



# Computational/Mathematical Model

A mathematical, logical, or graphical representation/abstraction

of a system/process

a set of descriptors/variables

depicting relationships between them

describe and predict some aspects of the  
system/process

<Time>

**Moose  
Population**

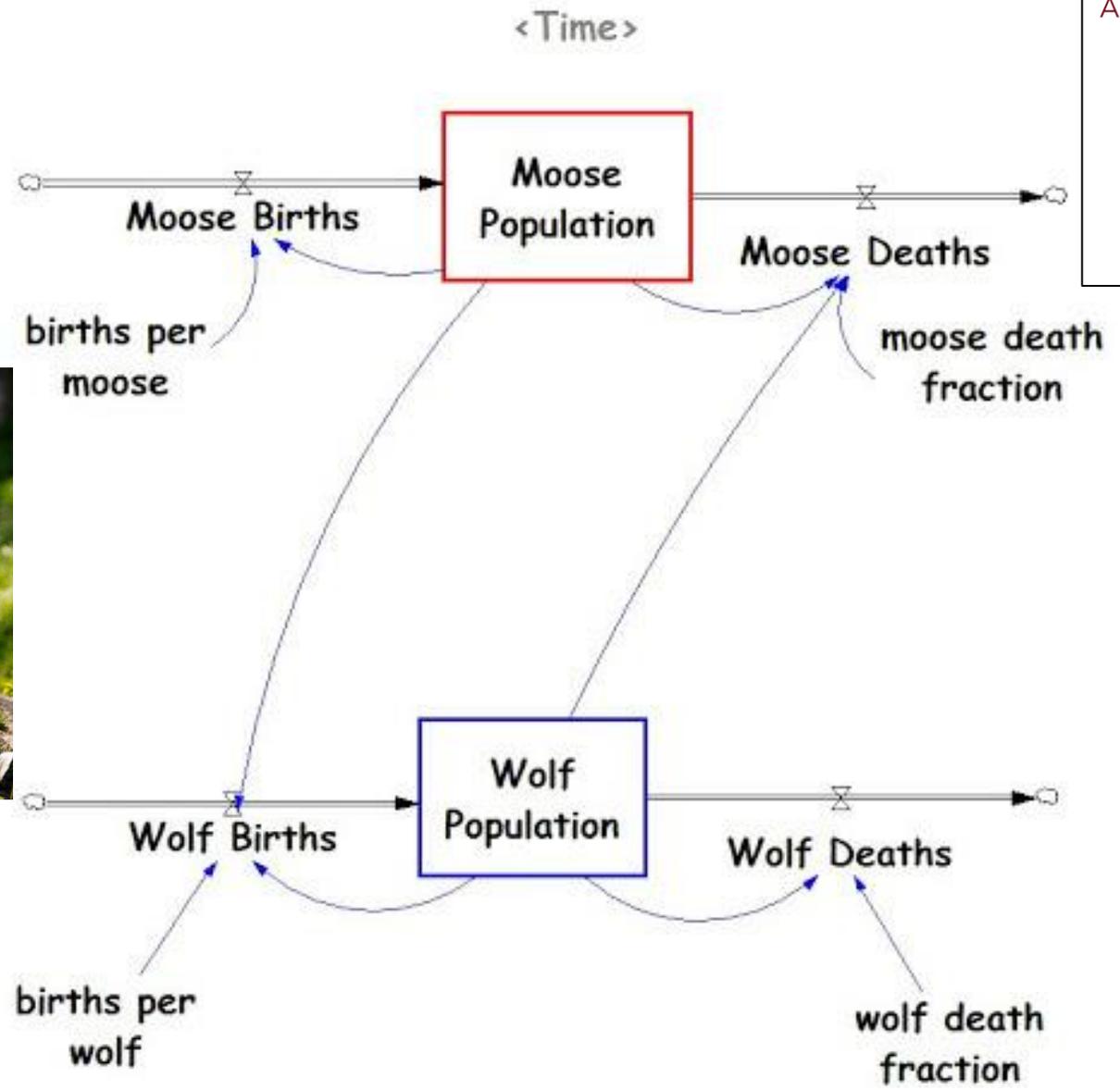
A mathematical, logical, or graphical representation  
of a system/process  
a set of descriptors/variables  
depicting relationships between them  
describe and predict some aspects of the  
system/process



