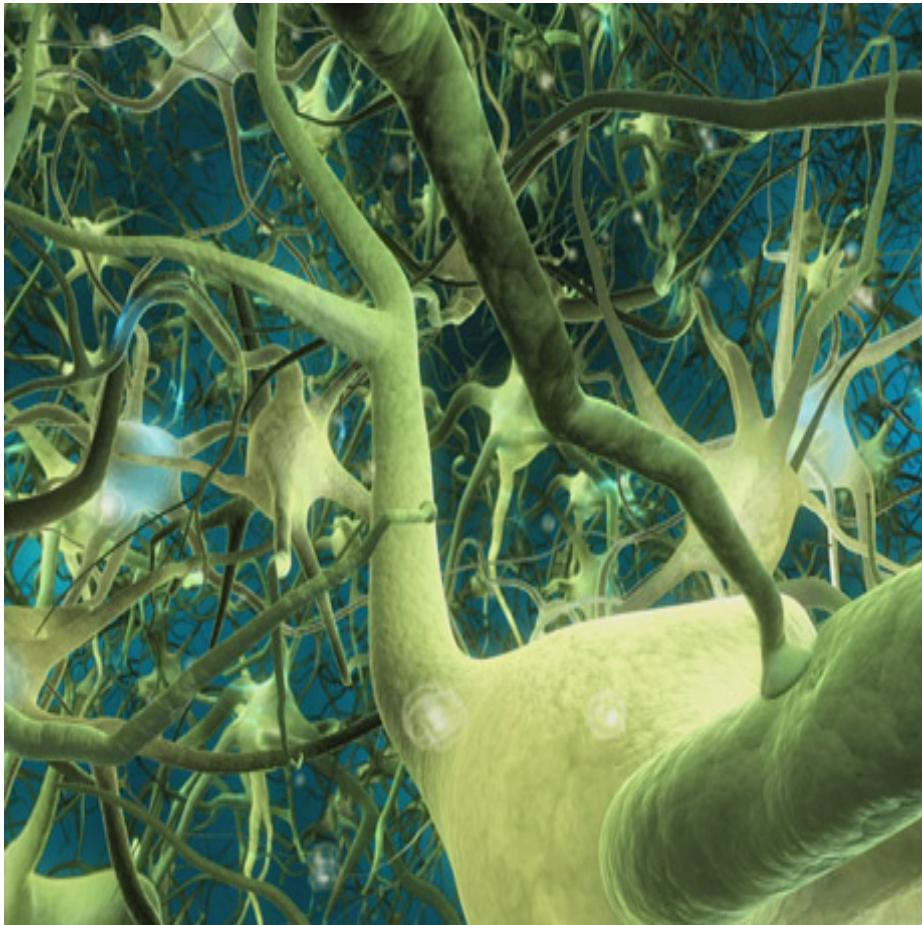
New York



“More Is Different”



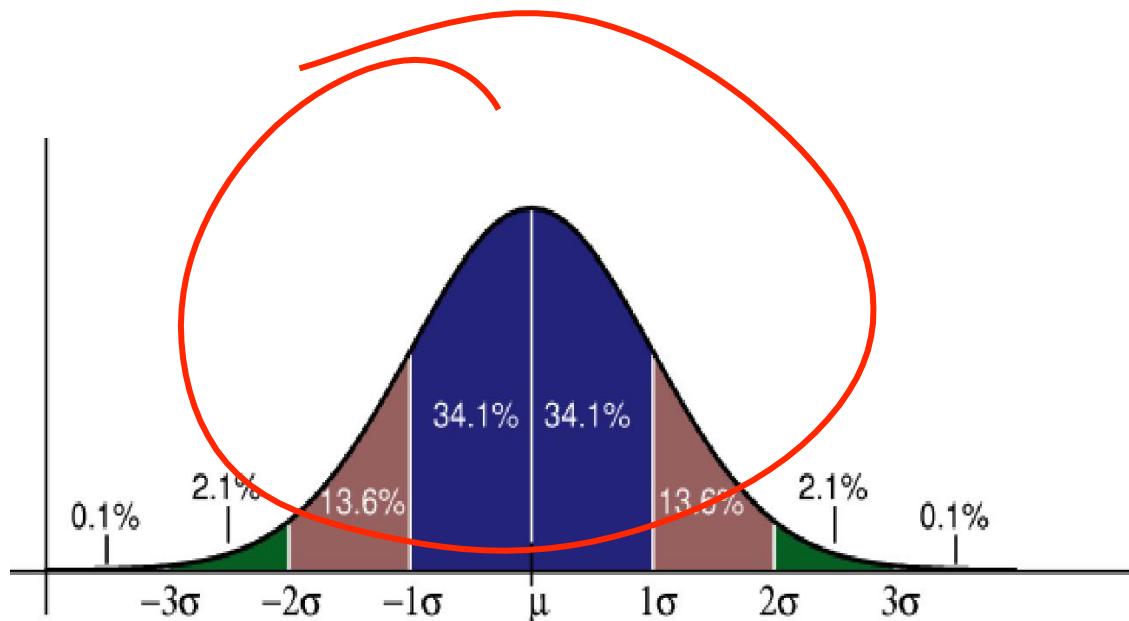
“More Is Different”



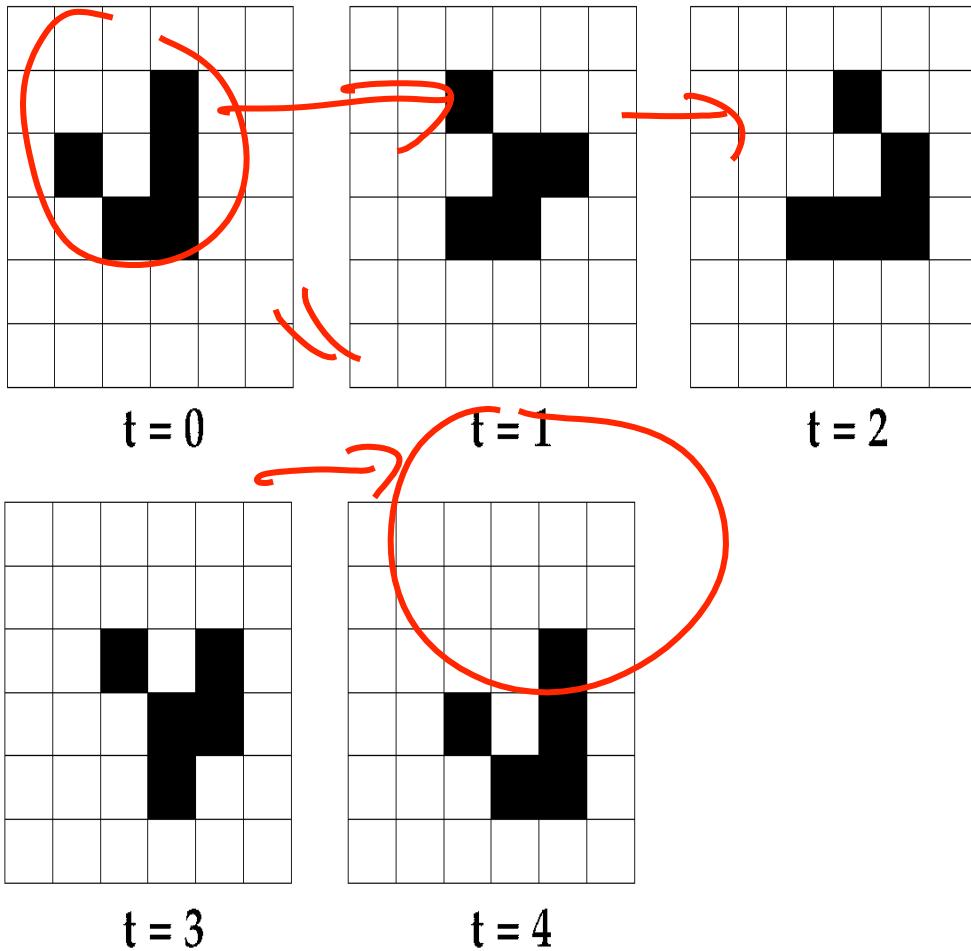
“More Is Different”

Aggregation

- Actions
- Single Rule
- Family of Rules
- Preferences



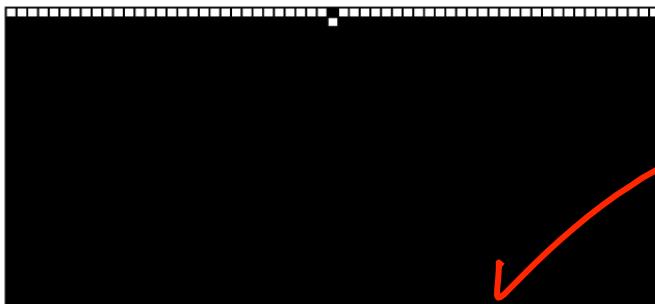
Predict Points Understand Data



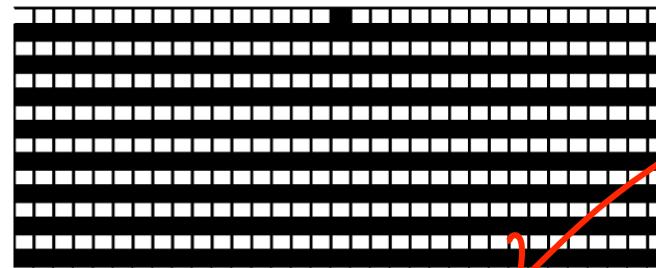
Understand Patterns

Understand Class of Outcome

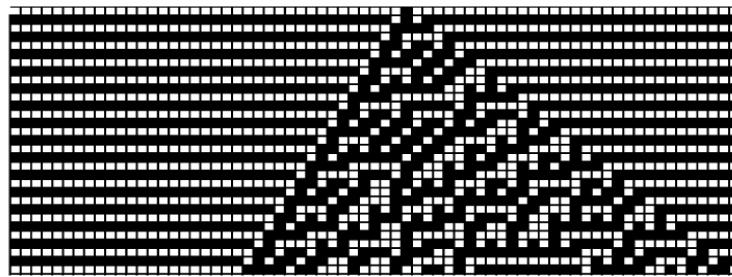
Class I: Rule 251



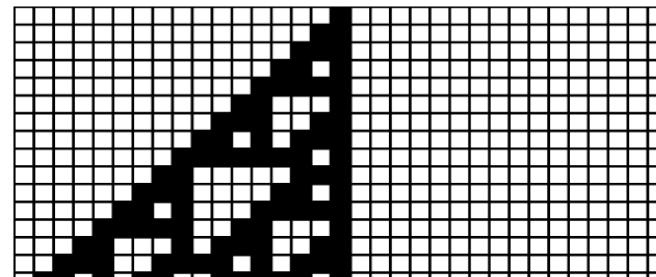
Class II: Rule 119



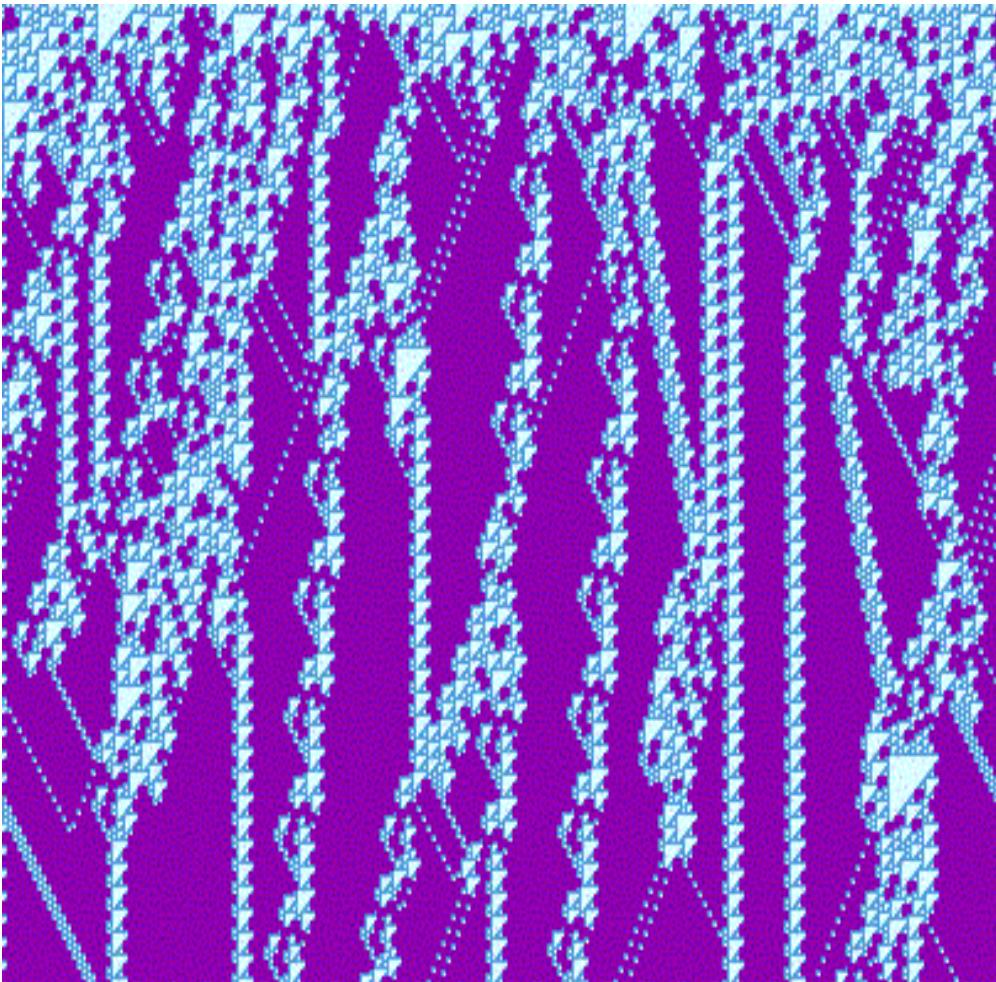
Class III: Rule 45

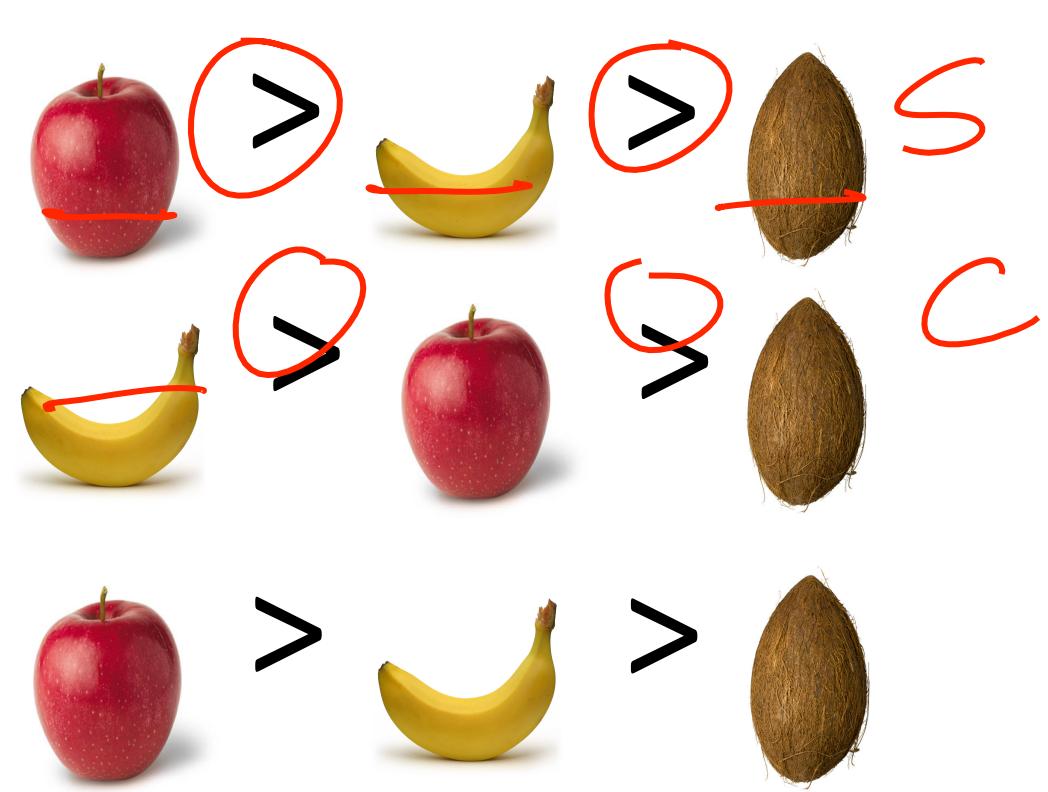


Class IV: Rule 110



Source: From Wolfram (2002, pp. 55-56)





