EAAP Session 19: Nutritional Modelling and Applications

Objective:

Increase the opportunities of meeting among European modellers

Session 19 proposed by

MODNUT-ASPA

Nutritional Modelling Committe

Approved in June 2022

Coordinators: Alberto S. Atzori (UNISS) & Antonio Gallo (UNICATT)

15 Members from Italian Universities

Outcomes

Modelling dossiers in divulgative Journals

Courses on nutrition modelling

Courses on Requirements and feeding values

Capacity building of Italian Scientific Community

Join the next generation publication model for open and transparent science

Peer Community In Animal Science

Free and transparent preprint and postprint recommendations in animal science

https://animsci.peercommunityin.org

contact@animsci.peercommunityin.org

@PCI_AnimSci

@pci-animsci.bsky.social

Systemic modelling application in animal science: archetypes for teaching and research in animal nutrition

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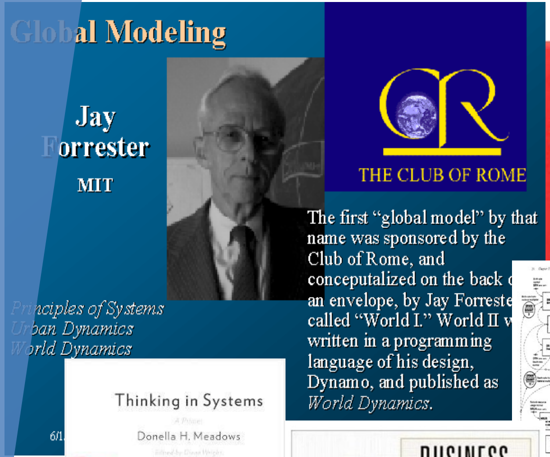
The systemic demand is largely increasing

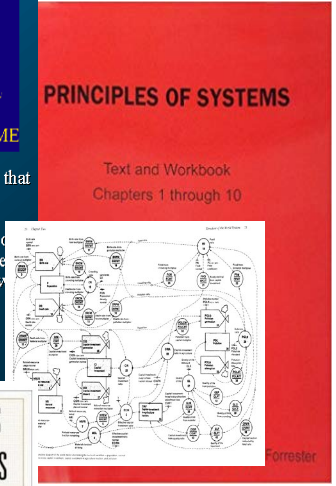
- Demand growth: whole picture vs. reductionist approach
- Teaching and learning from K-12 to MBA
- Global threats vs narrowed technical challenges
- Improve systemic views and apply holistic approaches
- Connect knowledges from different fields
- Wish of complexity understanding
- Simulation scenarios under changed conditions
  - climate adaptation!

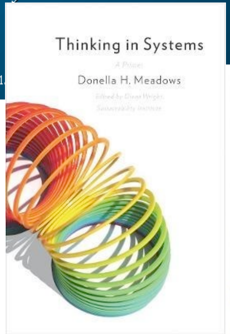
K-12

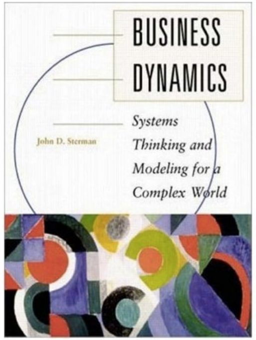
SYSTEM DYNAMICS (Origins):

COMPLEXITY UNDERSTANDING
WITH SYSTEM CONTROL THEORY

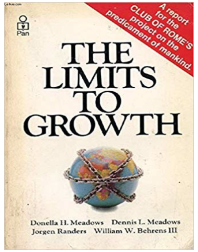


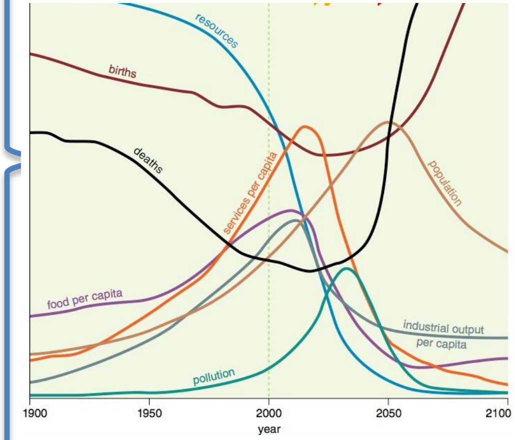




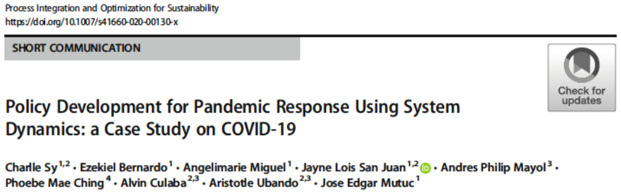


Meadows et al., 1972





- Agriculture & Food
- Biomedical
- Business
- Conflict, Defense and Security
- Education
- Energy
- Environmental
- Health Policy
- Information Science and Information Systems
- Model Analysis
- Psychology and Human Behavior


Process Integration and Optimization for Sustainability
https://doi.org/10.1007/s41660-020-00130-x