**Wolf  
Population**



A mathematical, logical, or graphical representation  
of a system/process  
a set of descriptors/variables  
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## Feedback Loop

# Why model?

## The 2 Feedback Loop Limitation

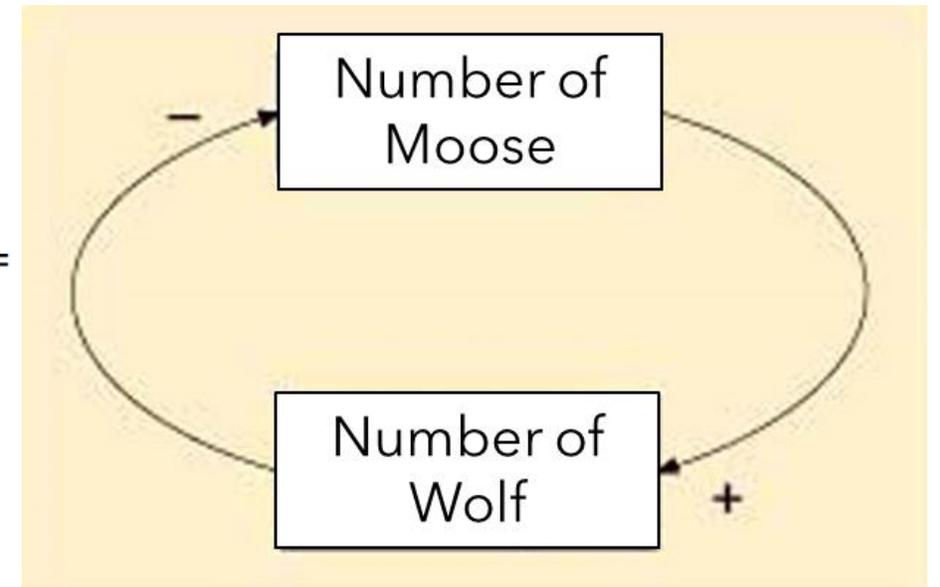
Humans unaided **CAN** predict behaviour of simple situations  
with **less than 2 feedback loops**

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Humans unaided **CANNOT** predict behaviour of complex situations  
with **2 or more feedback loops**



Dr. Terence Love, 2009



# Two categories

- **Phenomenological models**

Overall phenomenon is in focus;  
features of individual entities do not matter

- **Agent-based models**

Features of individual entities are in focus



# **Phenomenological model: Modelling Population Growth**



**Agent-based model:**

**Modelling The Game of Life**

# Rules of the game

## Premise

- Each cell has 8 neighbours
- Each cell - alive or dead, 2 states

## Rules

- **Alive**: if 3 neighbours are alive
- **Stay alive**: if 2 or 3 neighbours are alive
- **Dead**: otherwise

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

# Let's play the game

## Rules

- **Alive**: if 3 neighbours are alive
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6	7	8	9	10
11				15
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21	22	23	24	25

BLINKERS

# Let's play the game

## Rules

- **Alive**: if 3 neighbours are alive
- **Stay alive**: if 2 or 3 neighbours are alive
- **Dead**: otherwise

Time =0

1	2	3	4	5
6		8	9	10
11				15
16	17	18	19	20
21	22	23	24	25

# Let's play the game

## Rules

- **Alive**: if 3 neighbours are alive
- **Stay alive**: if 2 or 3 neighbours are alive
- **Dead**: otherwise

Time = 1

1	2	3	4	5
6		8	9	10
11			14	15
16	17		19	20
21	22	23	24	25

# Let's play the game

## Rules

- **Alive**: if 3 neighbours are alive
- **Stay alive**: if 2 or 3 neighbours are alive
- **Dead**: otherwise

Time =2

1	2	3	4	5
6			9	10
11			14	15
16			19	20
21	22	23	24	25

# Let's play the game

## Rules

- **Alive**: if 3 neighbours are alive
- **Stay alive**: if 2 or 3 neighbours are alive
- **Dead**: otherwise