Work Through Logic



www.mylot.com

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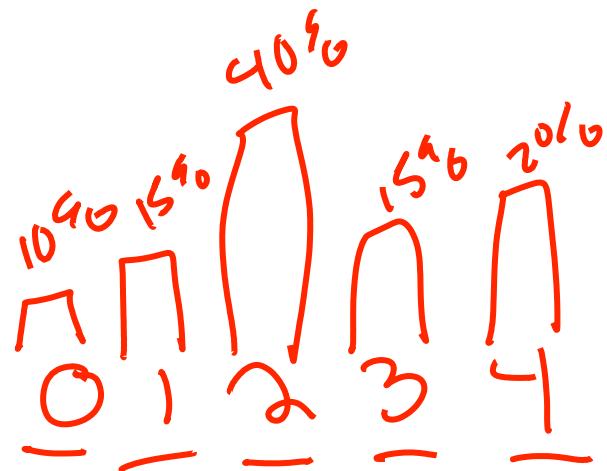
Model Thinking

Scott E Page

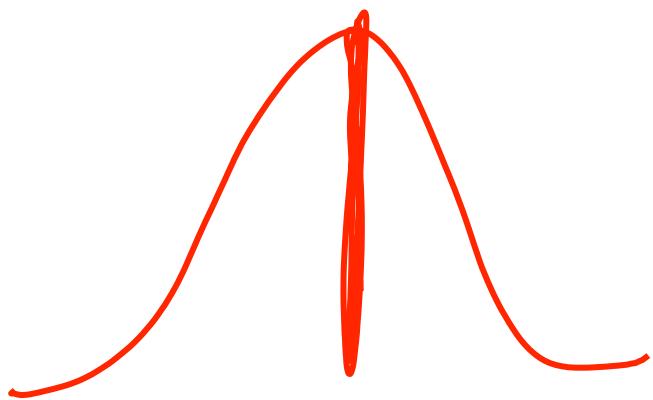
Model Thinking

Scott E Page

100%



Probability Distribution



Central Limit Theorem

Flip a Coin 2 Times

TT 0 $\frac{1}{4}$

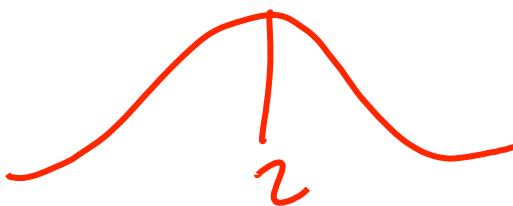
THS 1 $\frac{1}{4}$
HTS

HH 2 $\frac{1}{4}$



Flip a Coin 4 Times

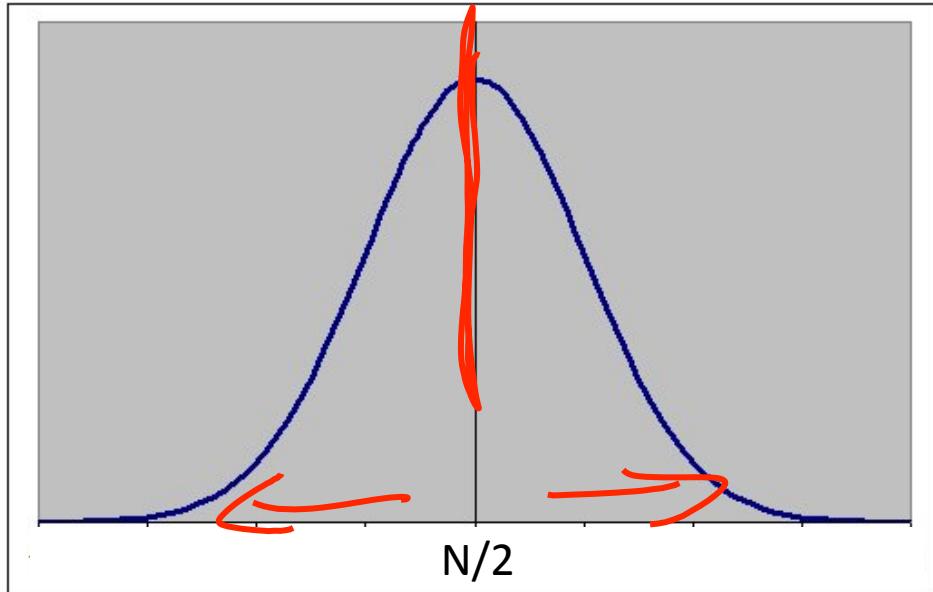
TTTT $1/16$
HTTT {
THTT } $4/16$
TT HT
TTT H $8/16$