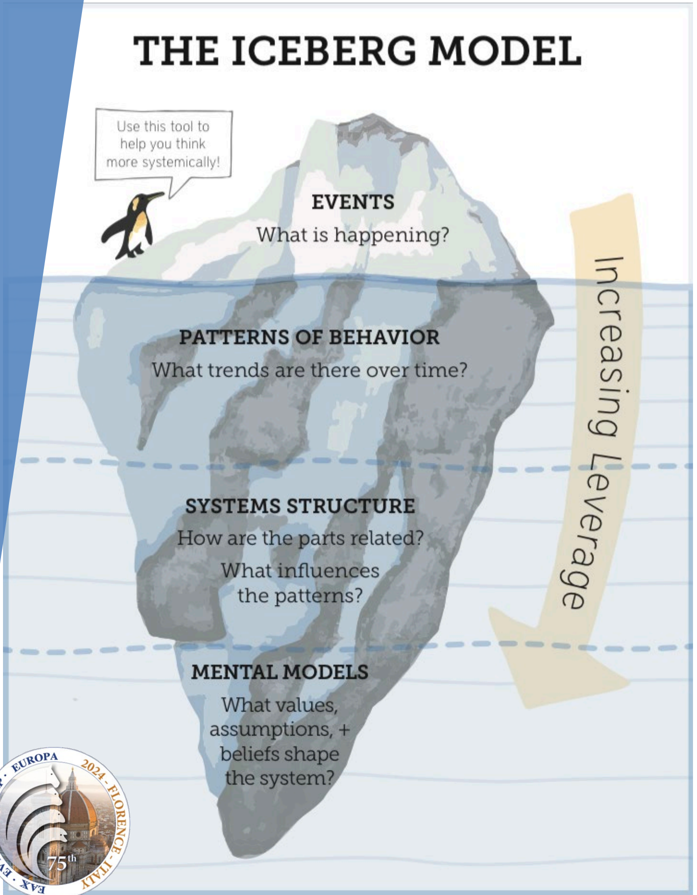
SHORT COMMUNICATION

Check for updates

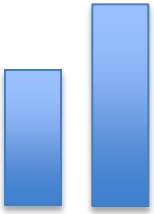
Policy Development for Pandemic Response Using System Dynamics: a Case Study on COVID-19

Charlle Sy[1,2] · Ezekiel Bernardo[1] · Angelimarie Miguel[1] · Jayne Lois San Juan[1,2] · Andres Philip Mayol[3] · Phoebe Mae Ching[4] · Alvin Culaba[2,3] · Aristotle Ubando[2,3] · Jose Edgar Mutuc[1]

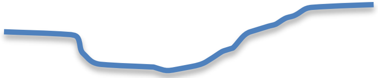
System dynamics approach

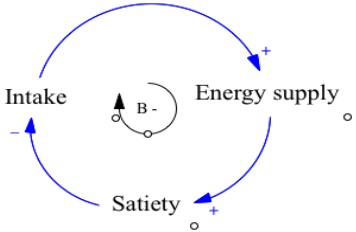


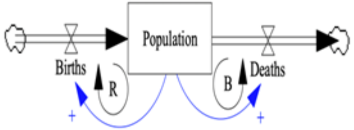
Data points



Pattern







3

The events (*phenomena*)

2

The pattern of behavior showing events

1

The structure that drove the behavior

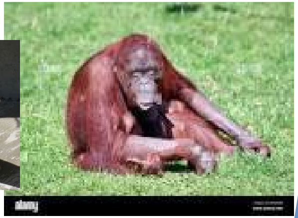
Leverage capacity

From "The System Zoo" to "The System Herd"

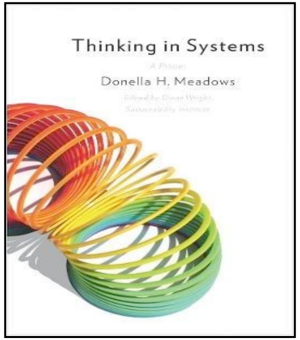
(Forrester, 1969; Meadows 2002)

- Goodman (1974): simple structures on commodity cycles, market dynamics, residential communities, epidemics, and ecology;
- Grant et al. (1997) ecological models for rangeland and forest management
- Ruth and Hannon (1997a; 1997b) biological and economic systems contexts;
- Deaton and Winebrake (1999) and Ford (1999) environmental science
- Sterman (2000) business, management, manufacturing, industry, supply chains;
- Fisher (2011) urban dynamics, population dynamics, and epidemics.
- Haefher (2005) biological systems;
- Agricultural Sciences/Animal Sciences?
    - Tedeschi et al., 2011; 2023
    - Turner et al., 2016, 2015;
    - Turner and Goodman, 2018, 2020, .. Etc
    - Setianto et a. 2014

Denver



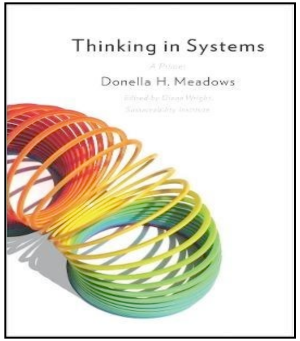
System Zoo



London

Objective

System Zoo



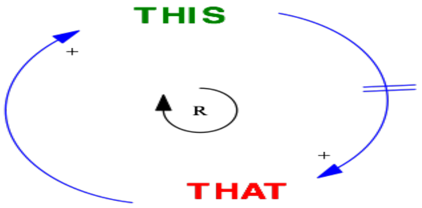
Question: Which basic elements for applications in animal nutrition?
(Archetypes, well known structures, etc)

Objective:
to contribute to the whole “System Herd” with the basic pieces of Systemic structures and basic SD models
(and feedback loops)

The teaching/learning barriers

Two barriers in learning complexity understanding and system modelling

1) The non-linear thinking (qualitative):
(identify feedbacks, thinking for loops,
What is nexts?



2) The understanding of stock dynamics (quantitative)
Stock level changes

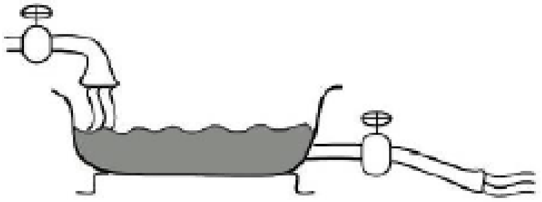


Figure 1. Bathtub

1) The non-linear Systemic Thinking

- Awareness and Causality
- Feedback and loops
- Complexity Understanding
- Insighfulness (“Eureka” or “Ah-Ah” Experience!)