Time =2

1	2	3	4	5
6			9	10
11			14	15
16			19	20
21	22	23	24	25

GROWTH

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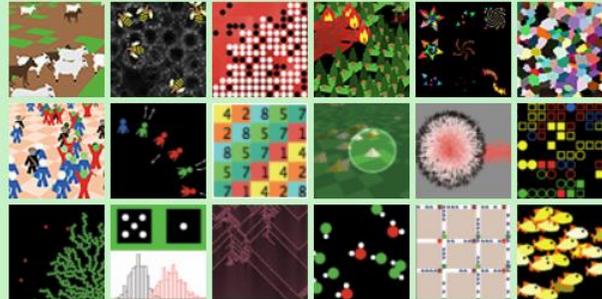
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# DIY: Some classic initial conditions

1	2	3	4	5
6			9	10
11			14	15
16	17	18		
21	22	23		

BEACON

1	2	3	4	5
6	7			10
11			14	15
16	17		19	20
21	22	23	24	25

F-Pentomino

**THE CONWAY'S GAME OF LIFE  
IS A FAMOUS CELLULAR  
AUTOMATA**

# Take home messages

## 1. Simple model → Complex pattern

4 August 1972, Volume 177, Number 4047

# SCIENCE

2.

**More Is Different**

Broken symmetry and the nature of the hierarchical structure of science.

P. W. Anderson

The reductionist hypothesis may still planation of phenomena in terms of

less relevance they seem to have to the very real problems of the rest of science, much less to those of society. The constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity. The behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear, and the understanding of the new behaviors requires research which I think is as fundamental in its nature as any other. That is, it seems to me that one may array the sciences roughly linearly in a hierarchy,