Flip a Coin N Times

N/2

Bell Curve



Binomial Distribution

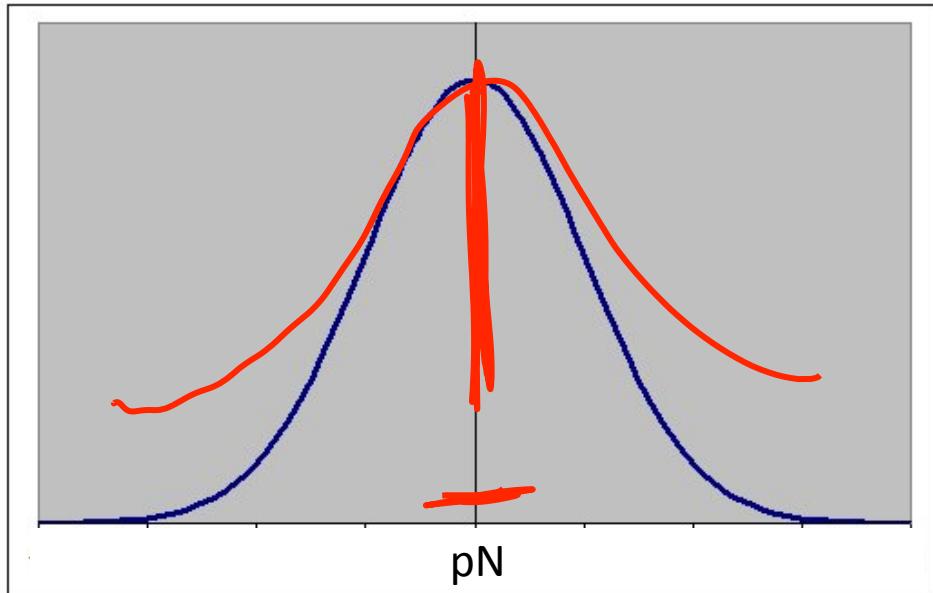
$$\text{Mean} = pN$$

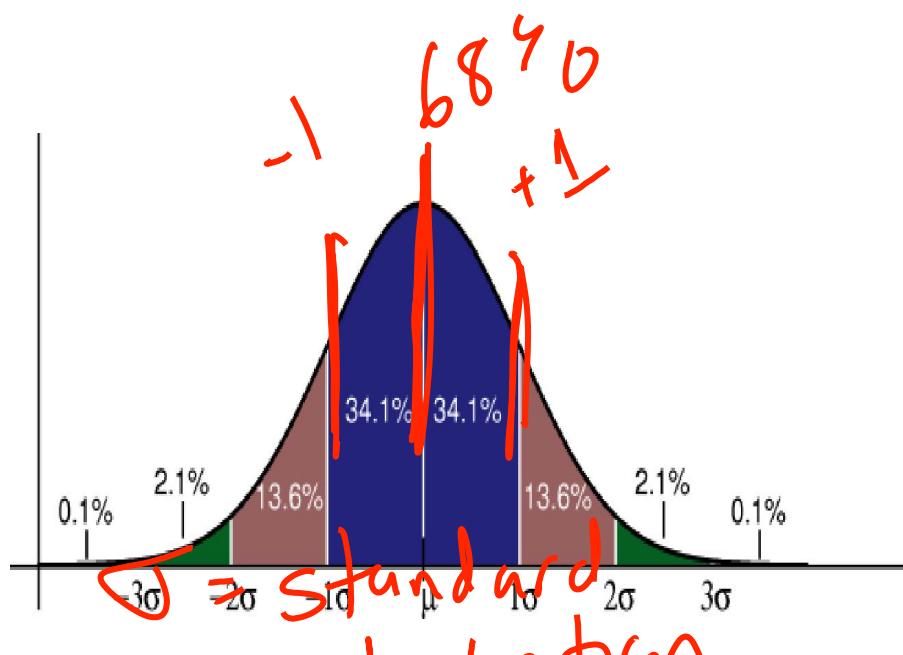
$$N = 1000$$

$$P = .15$$

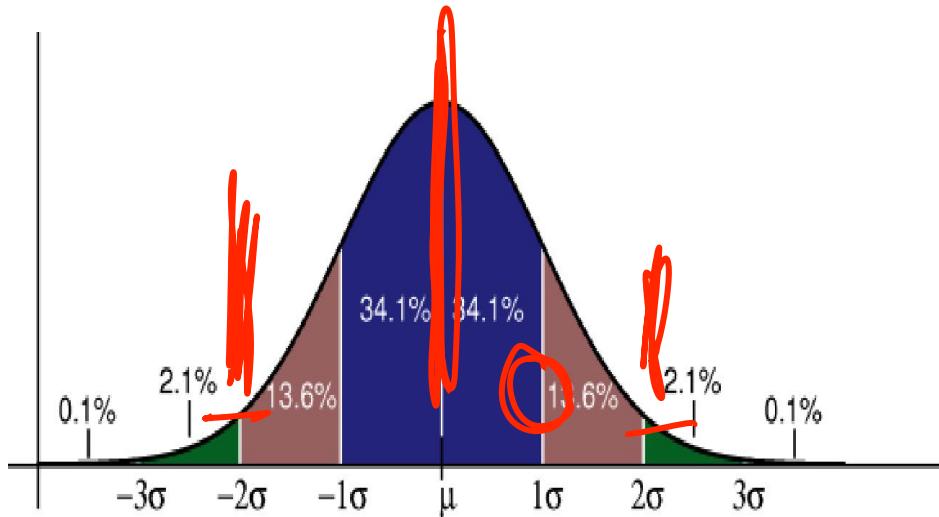
$$pN = 150$$

Bell Curve





Standard
deviation



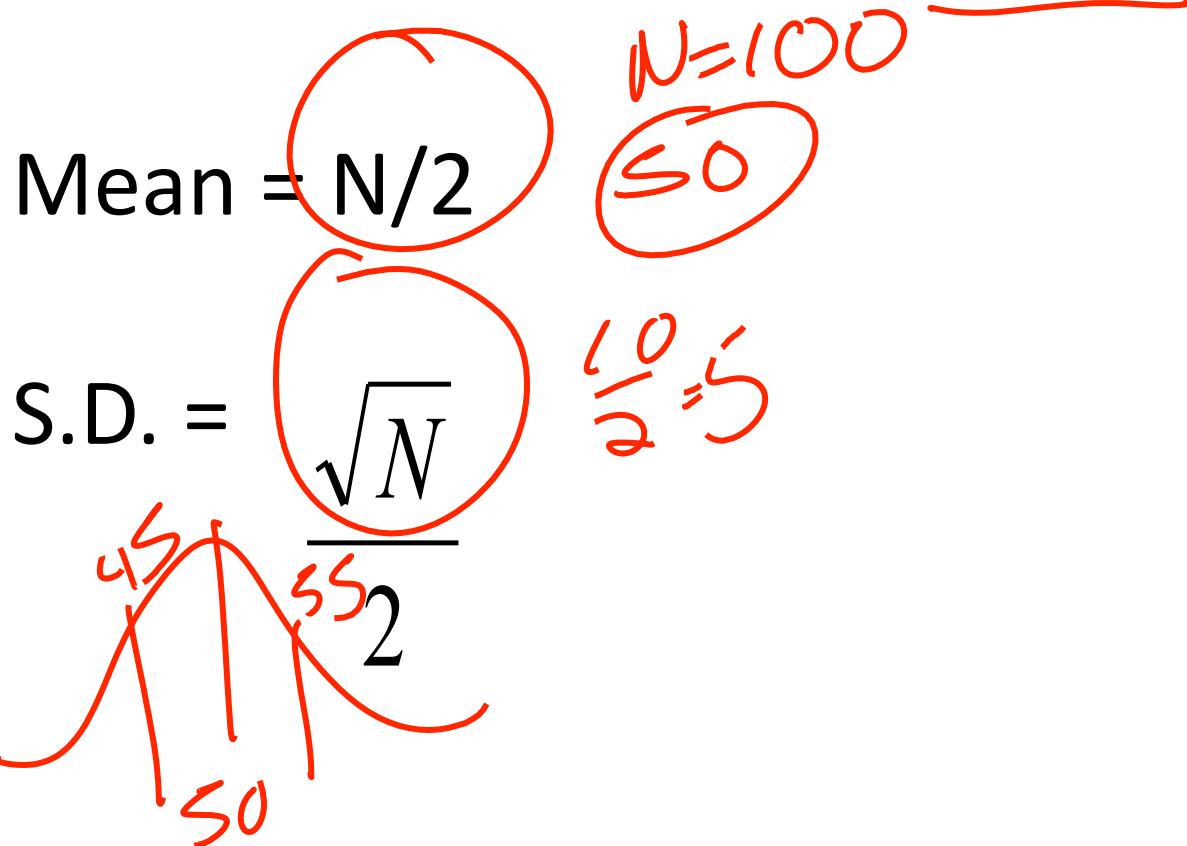
± 1 s.d. 68%

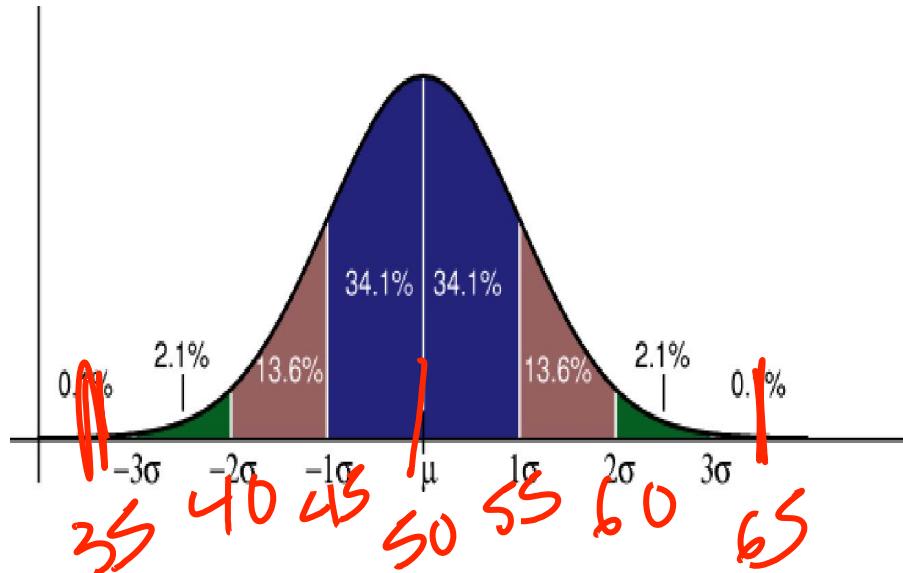
± 2 s.d. 95%

± 3 s.d. 99.75%

$$\sigma = \frac{\text{range}}{3}$$

Binomial Distribution $P=1/2$





Binomial Distribution

$$\text{Mean} = pN$$

$$\text{S.D.} = \sqrt{p(1-p)N}$$

$$\sqrt{\left(\frac{1}{2} \cdot \frac{1}{2}\right) N}$$

$$\frac{1}{2} \sqrt{N}$$

Boeing 747: ~~380~~ seats

~~90%~~ show up rate

Sell 400 Tickets

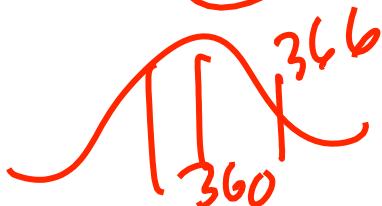
$$400(.9) = 360$$

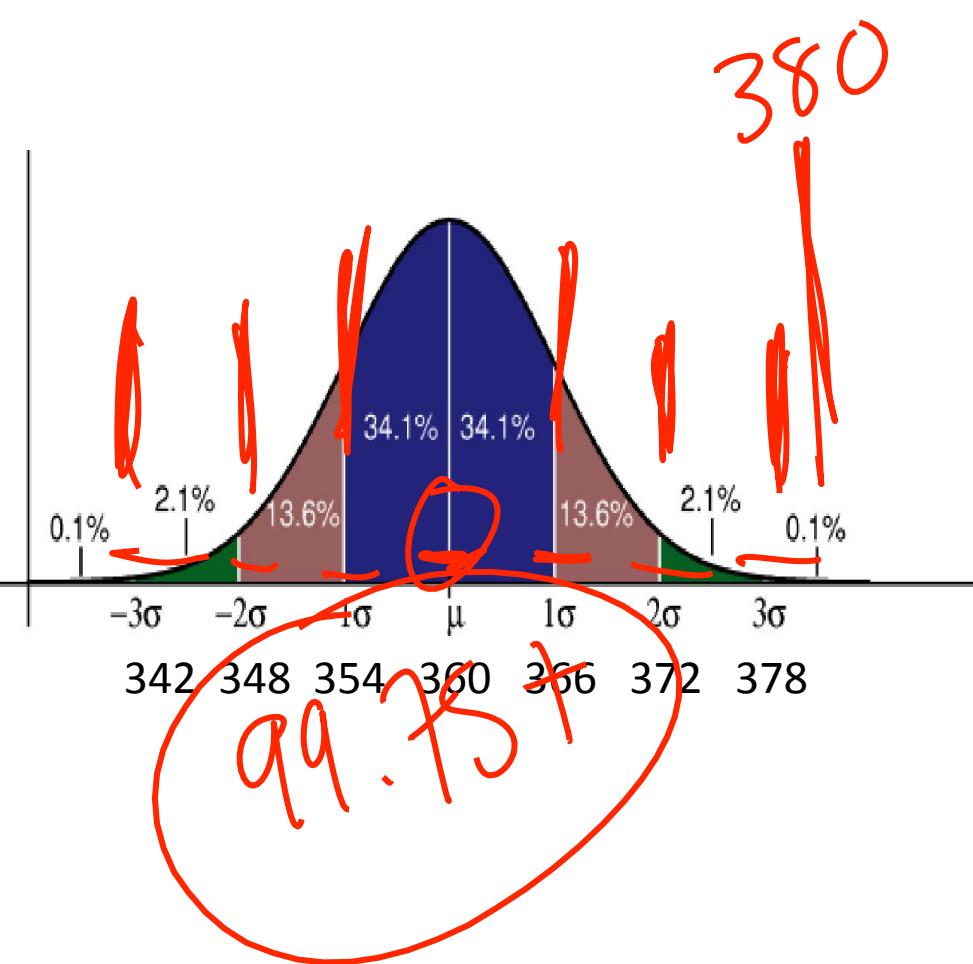
$$N = 400 \quad p = .9$$

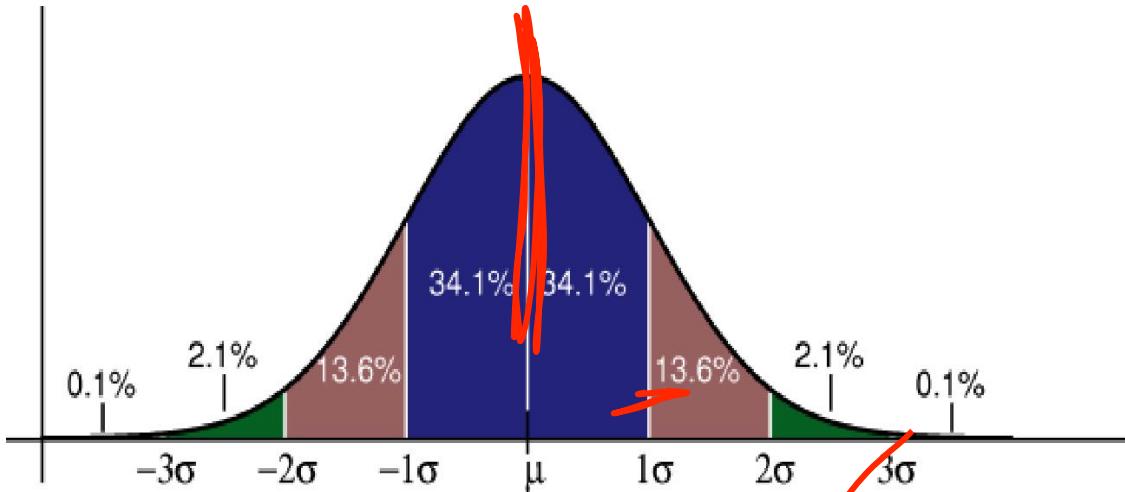
$$\text{Mean} = pN \quad 360$$

$$\text{S.D.} = \sqrt{p(1-p)N}$$

$$\sqrt{36} = 6$$







Number people on plane

Total weight of bags

Number of snack boxes buy

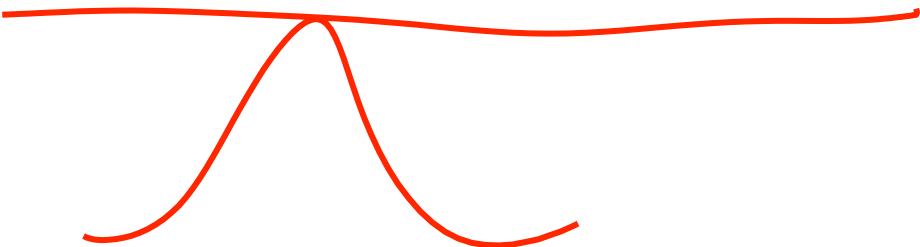
Total Age

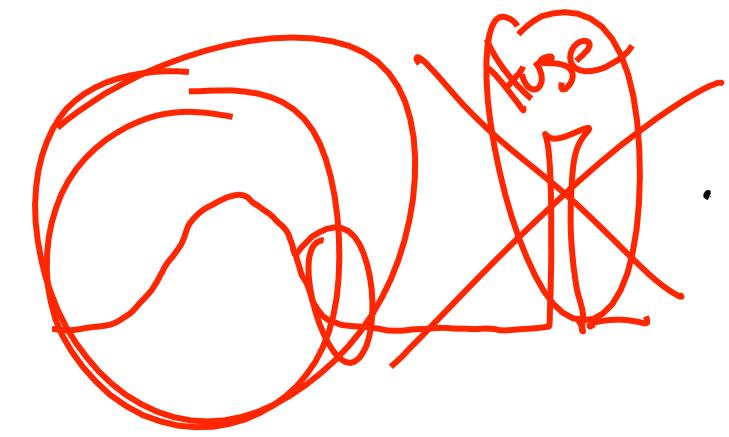
Central Limit Theorem:

Add random variables

- **independent**
- **finite variance**

Sum to a normal distribution





Bimodal Distribution

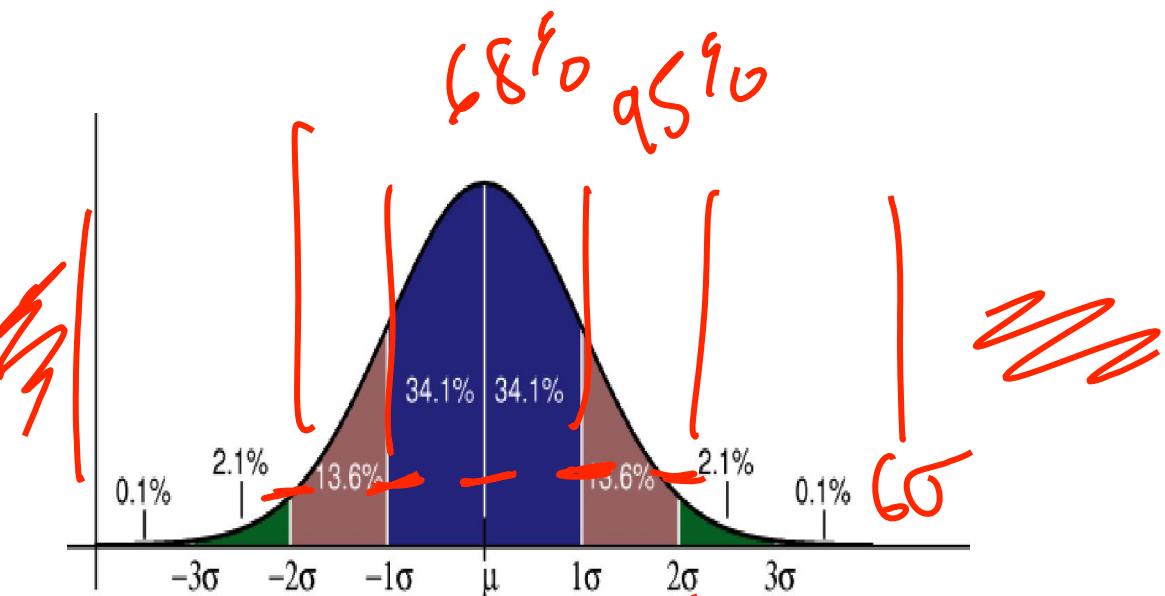
Model Thinking

Scott E Page

Model Thinking

Scott E Page

Six Sigma



3.4 in a million



Average Banana Sales:

500 lbs

Standard Deviation:

10 lbs

$$\sigma = 10$$

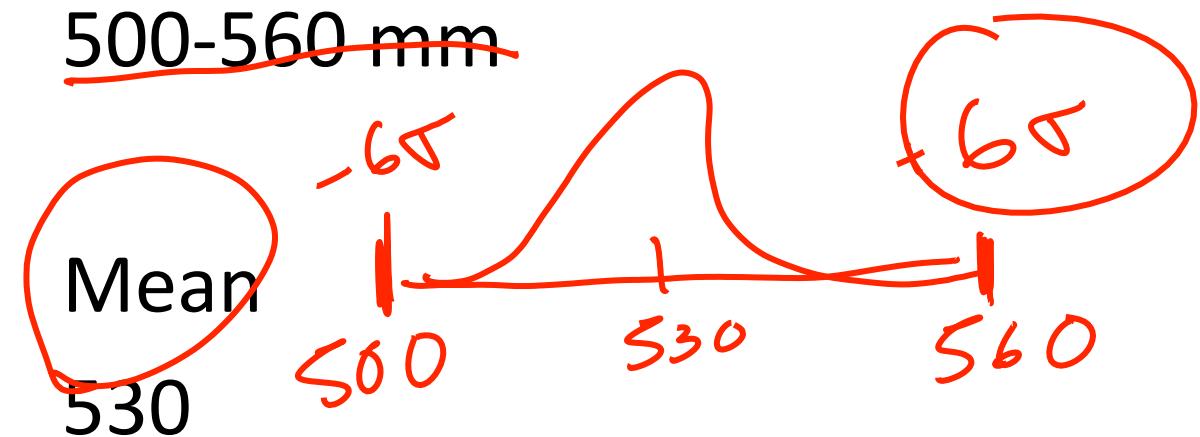


$$6\sigma = \underline{\underline{60}}$$

560

Required Metal Thickness:

~~500-560 mm~~



~~Six Sigma Standard Deviation?~~

A hand-drawn red equation showing the calculation of standard deviation: $560 - 530 = 30$. The result '30' is circled. Below the equation, there is a red circle containing the Greek letter sigma (σ) followed by an equals sign and the number '5'.

Model Thinking

Scott E Page

Model Thinking

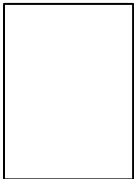
Scott E Page



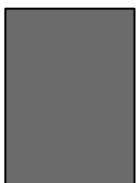
Game of Life

1	2	3
4	X B	5
6	7	8

Dead off



Alive on



Rules

If **off** you turn **on** if
3 neighbors on

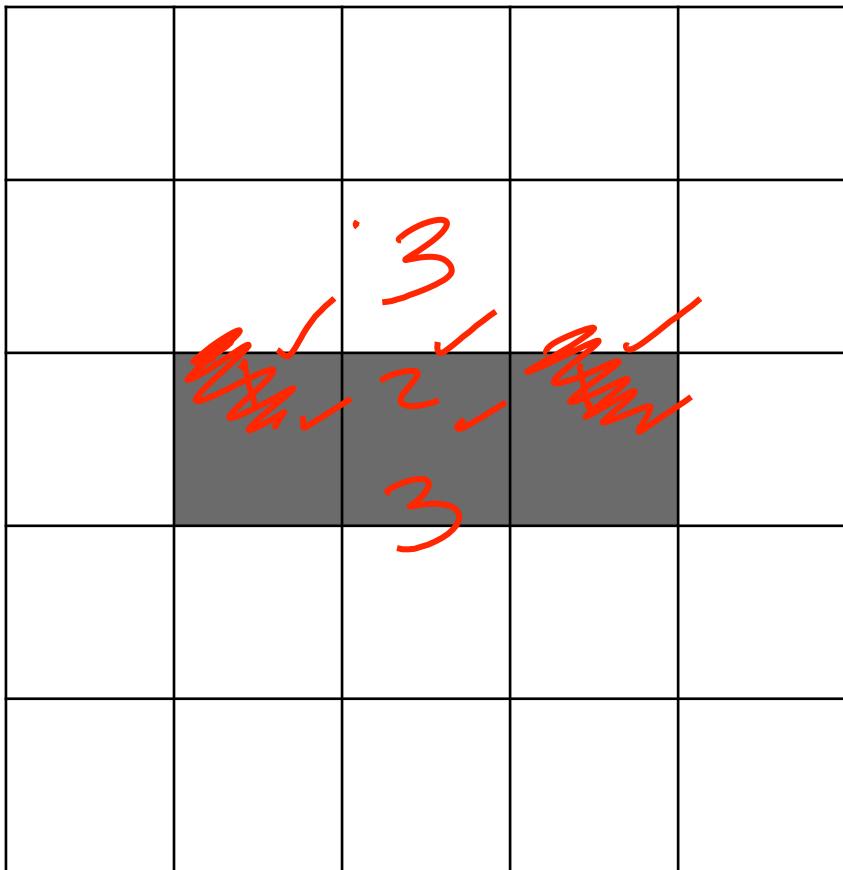
If **on** stay **on** if 2 or
3 neighbors on