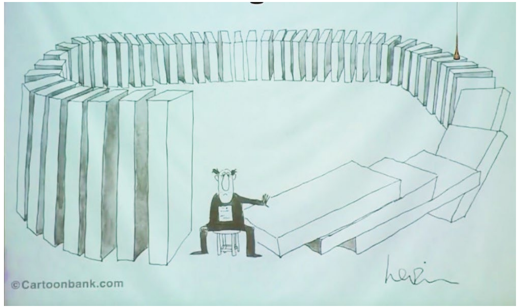
Senge, 1998

LINEAR APPROACH

Scientific question → Narrowed trial → Result Good practices → Policy

TIME?

Unintented consequences



NON-LINEAR WORLD (complexity)

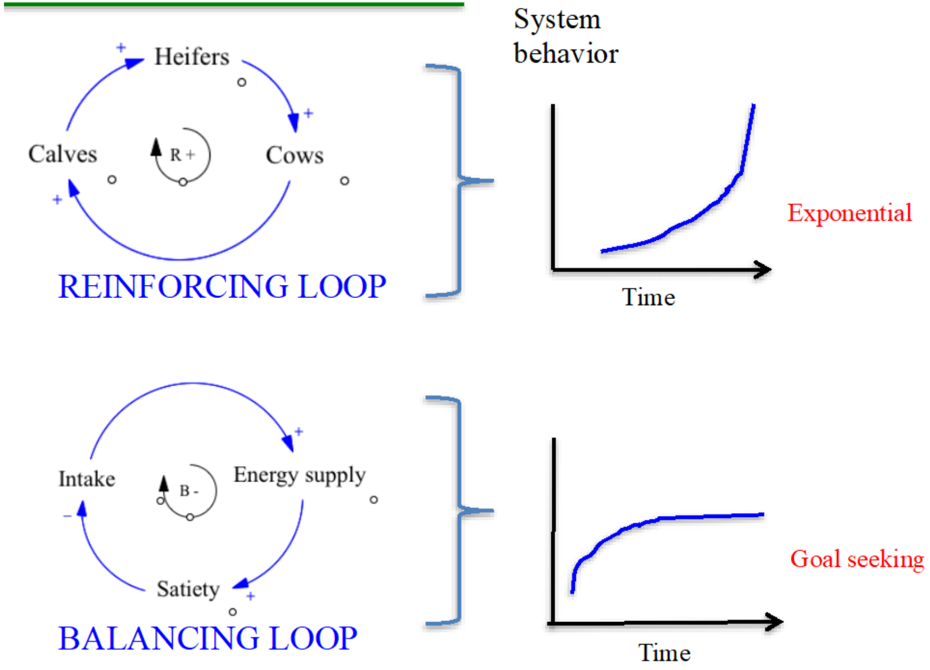
Sterman, 2000

Non linear approach: basic annotation

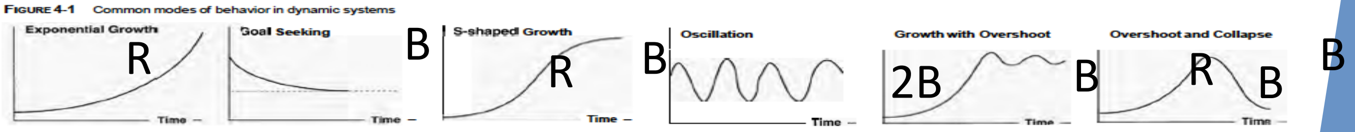
Dynamics arise from
Feedback Loop Interactions

Understanding future trends:
ability to trace feedback loops
and their effects over time

Time



(Adapted from Sterman, 2000)

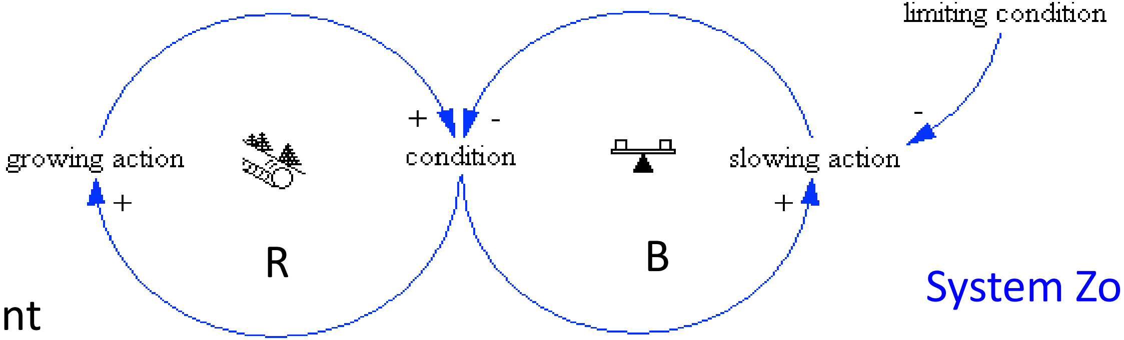


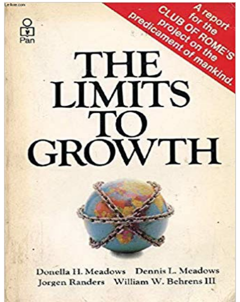
The system zoo: Qualitative (Archetypes)

System Archetypes common dynamics that seem to recur in many different settings.
Various combinations of loops, showing real-world examples and tips to system thinking