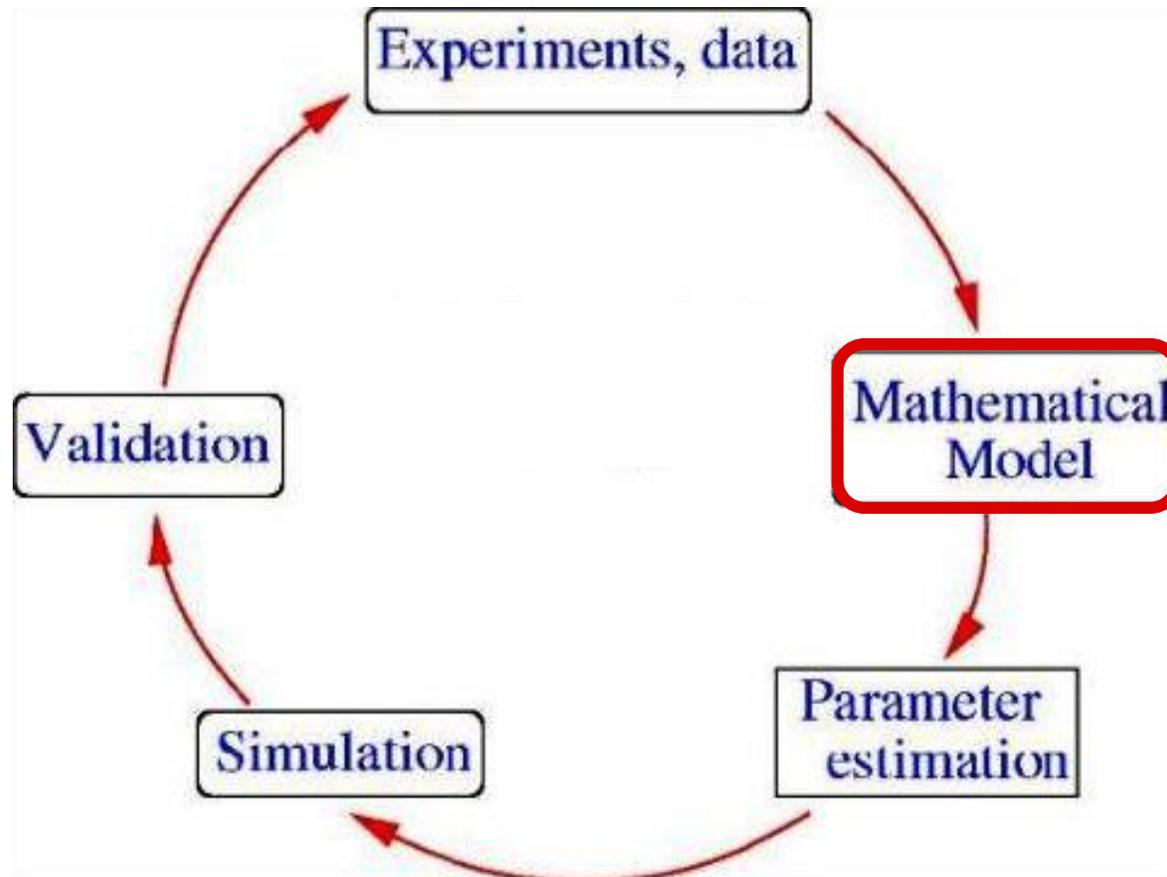
# Always remember the model assumptions

*All models are wrong  
but some are useful*



George E.P. Box

# In the greater scheme of things



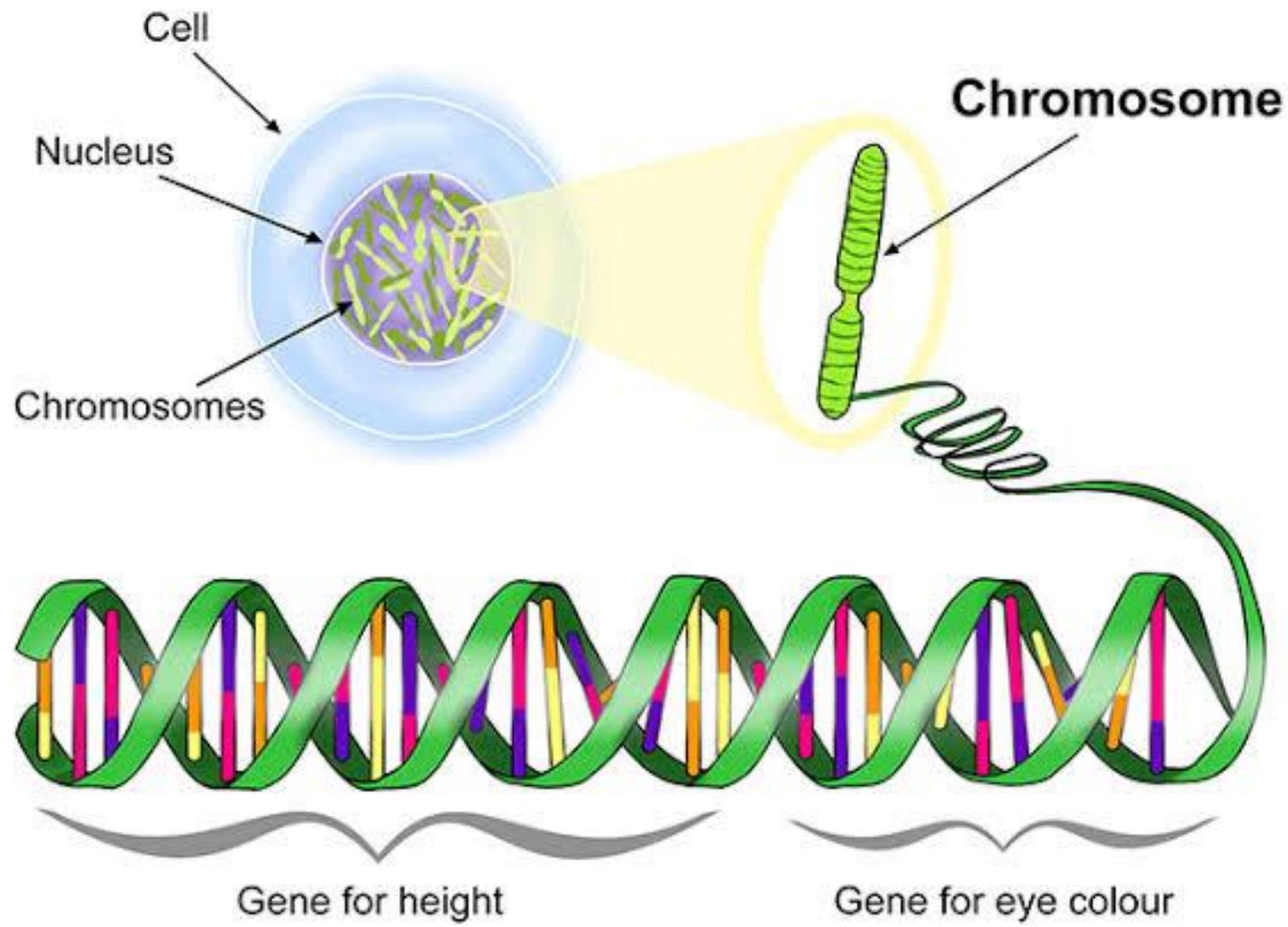
Computational  
/mathematical  
models  
complement  
experiments,  
and vice versa.