1	2	3
4	2 3 4 5	5
6	7	8

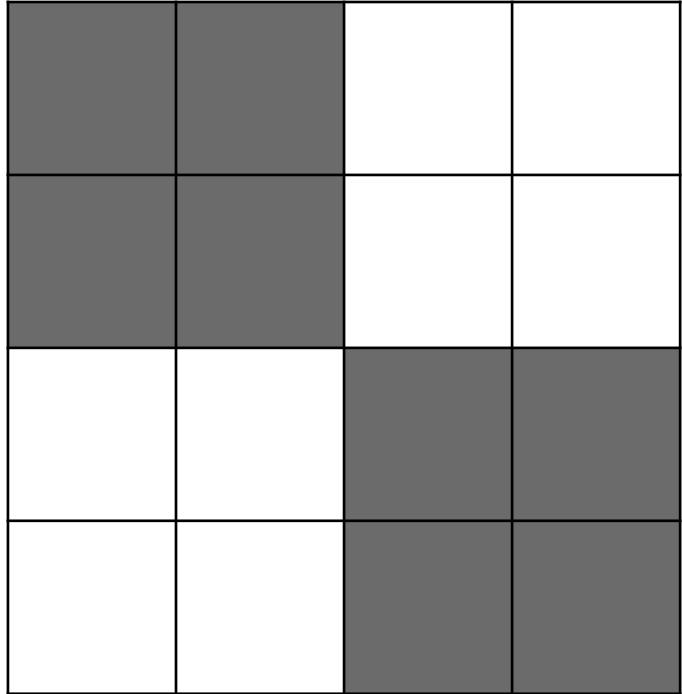
1	2	3
4	X	5
6	7	8

1	2 2	3
4 1	X	5 3
6	7	8 4



	2	3		
	2	2	1	
		3		



Beacon

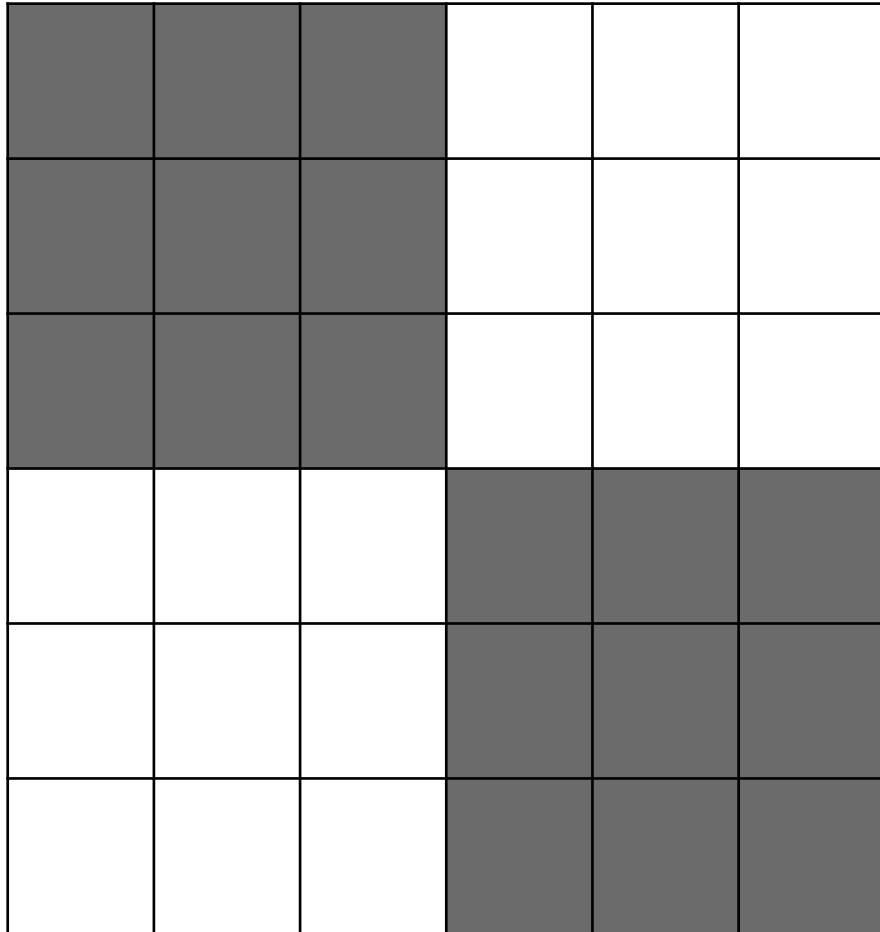
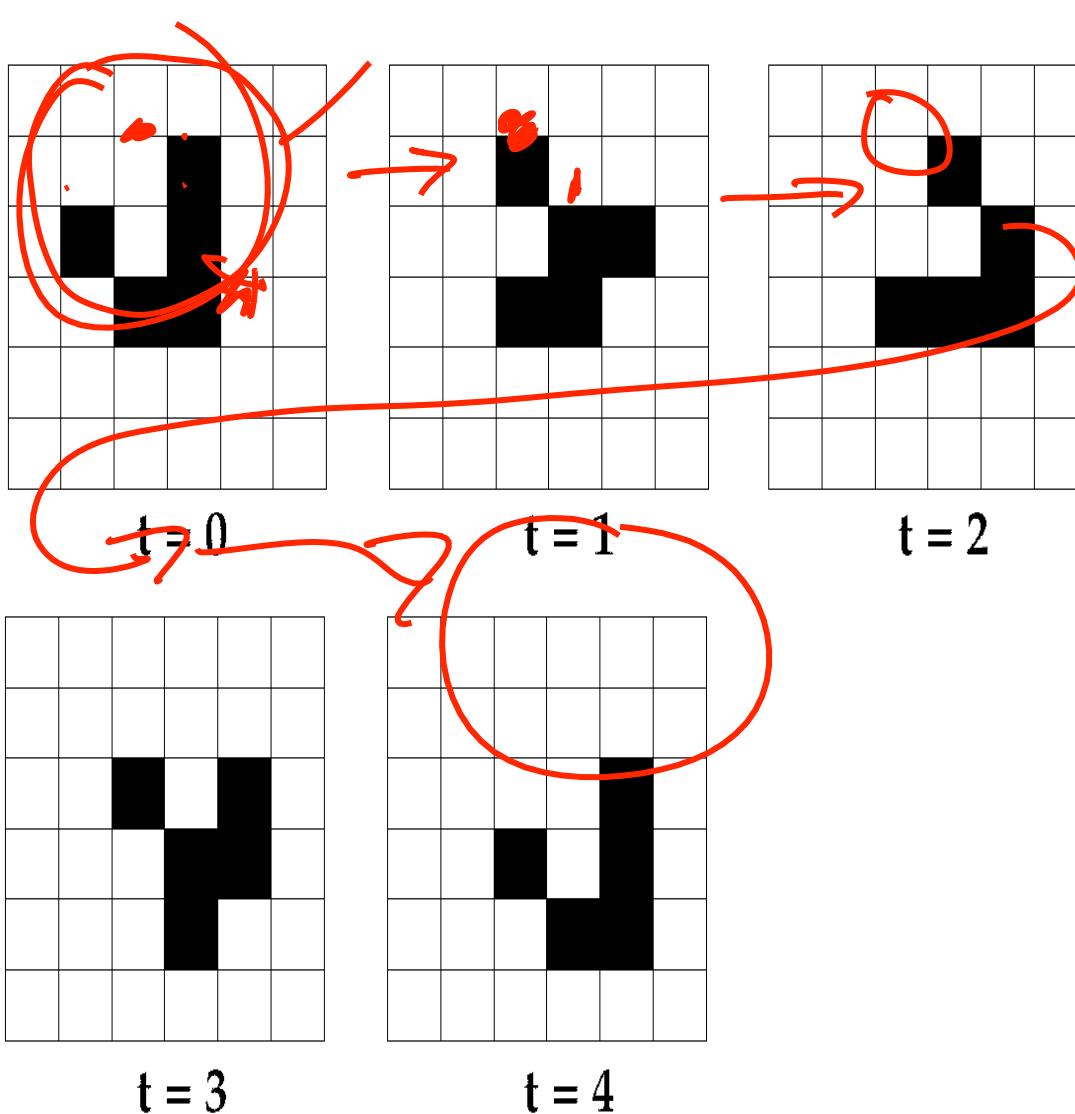


Figure 8

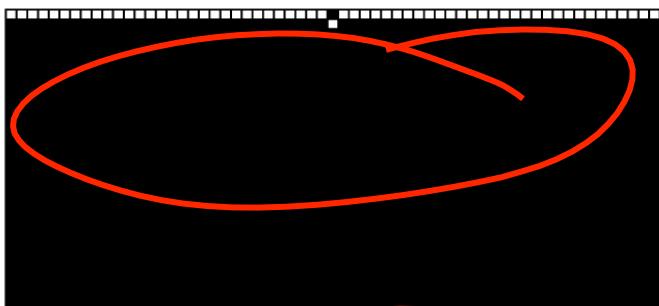
F-Pimento

Netlogo

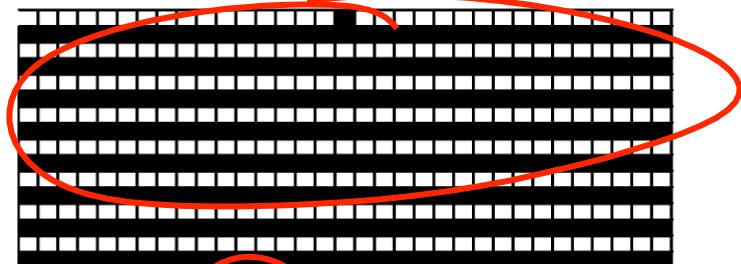


Understand Class of Outcome

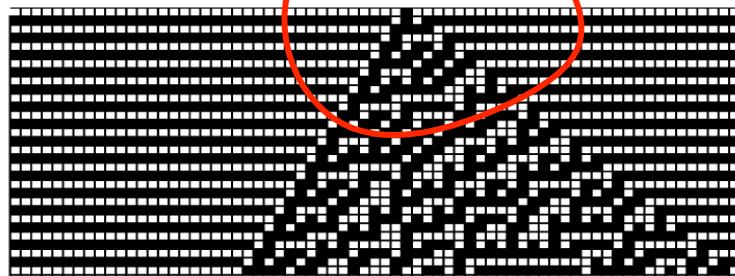
Class I: Rule 251



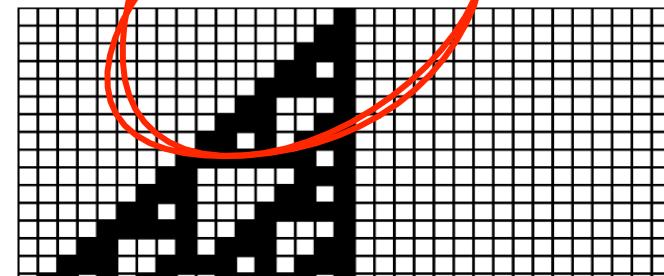
Class II: Rule 119



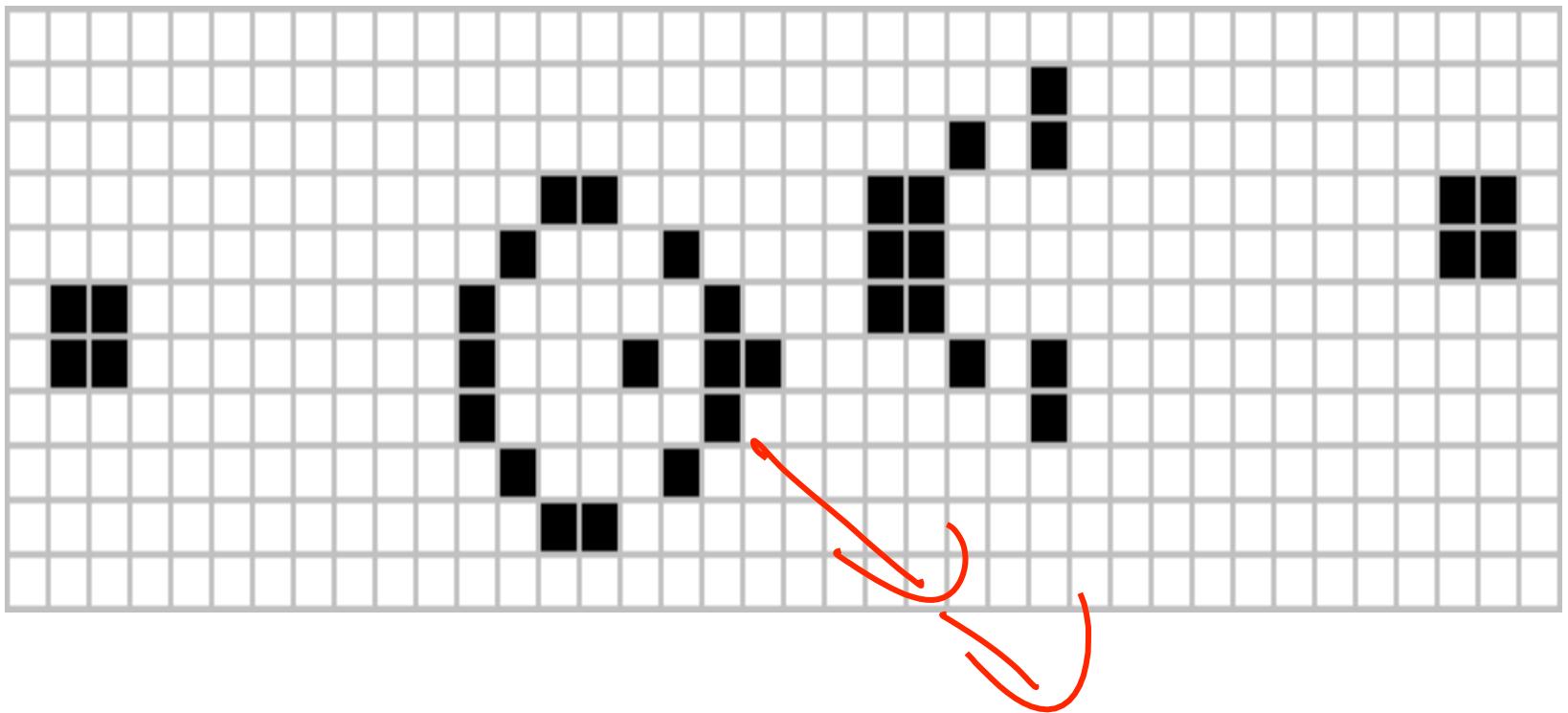
Class III: Rule 45



Class IV: Rule 110



Source: From Wolfram (2002, pp. 55-56)



Self Organization:

Patterns appear without
a designer

Emergence

Functionalities appear:

gliders, glider guns

counters, computers

Logic Right:

Simple rules produce
incredible phenomena

Model Thinking

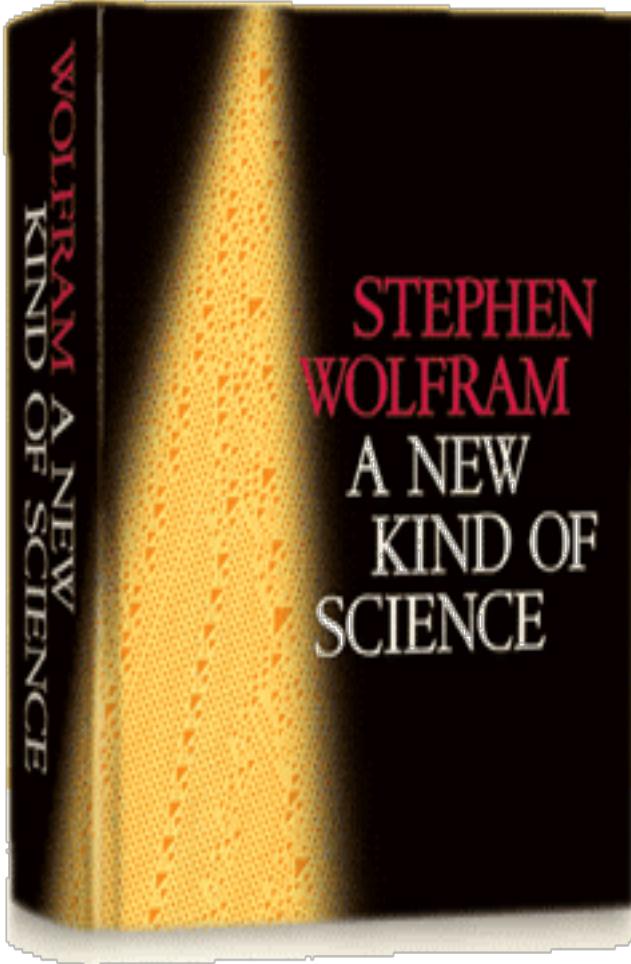
Scott E Page

Model Thinking

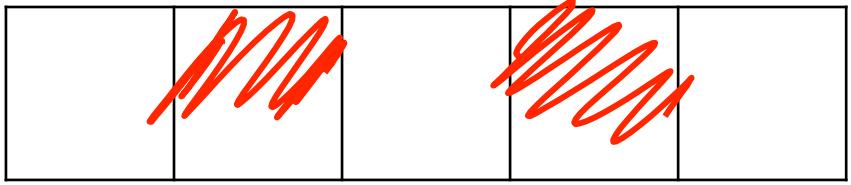
Scott E Page



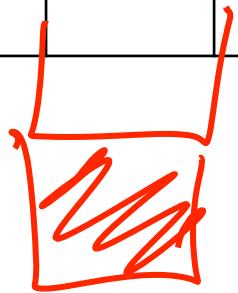
1D Cellular Automata

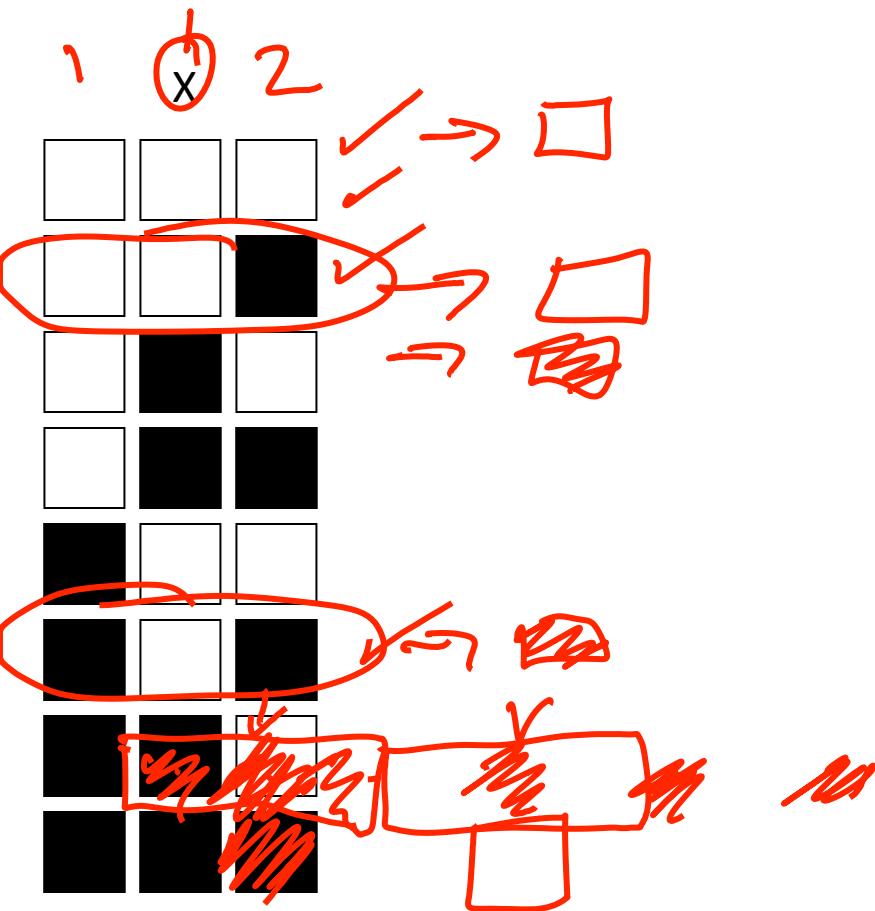


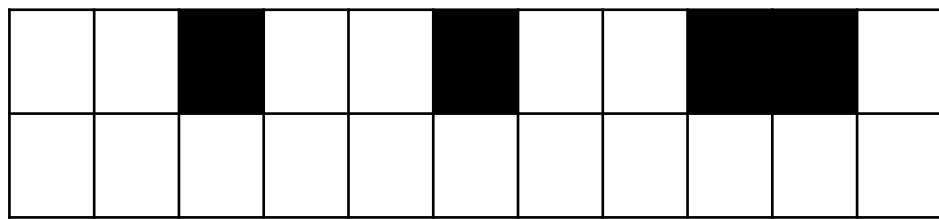
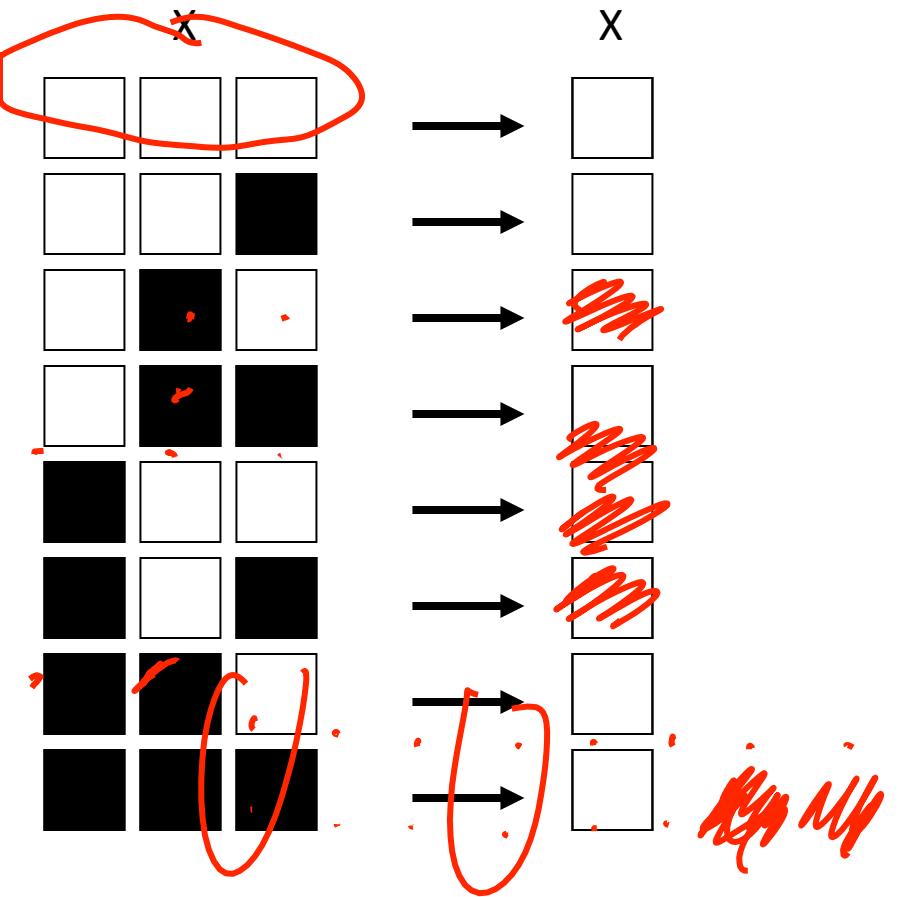
1D Cellular Automata