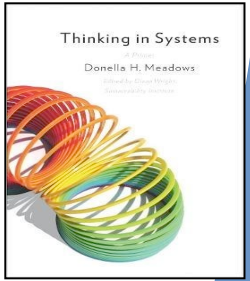
1. Limits to Growth
2. Drifting Goals,
3. Shifting the Burden
4. Success to the Successful
5. Fixes That Fail
6. Tragedy of the Commons
7. Growth and Underinvestment
8. Escalation
9. …..
10. ……

LIMITS to GROWTH





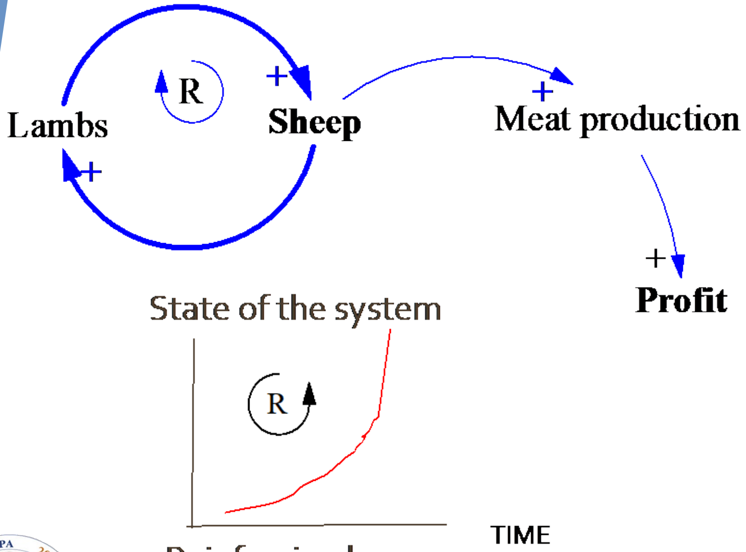
System Zoo



Examples from the System Herd

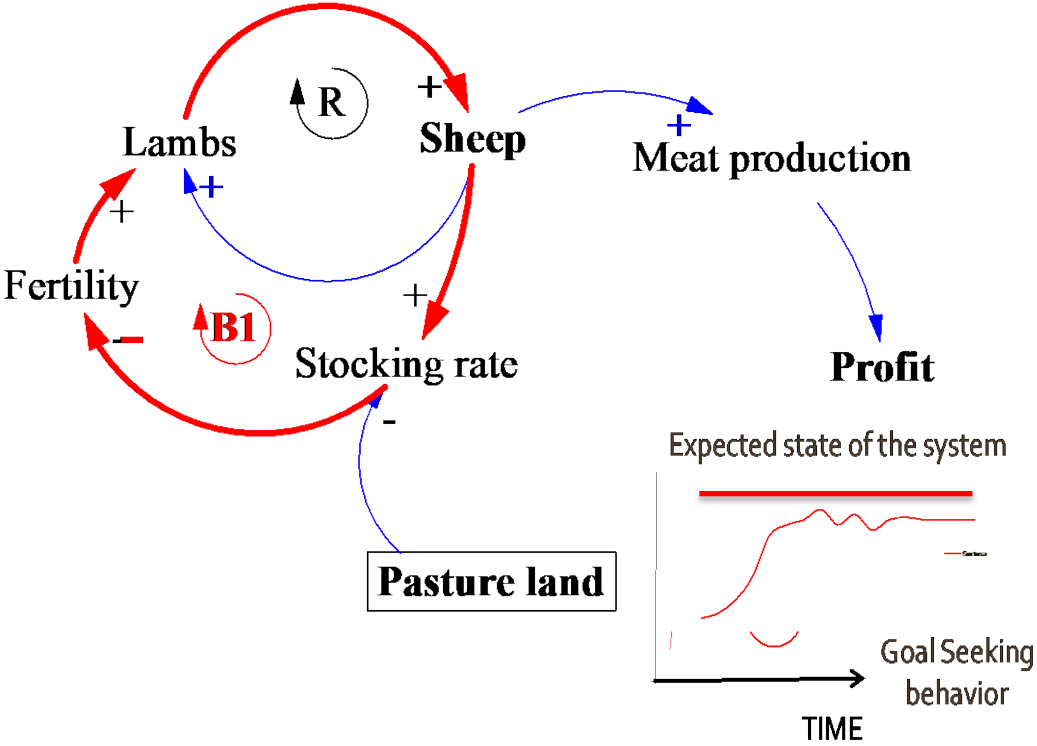
System Archetypes combinations of loops, real-world examples and tips to system thinking:

Unlimited



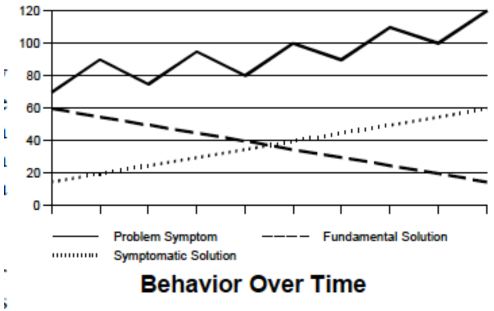
Reinforcing loops
Drive exponential growth

Limits to Growth



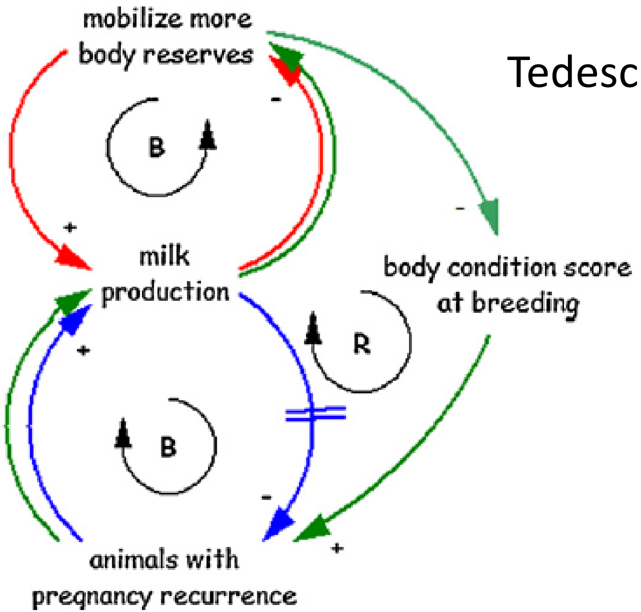
Examples from the System Herd

System Archetypes combinations of loops, real-world examples and tips to system thinking:



Tedeschi et al., 2011

Shifting the Burden

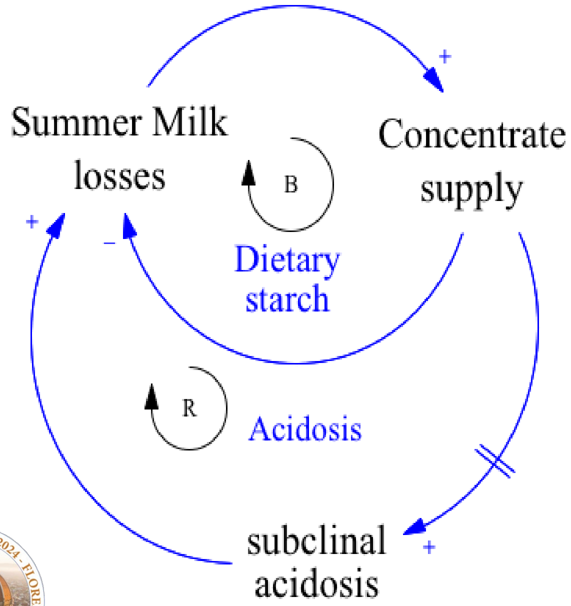


Tedeschi et al., 2012

Example from the System Herd

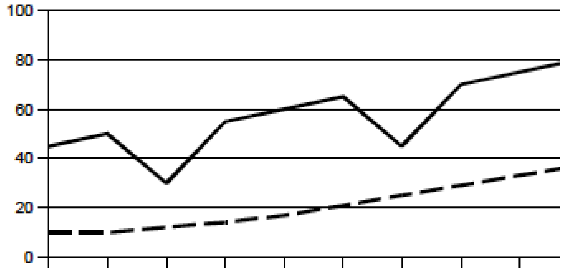
System Archetypes combinations of loops, real-world examples and tips to system thinking

Acidosis

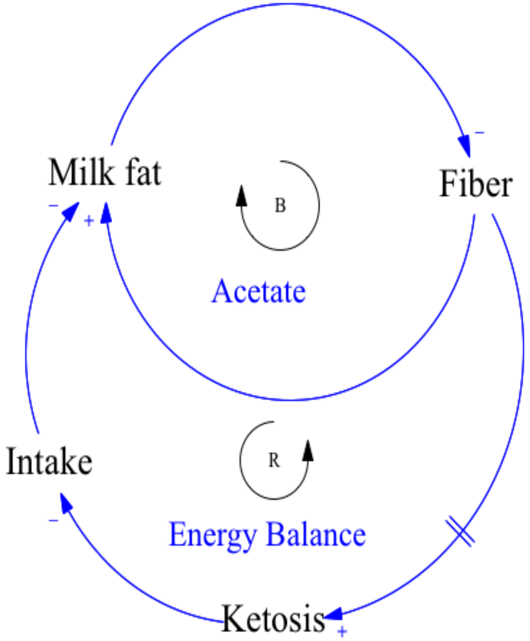


Fix that fails

(unintended consequences)



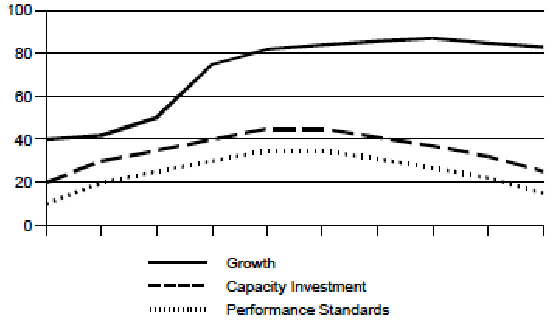
Ketosis



Example from the System Herd

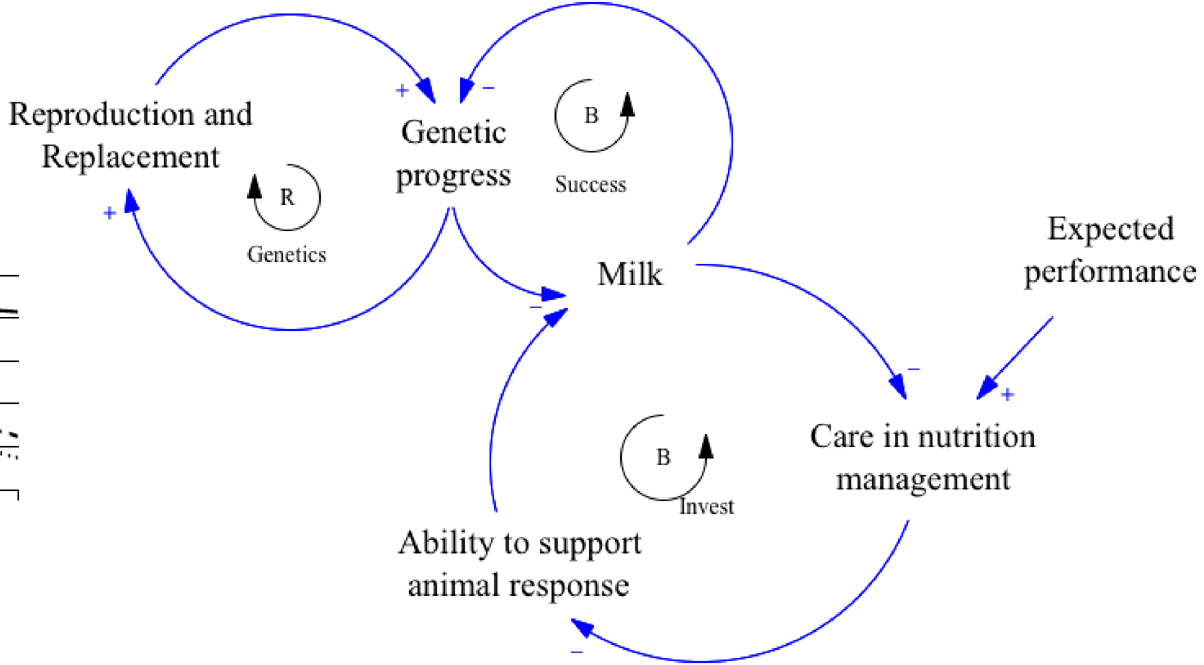
System Archetypes: combinations of loops, real-world examples and tips to system thinking