Any questions?



# DNA, genes and alleles



Gene → Portion of DNA sequence that codes for a protein

Alleles → Versions of a gene

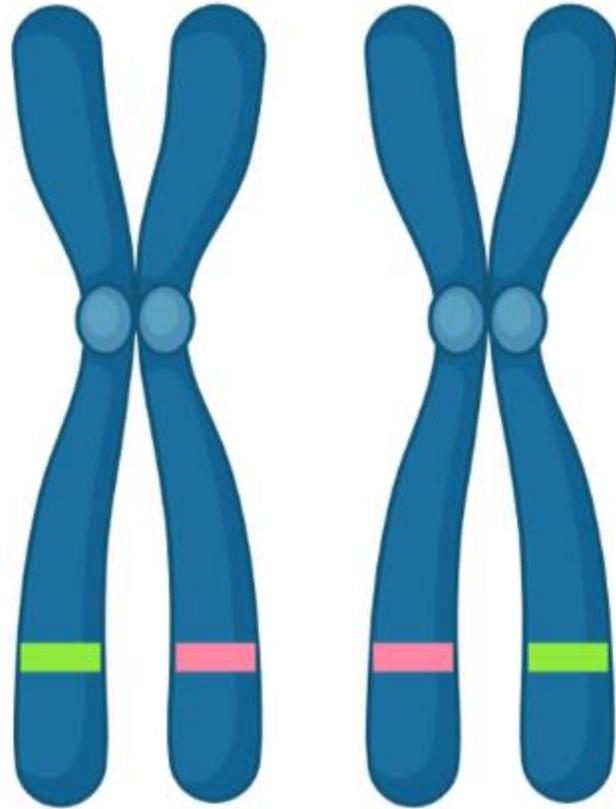
GGCACACGTGAGTCACTT	
GGC <b>G</b> CACGTGAGTCACTT	
GGC <b>G</b> CACGTGAGTC <b>T</b> CTT	

Genotype → Representation of an individual in terms of alleles

Phenotype → Representation of an individual in terms of observable traits



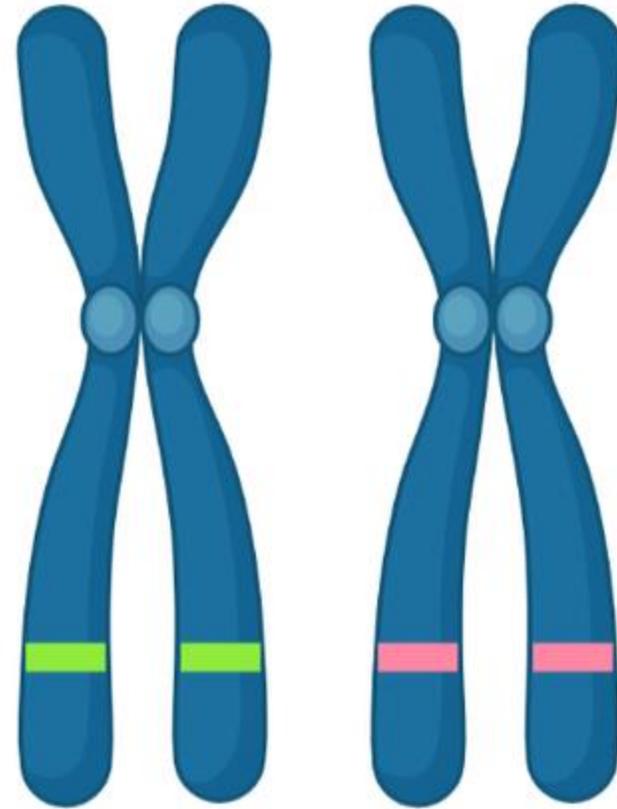
heterozygous



Aa

aA

homozygous



AA

aa