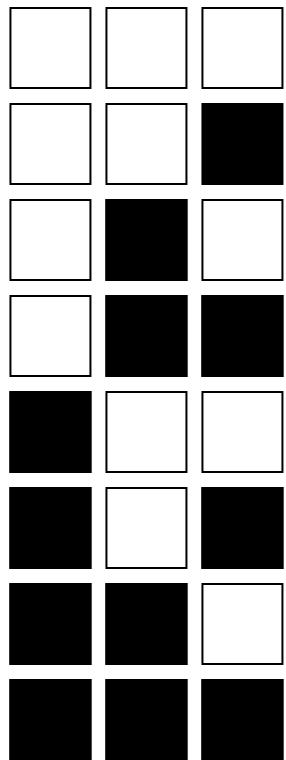
		1	Other	2	
--	--	---	------------------	---	--



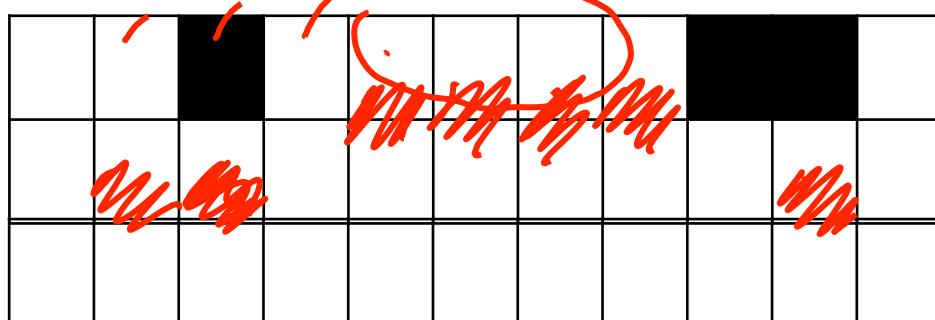
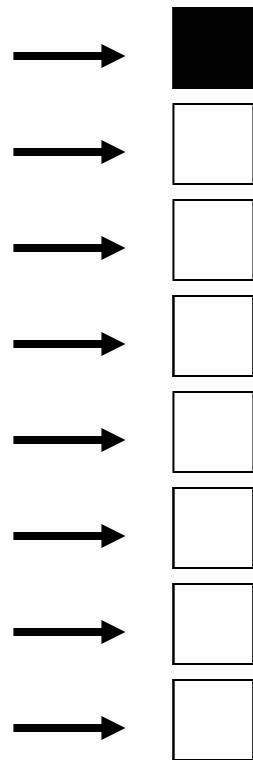




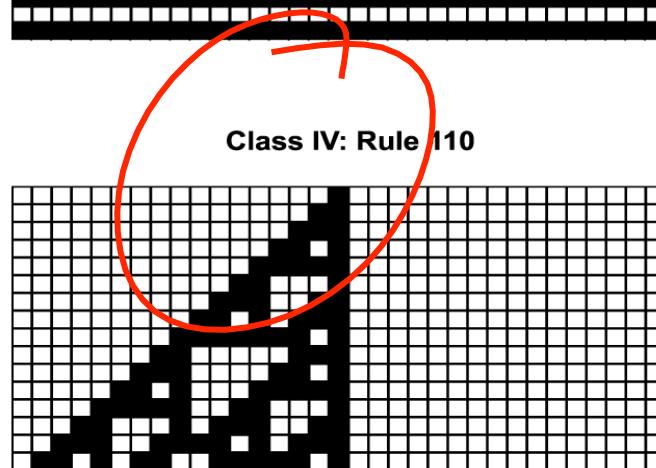
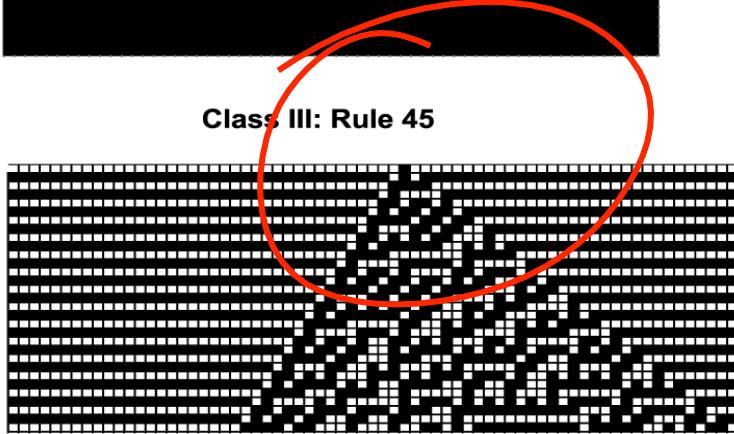
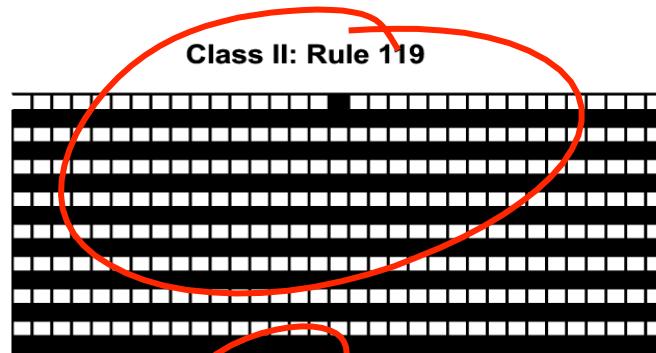
X



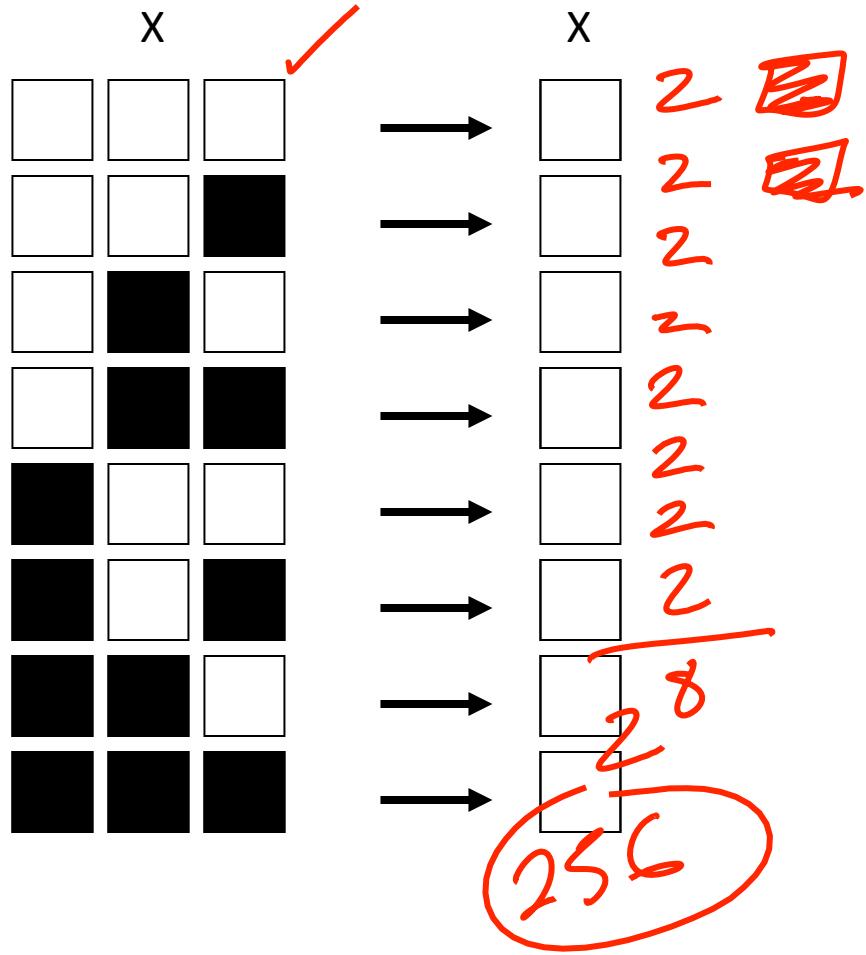
X



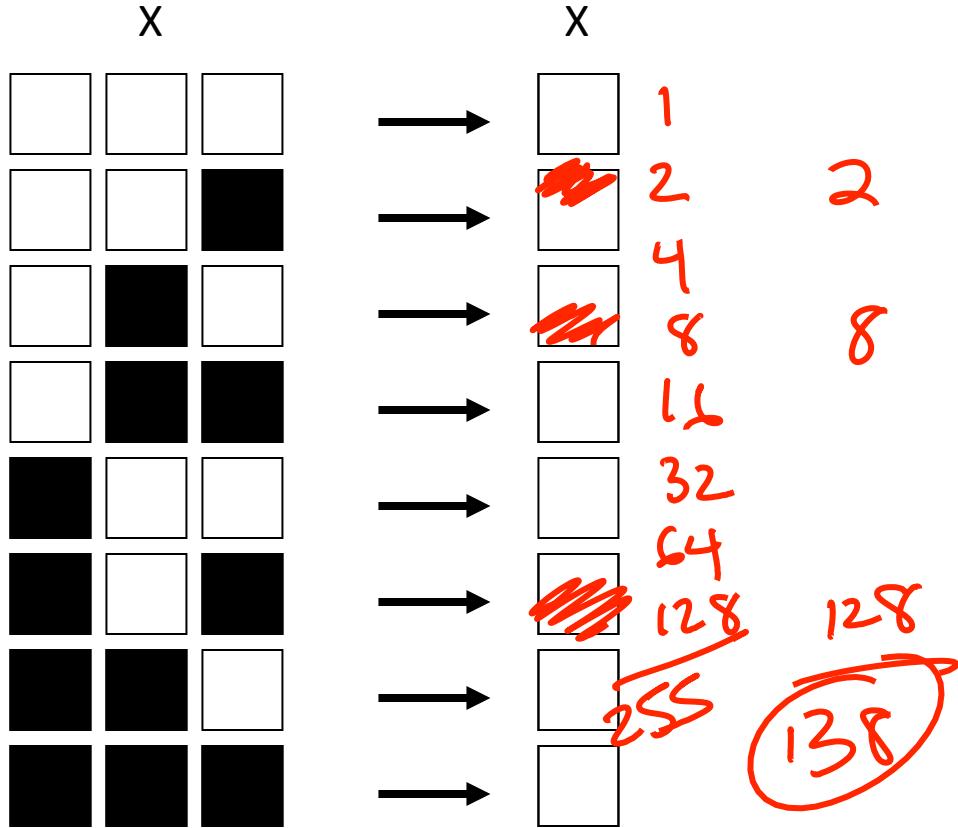
Four Classes of Behavior



Source: From Wolfram (2002, pp. 55-56)

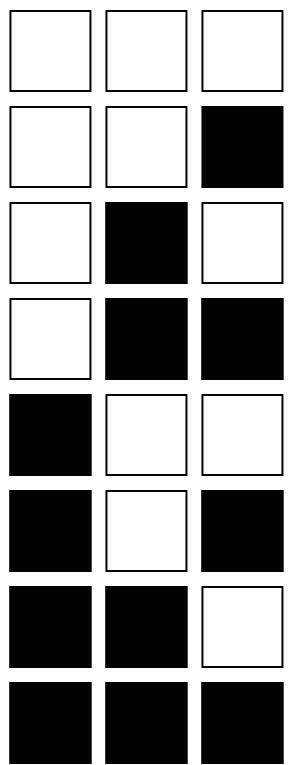


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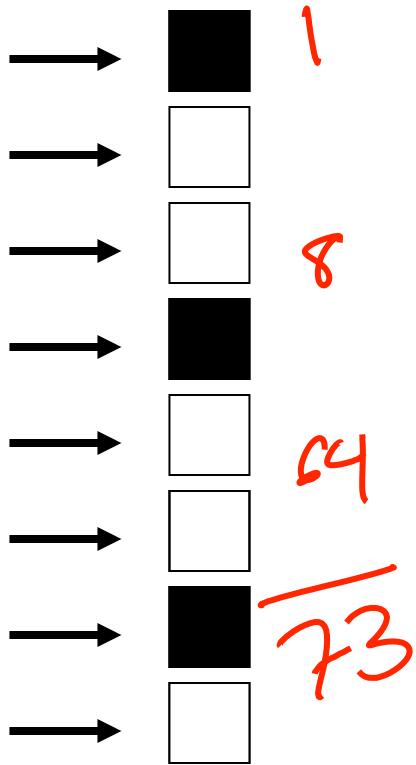


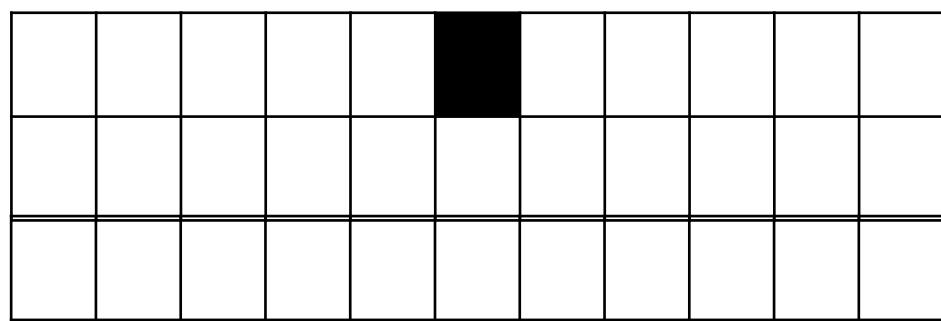
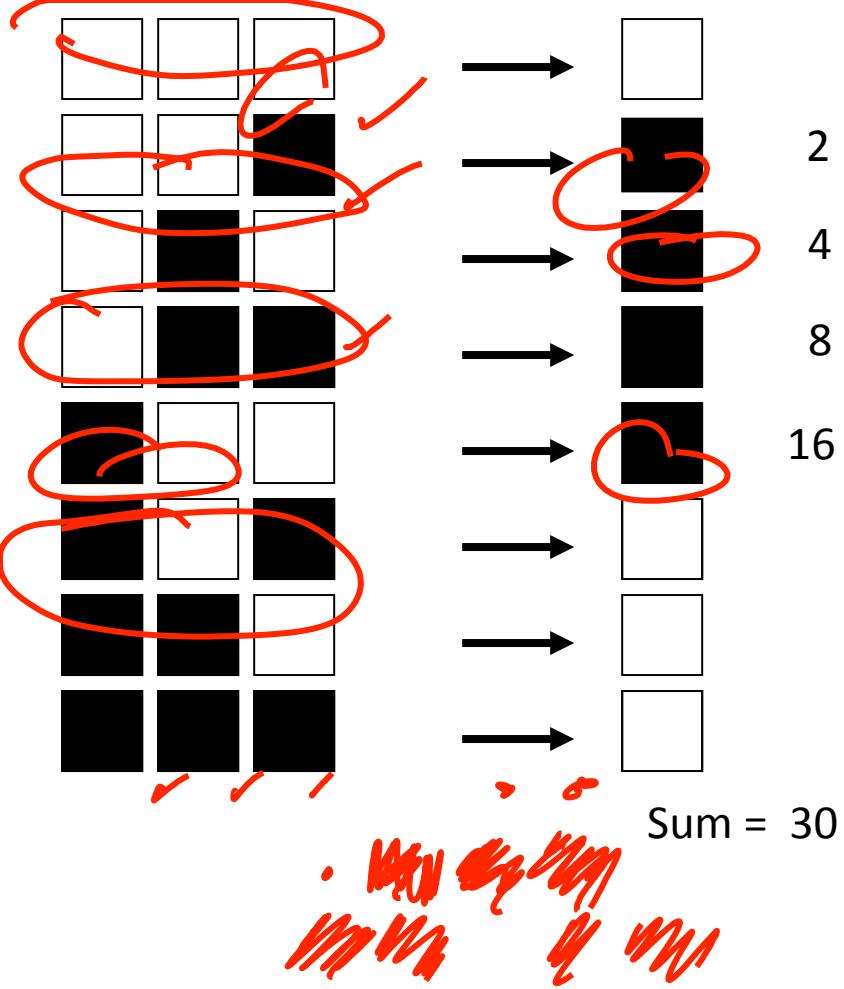
1