Growth and underinvestiments



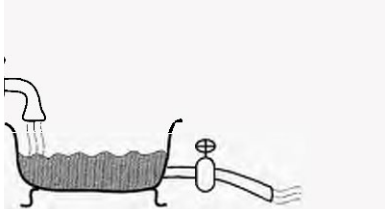
Behavior Over Time

GROWTH AND UNDERINVESTMENTS



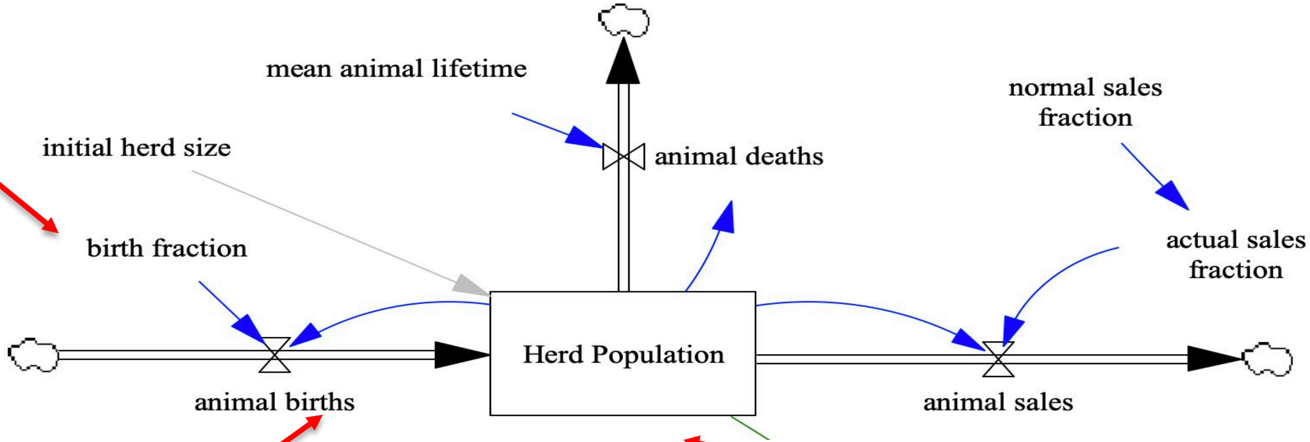
Barriers: 2) Understanding Stock Dynamics

Hydraulic Metaphore



(Sterman, 2000)

Constants



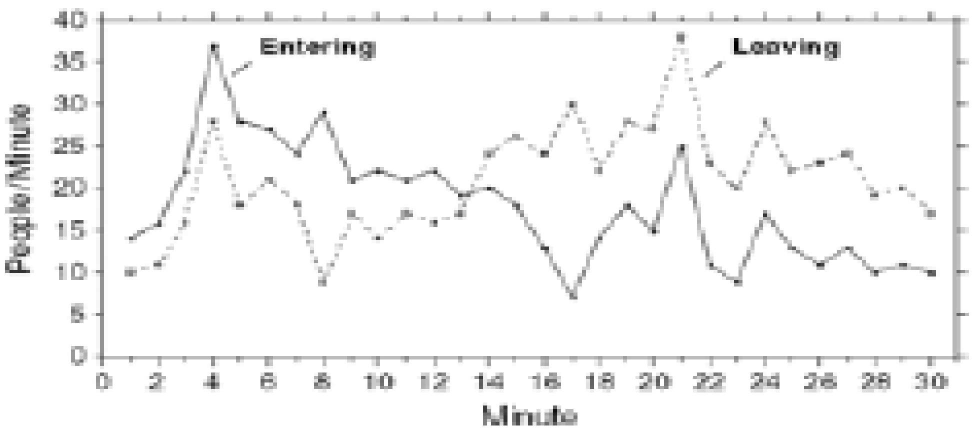
Atzori et al., 2011

Flows: rates (units/time) Dx/Dt

Stock: state variables (units)

Understanding of Stock and flows Dynamics

(Booth Sweeney and Sterman 2000)



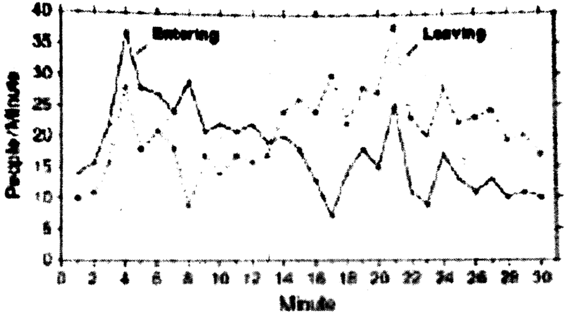
Results
People
> 90% people identifies Flows
< 45% identifies Stocks