X

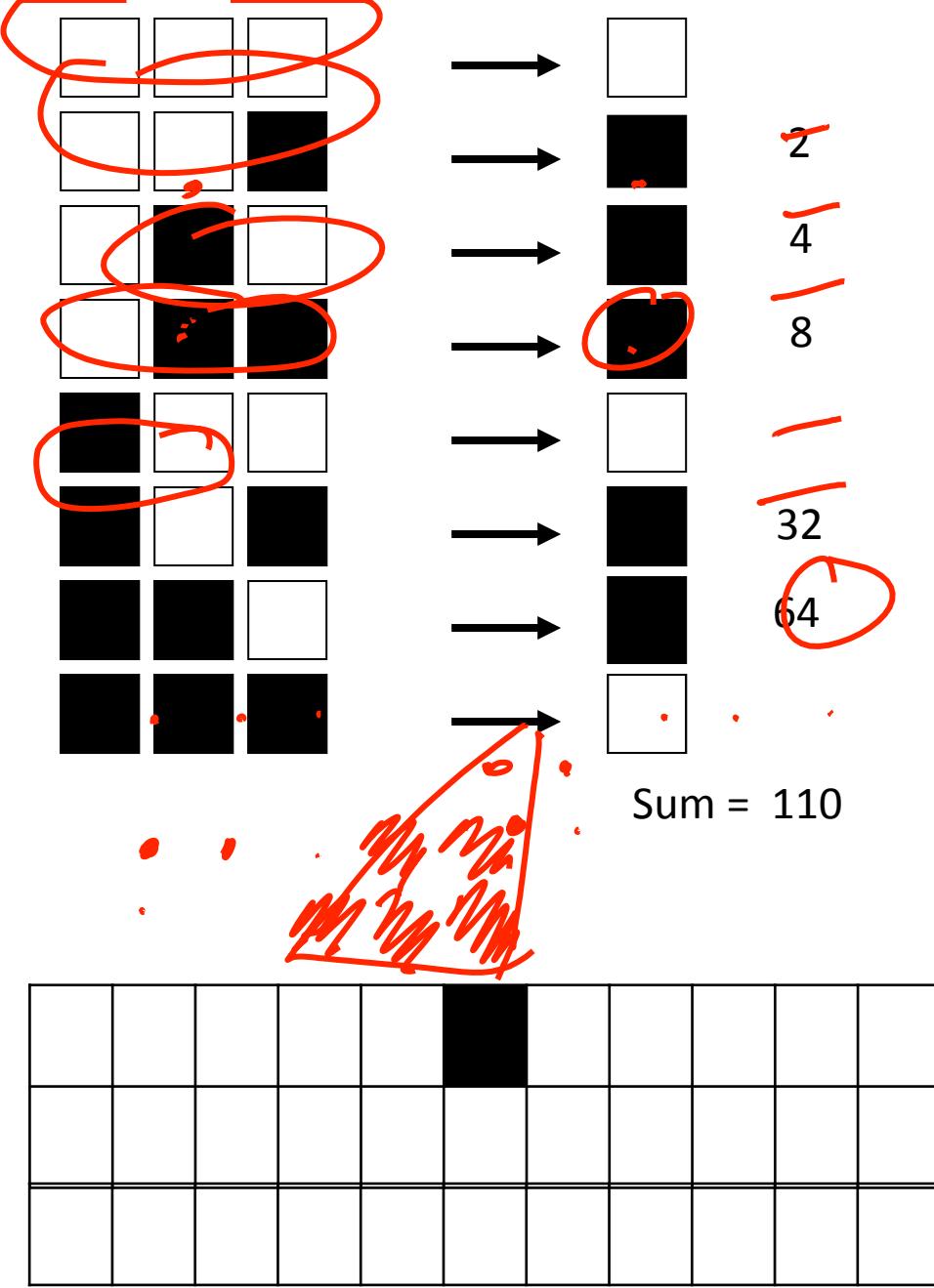


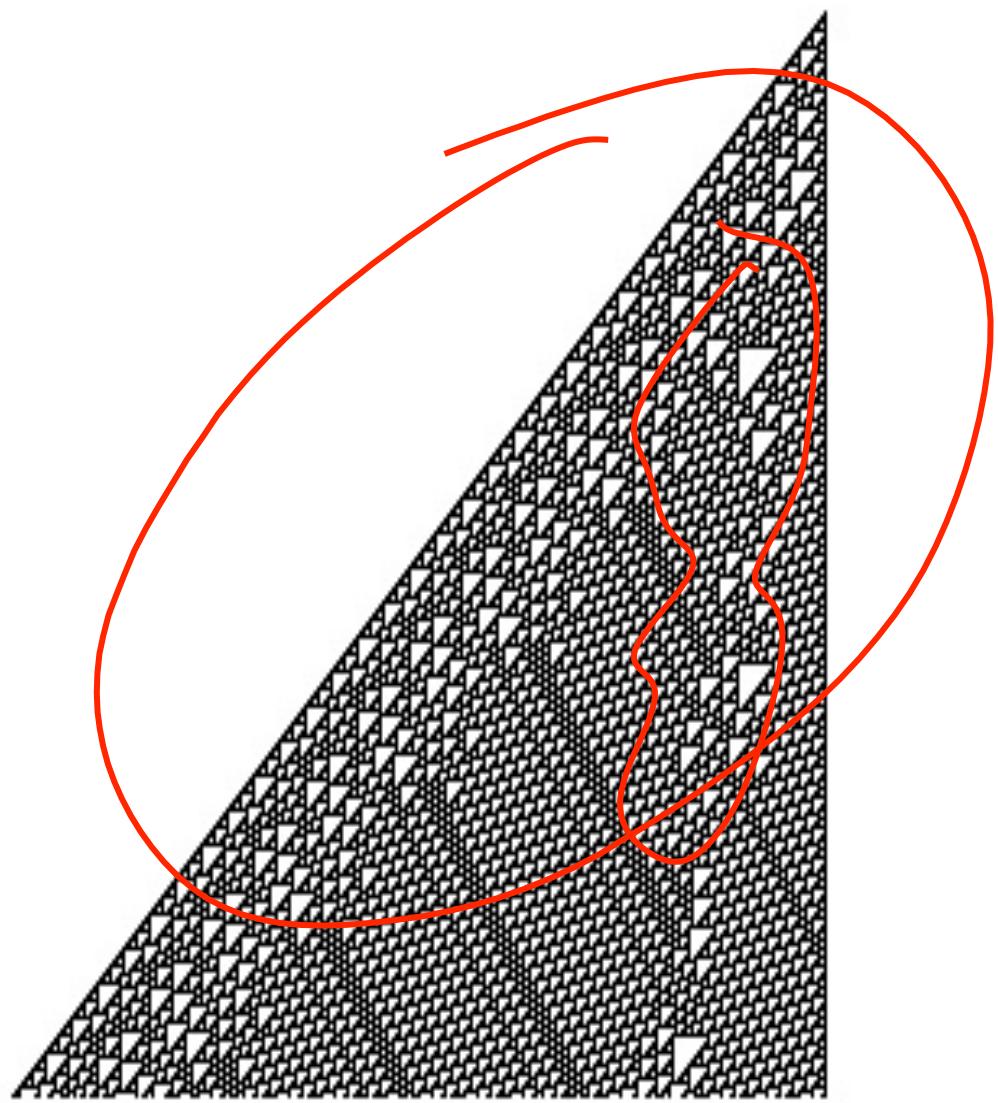
X

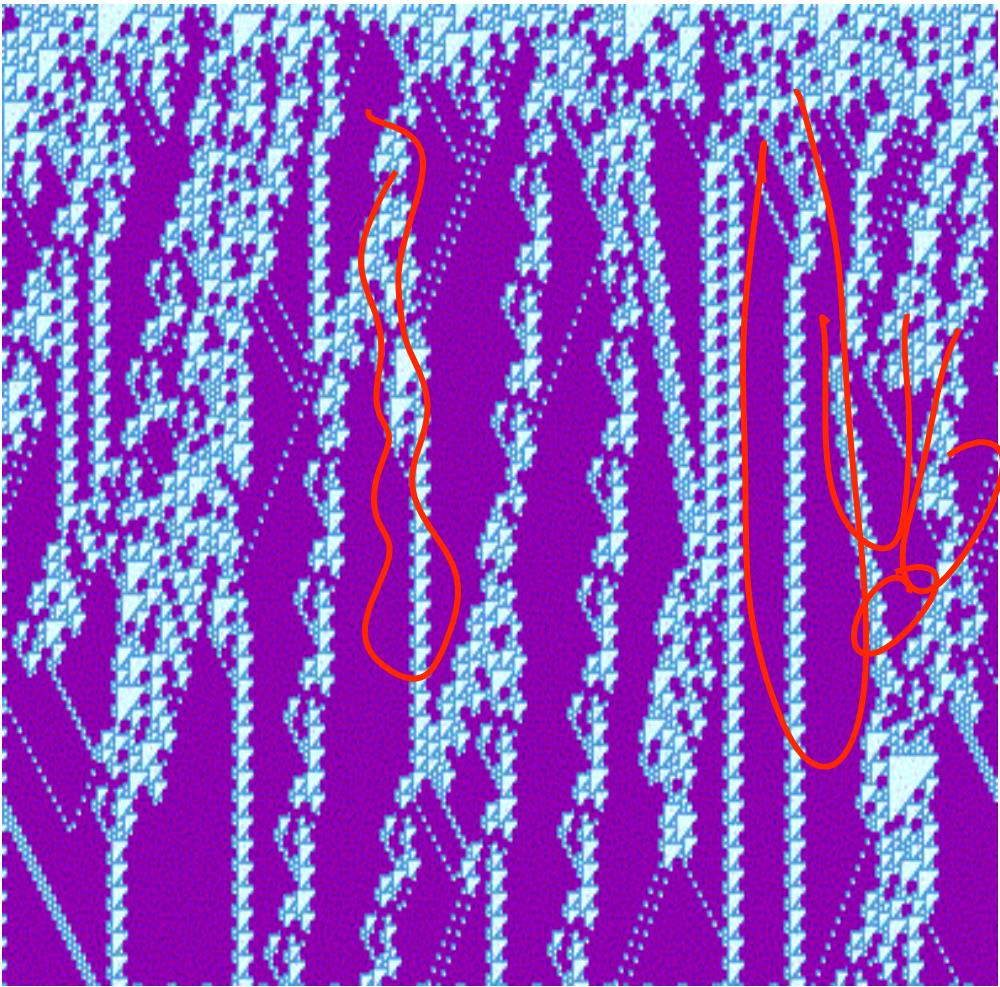




Netlogo

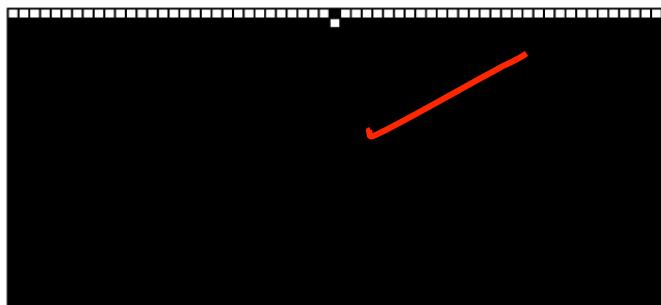




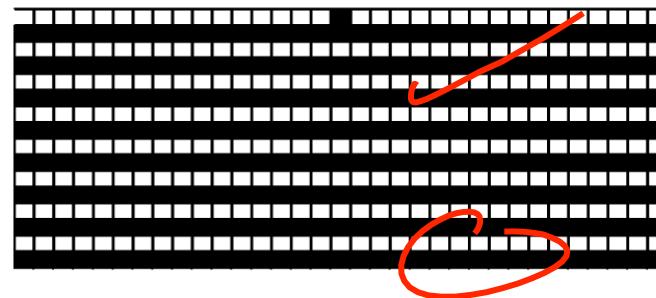


Four Classes of Behavior

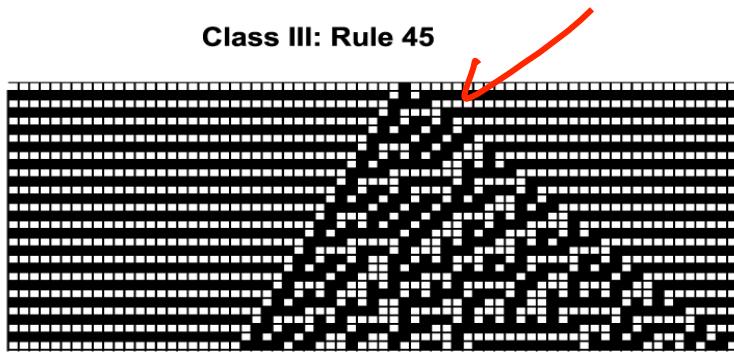
Class I: Rule 251



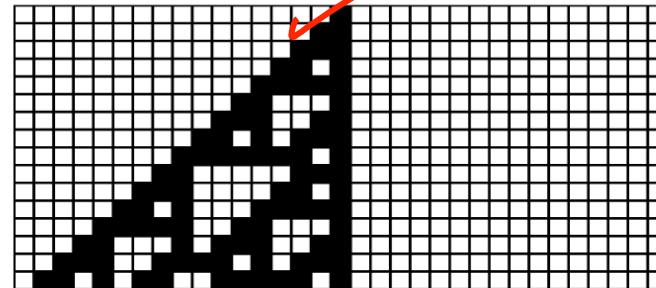
Class II: Rule 119



Class III: Rule 45

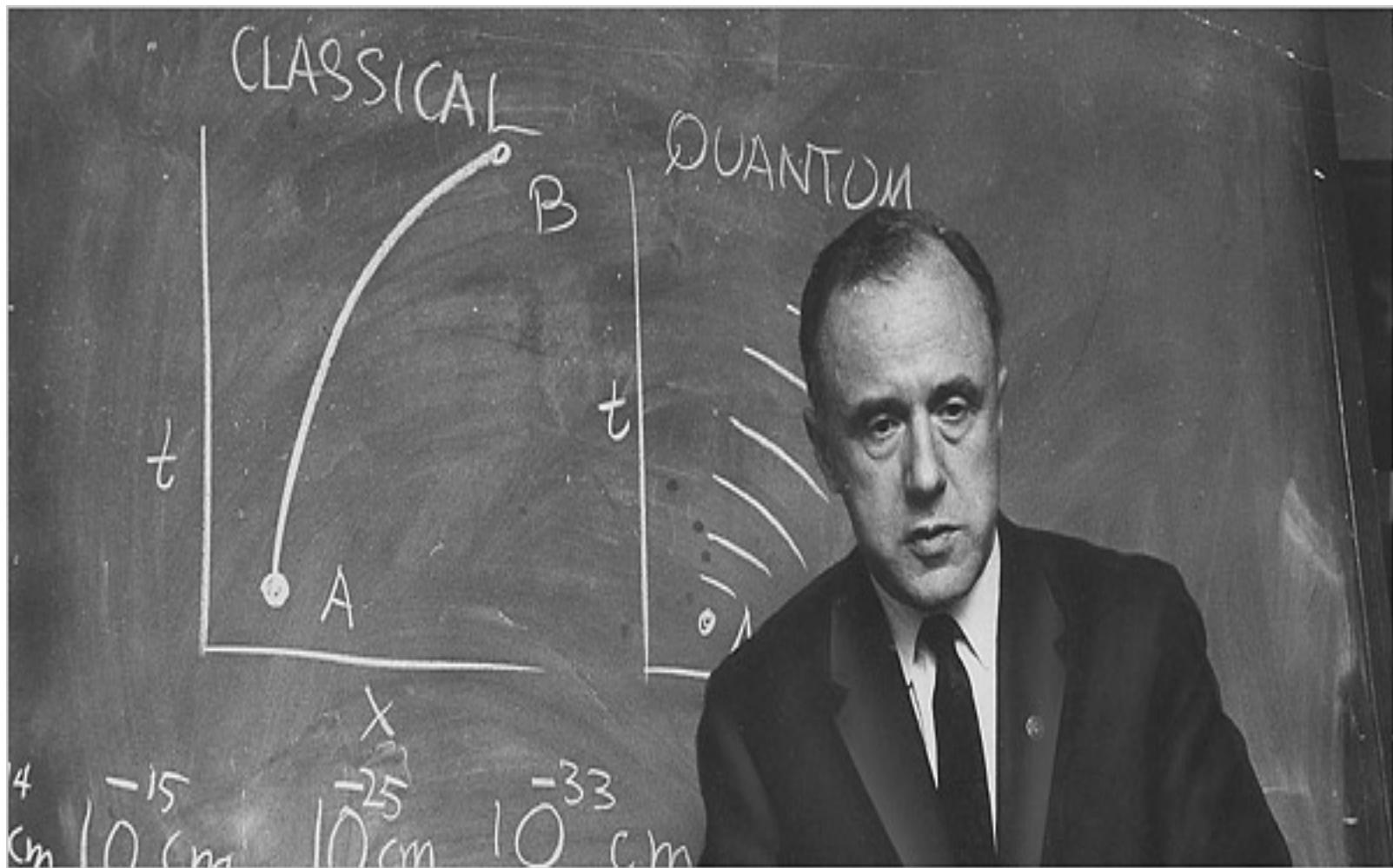


Class IV: Rule 110



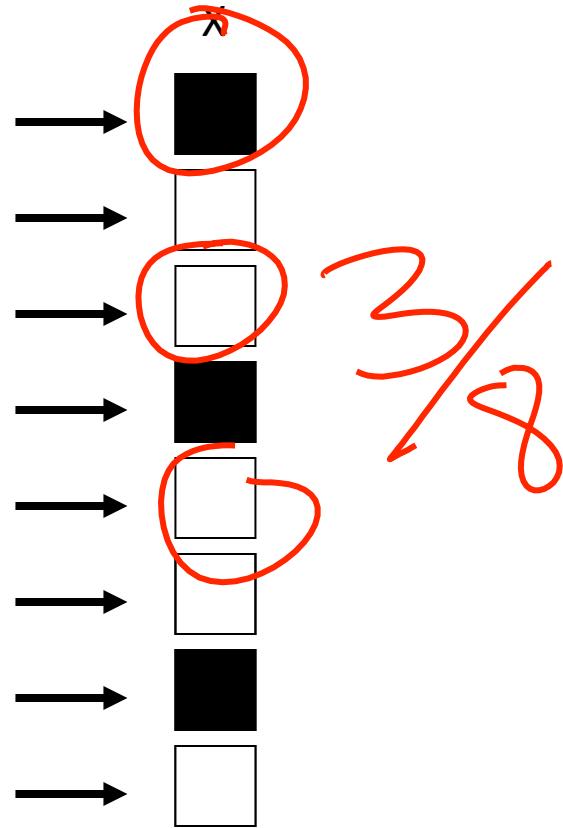
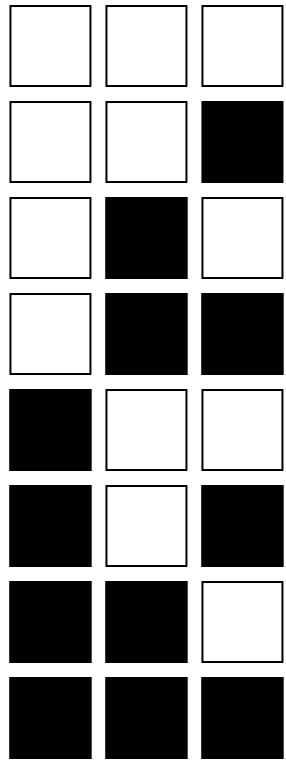
Source: From Wolfram (2002, pp. 55-56)

“It From Bit”



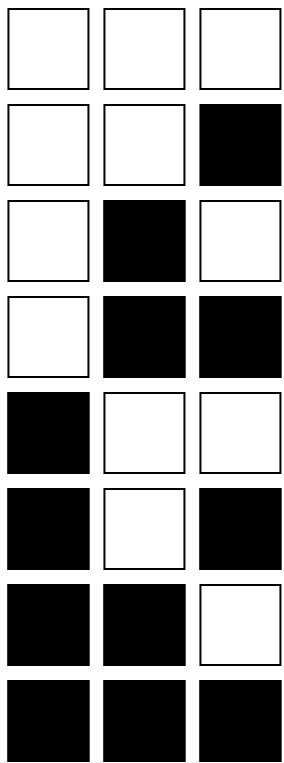