- During which minute did the most people <u>enter</u> the store? **4 (94%)**
- During which minute did the most people <u>leave</u> the store? **21 (94%)**
- During which minute were the <u>most</u> people in the store? **13 (42%)**
- During which minute were the <u>fewest</u> people in the store? **30 (30%)**

Understanding of Stock and flows Dynamics

Adapted from Booth Sweeney and Sterman 2000

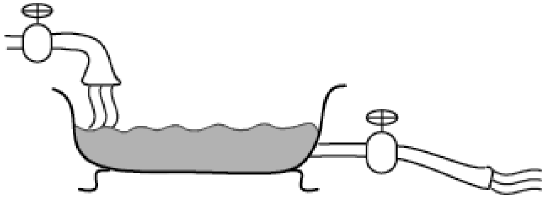
Satellite Workshop on SD
10th MODNUT Alghero 2022



Researchers	Age	Already SD soft	Inflow	Outflow	Stock	Stock
17	20-30	50%	82%	71%	6%	24%
12	30-40	40%	83%	83%	17%	25%
4	40-50	8%	75%	75%	25%	50%
3	>50	5%	100%	100%	0%	33%
36	all	55%	83%	78%	11%	28%
B. Sweeney and Sterman 2000			94%	94%	42%	30%

- During which minute did the most sheep enter the barn ? 4
- During which minute did the most sheep leave the barn ? 20
- During which minute were the most sheep in the barn ? 8
- [During] which minute were the fewest sheep in the barn ? 17

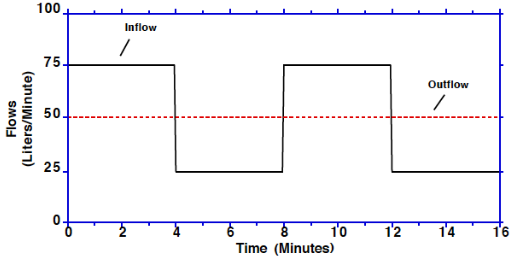
Understanding of Stock and flows Dynamics

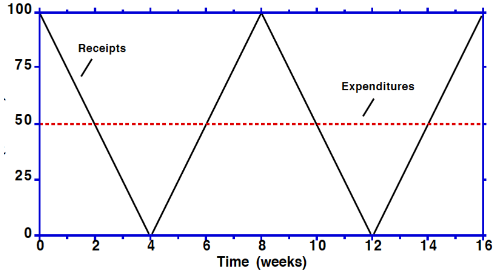


Assume the initial quantity in the tub (at time zero) is 100 liters.

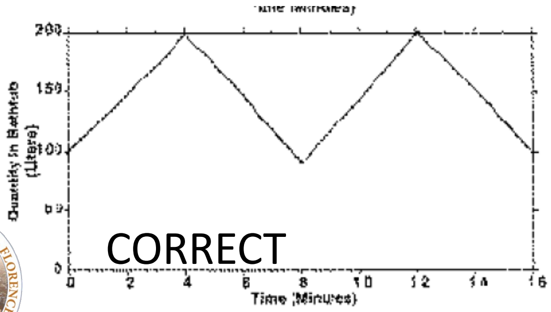
The Bathub Test: awareness of stock changes

Booth Sweeney and Sterman 2000

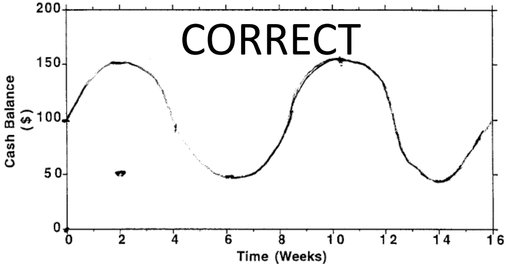




"subjects from
an elite business school (MBA)
with no prior exposure to SD,
have a poor understanding
of stock and flow"



CORRECT

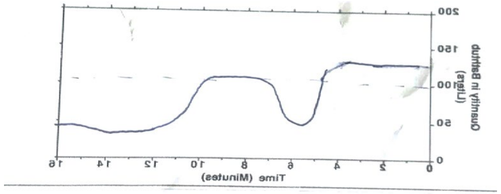


CORRECT

start bal
=
end bal

UNCORRECT

Very creative!