Langton's λ

X

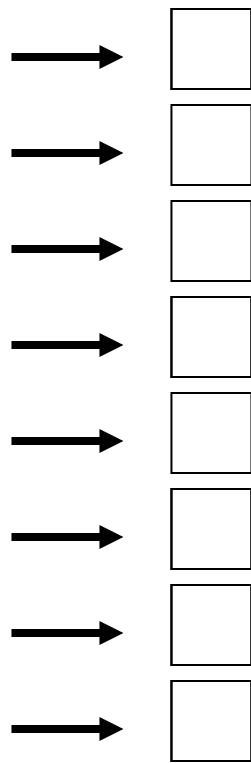


Langton's λ

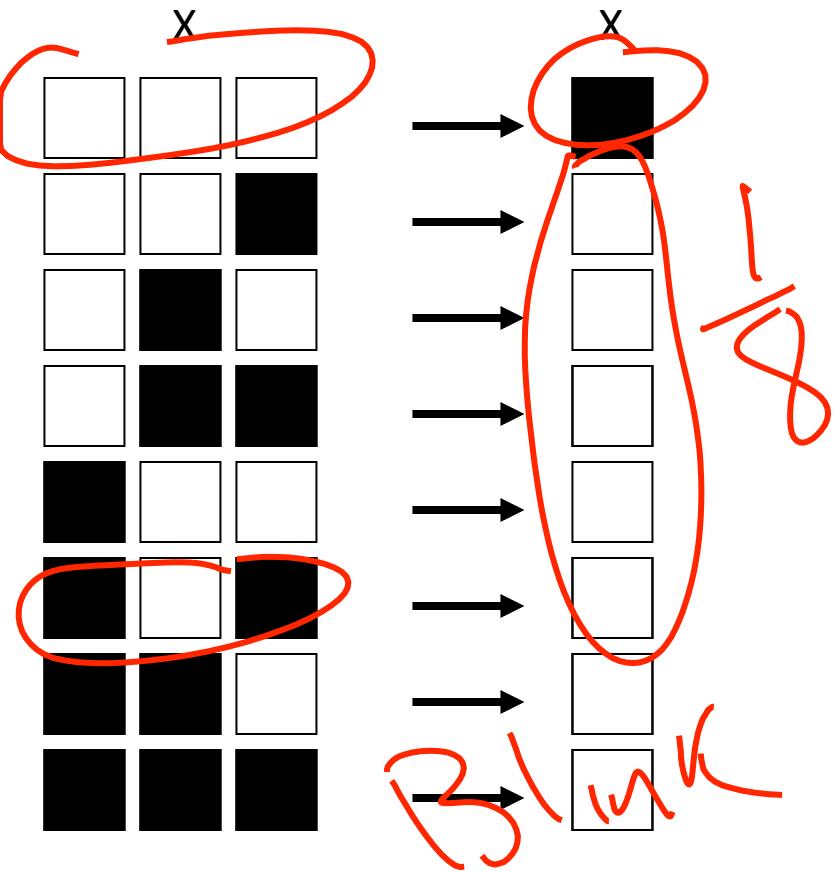
X

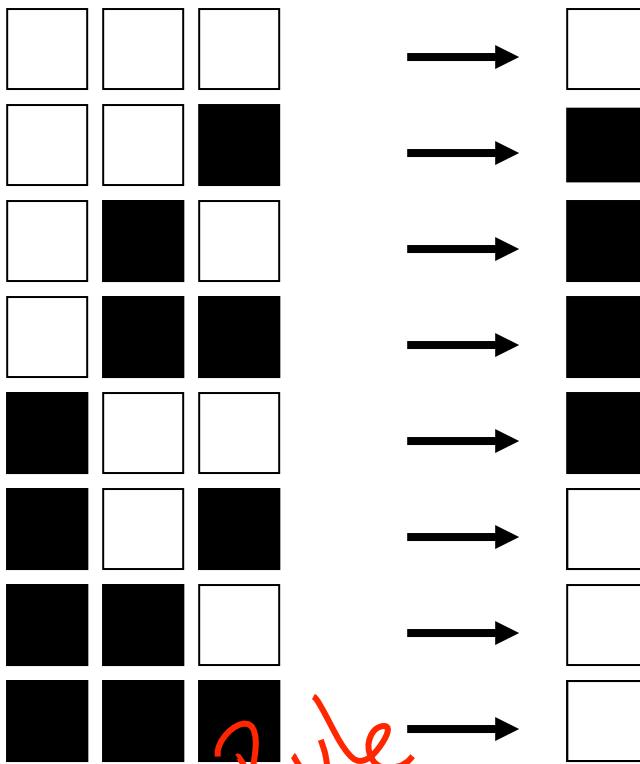


X



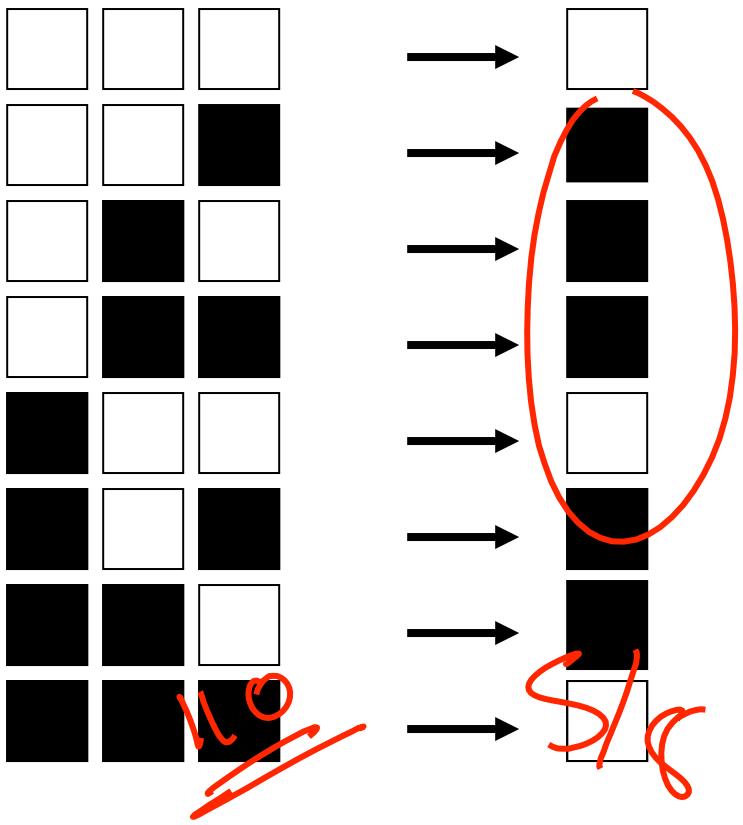
O/S





Rule
37
chaotic

~~JGJ~~

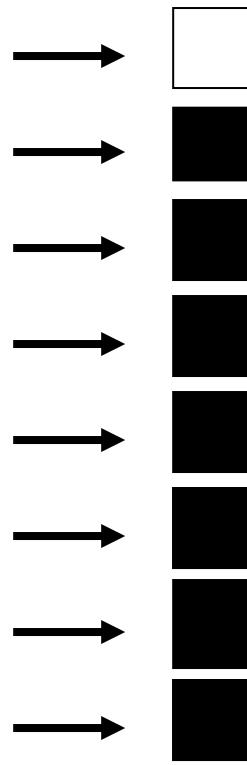
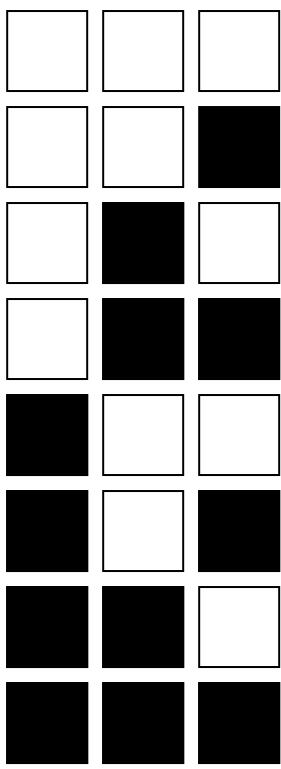


Complex

chaos

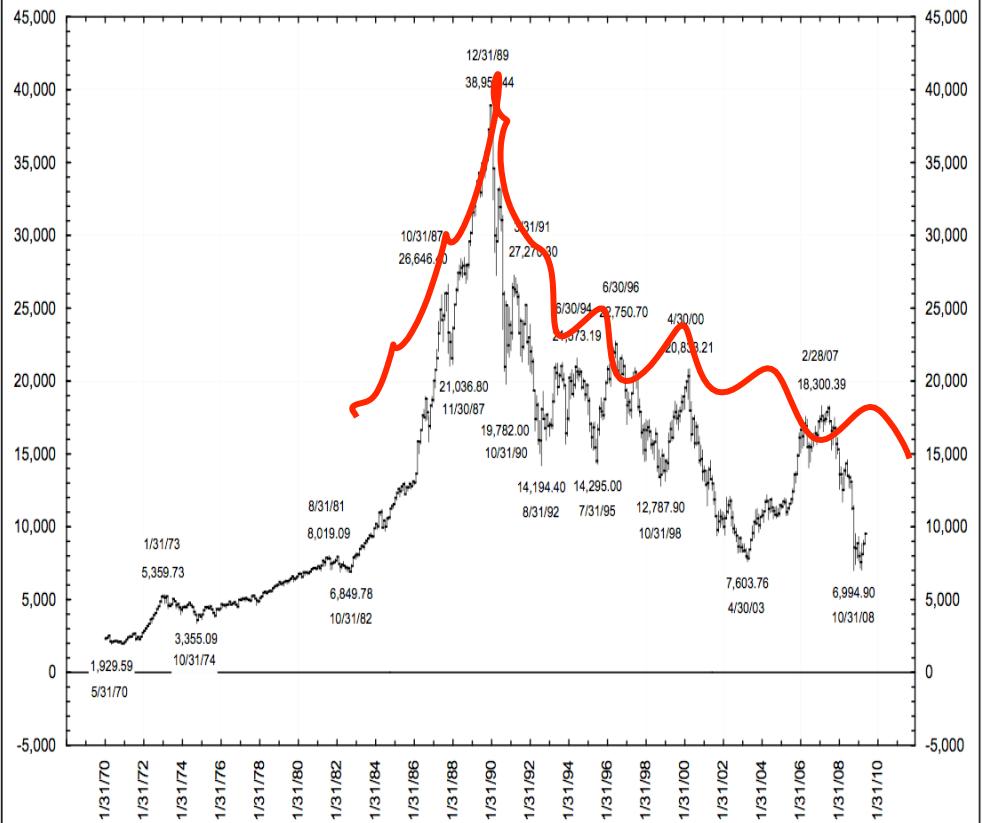
complet

λ	ALL Rules	Class III	Class IV
0	1	0	0
1	8	0	0
2	28	2	0
3	56	4	1
4	70	20	4
5	56	4	1
6	296 38	2	0
7	8	0	0
8	1	0	0



~~7/8~~

Nikkei 225 (Monthly)



- Simple rules combine to form anything
- “it from bit”
- Complexity and randomness require interdependency

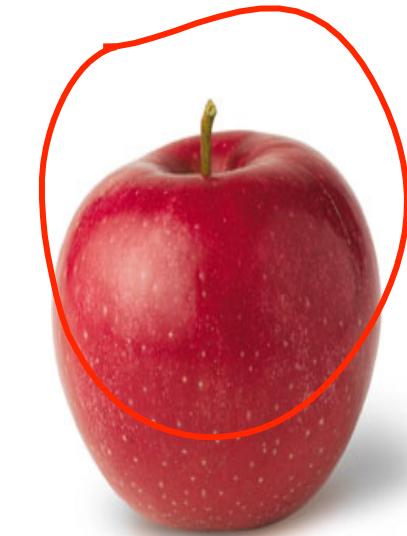
Model Thinking

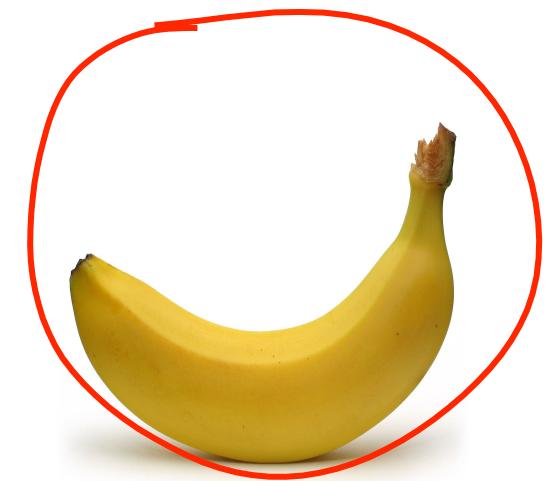
Scott E Page

Model Thinking

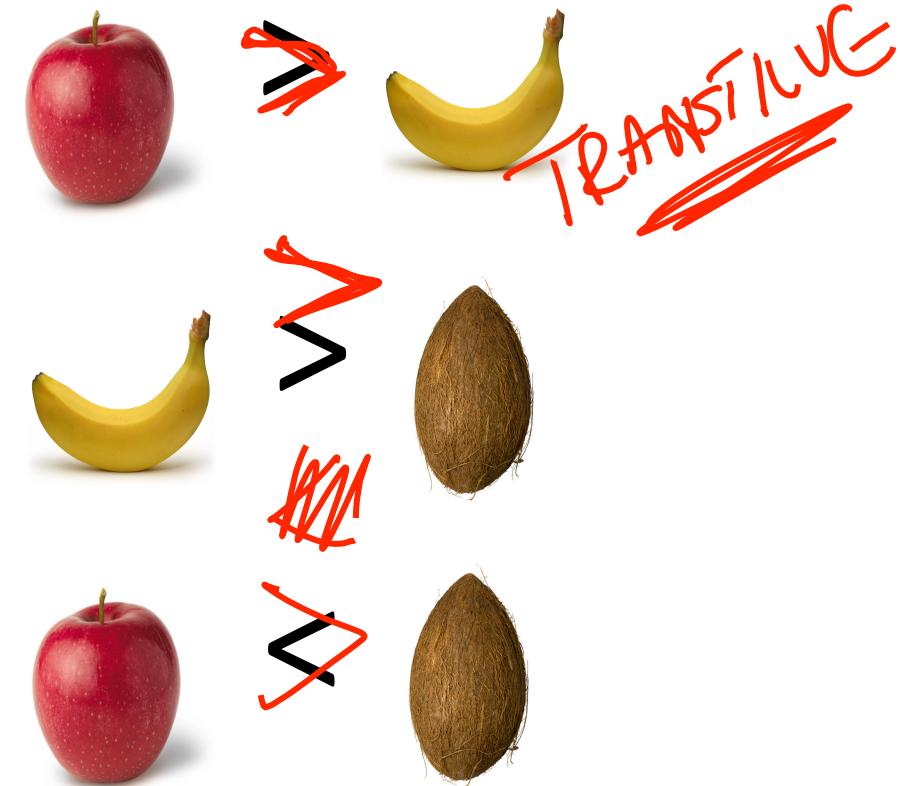
Scott E Page

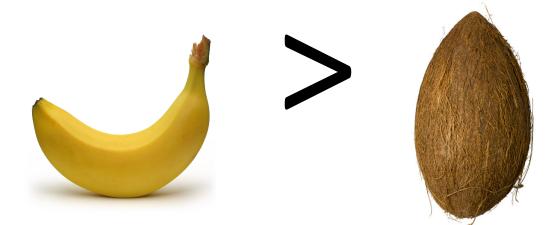
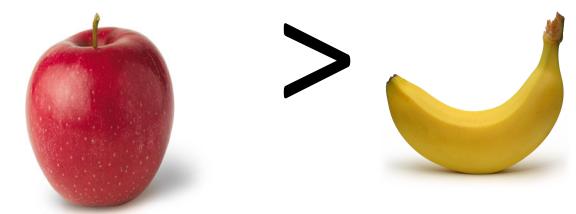
Preference Aggregation



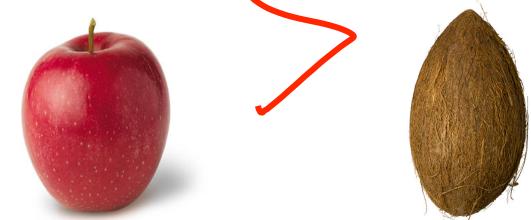


How Many?

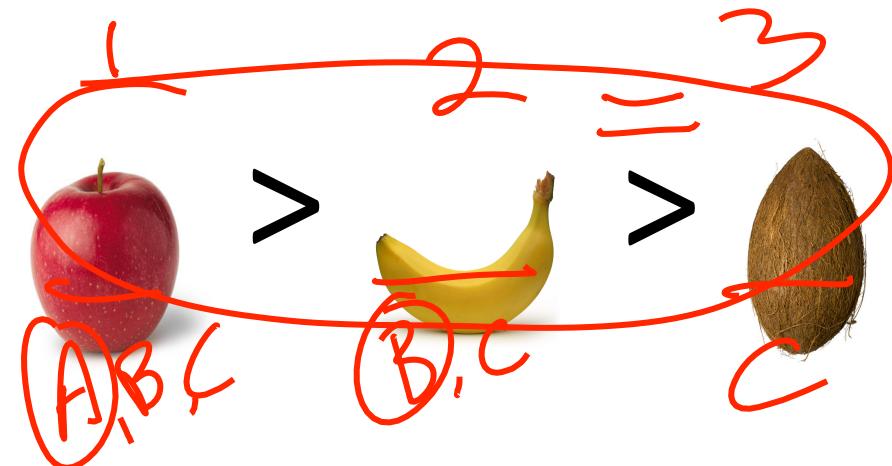




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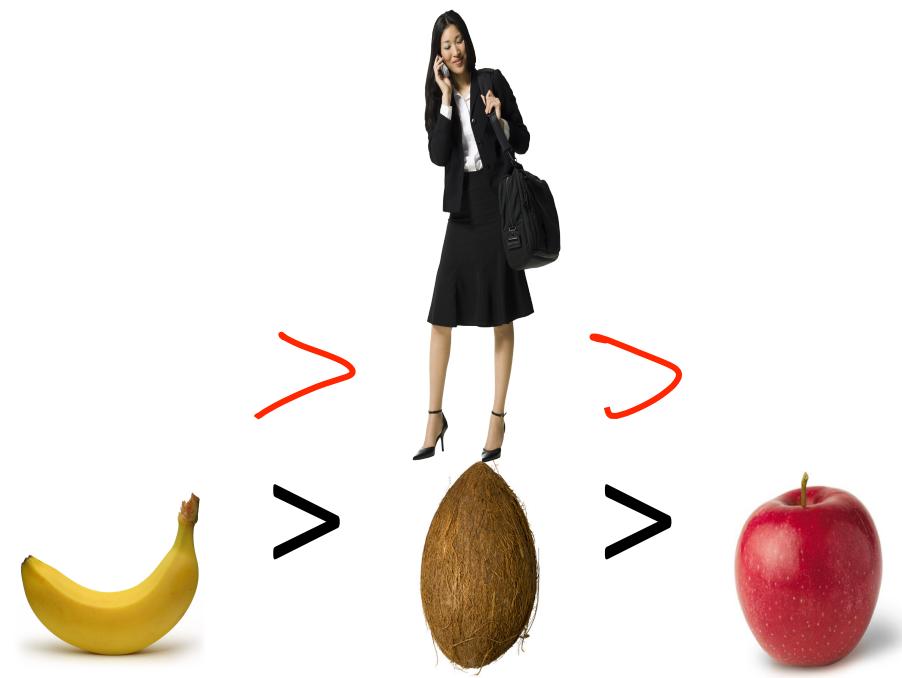


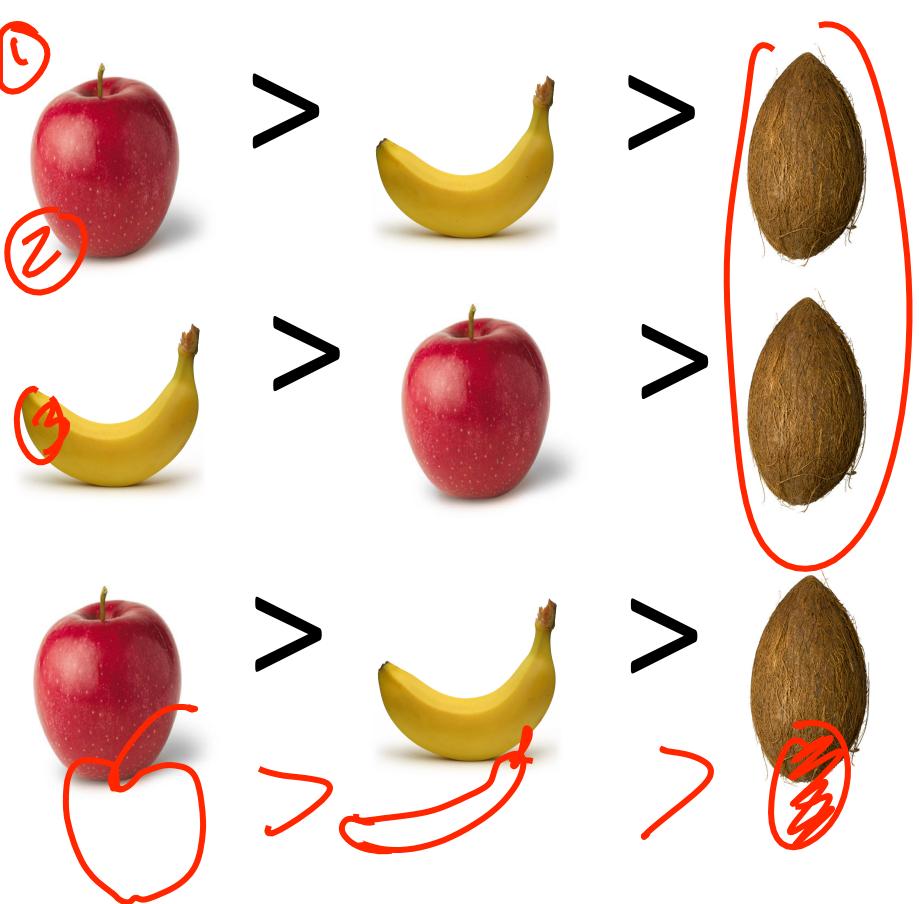
How Many?

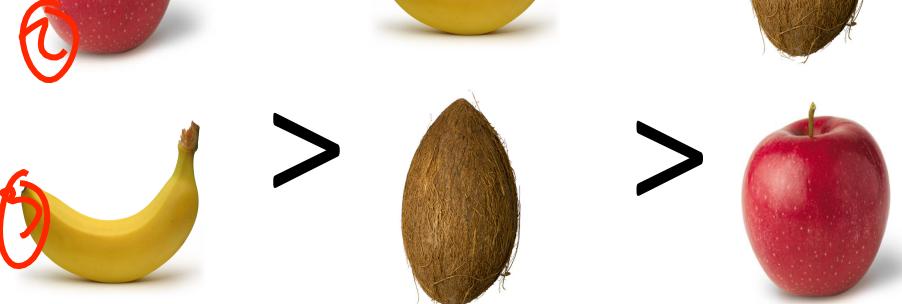
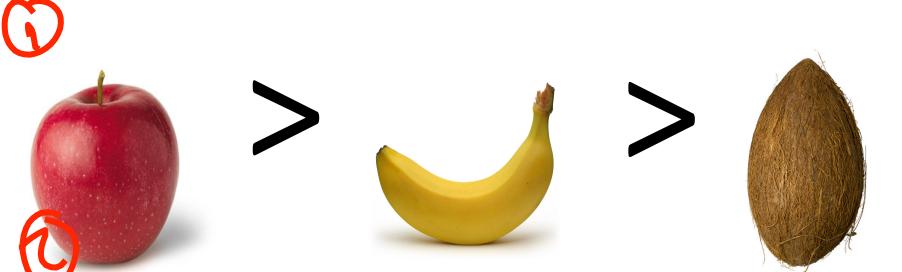


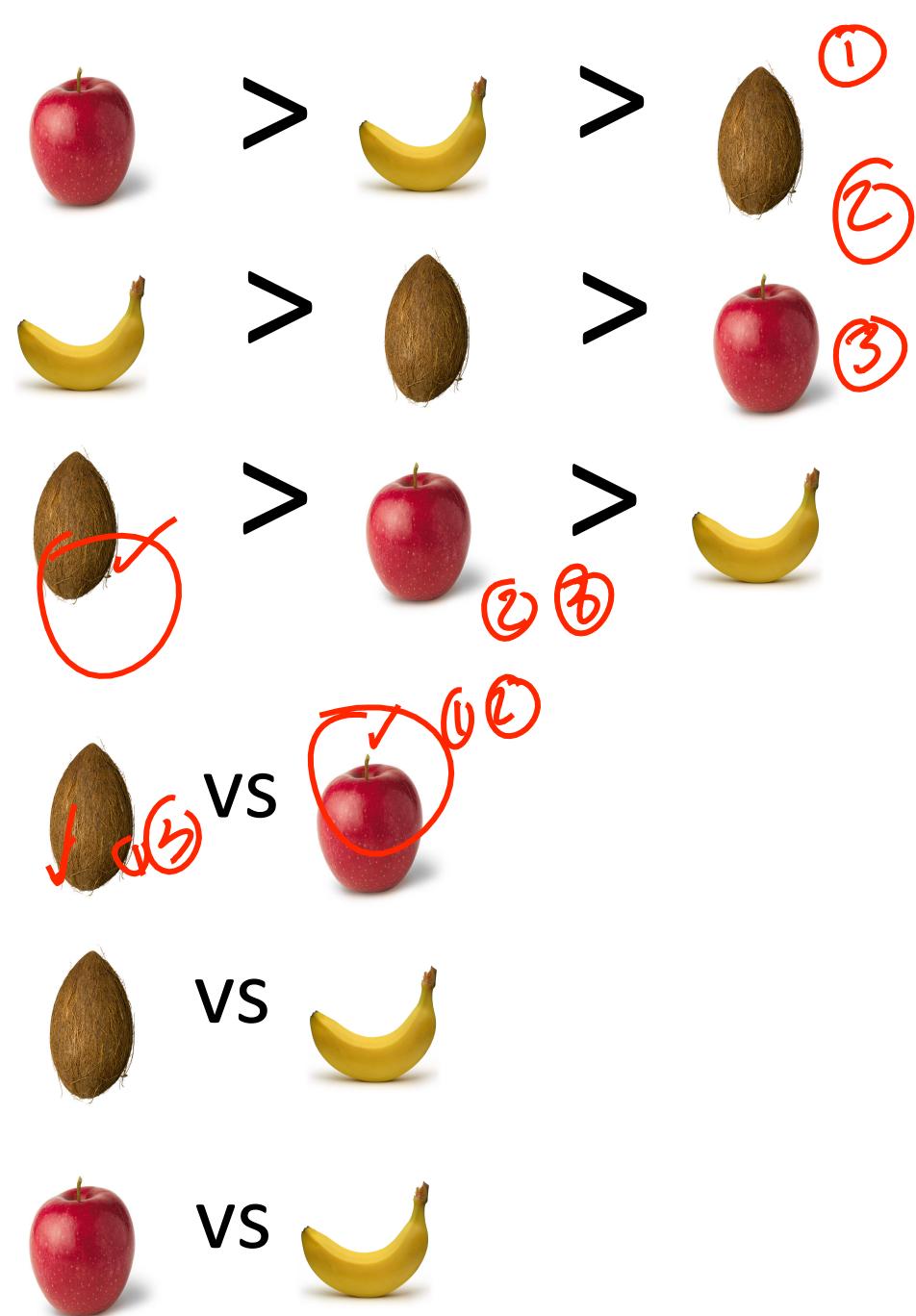
$$3 \times 2 \times 1$$

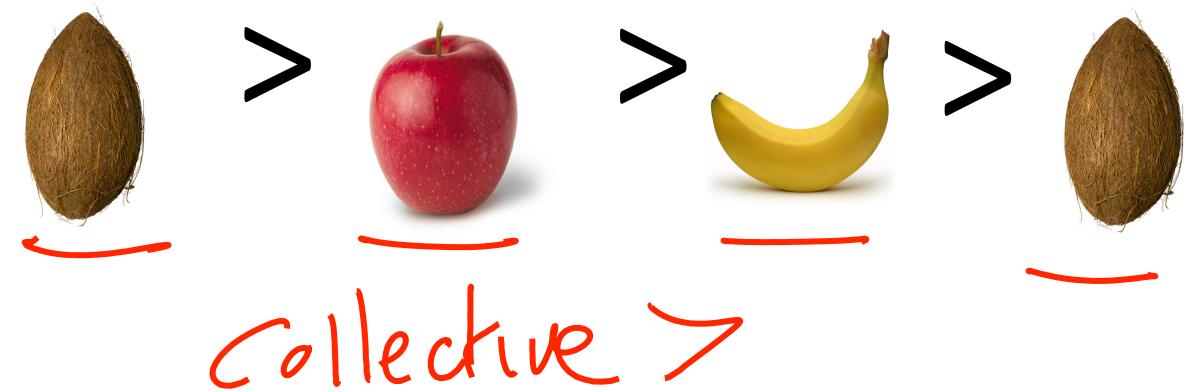
6











Condorcet Paradox

Each Person Rational



Collective NOT



apple > banana > coconut

banana > coconut > apple

coconut > apple > banana



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Model Thinking

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