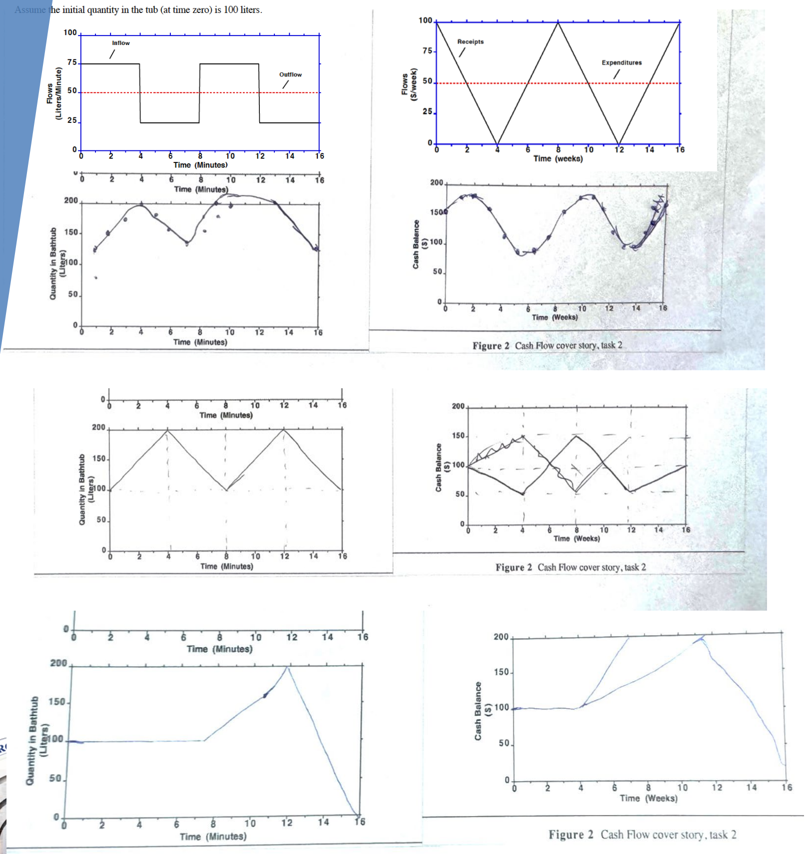


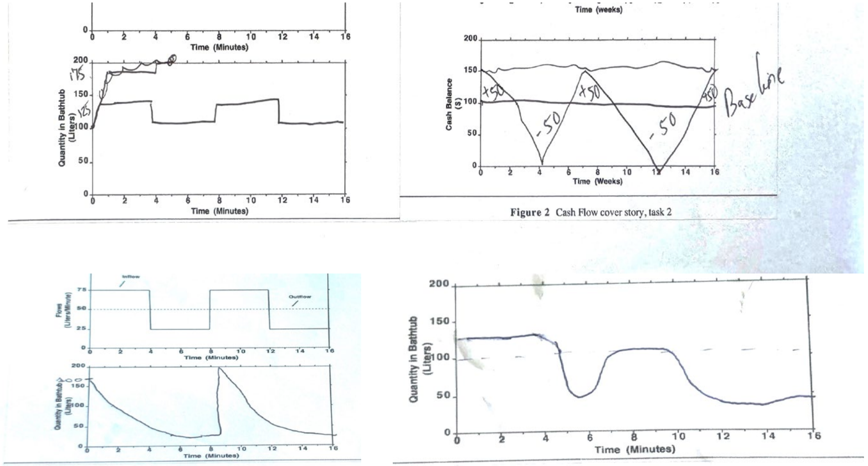
Understanding of Stock and flows Dynamics

Adapted Booth Sweeney and Sterman 2000

Satellite Workshop on SD
10th MODNUT Alghero 2022

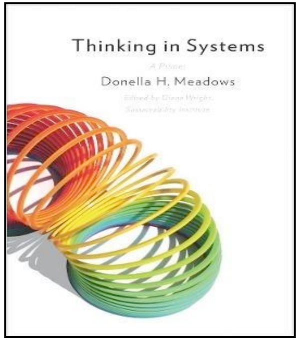
Student/ Researchers	Age	Already Vensim	Constant flow left	Linear changes right
17	20-30	53%	18%	8%
12	30-40	42%	8%	0%
4	40-50	100%	0%	0%
3	50+	100%	0%	0%
36		ठ्ठप्	झझस़	ट्प़





The system Zoo: Quantitative Modelling

The System Zoo



Meadows (1997; 2008)

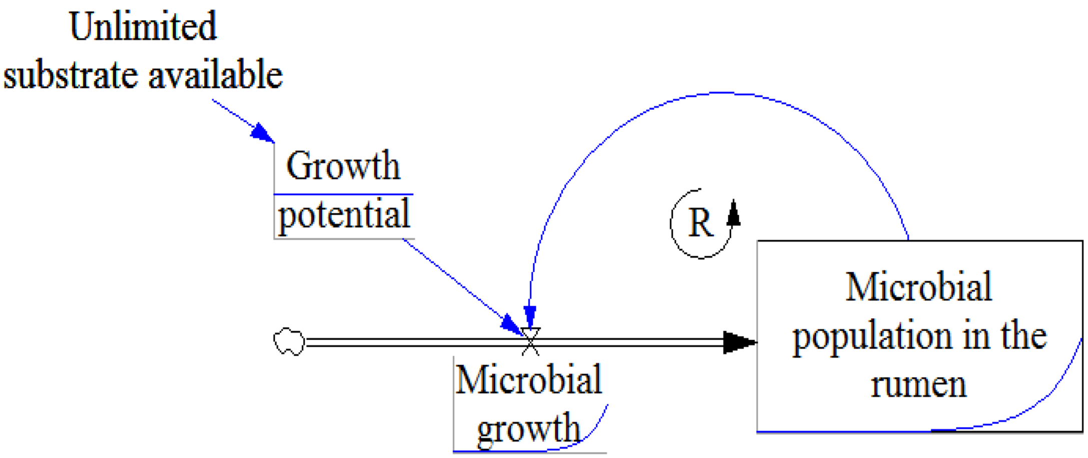
One stock structure

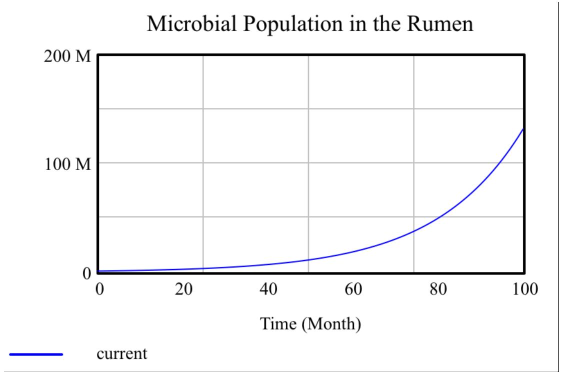
- Reinforcing loop (expontential growth)
- Balancing loop (exponential decay)
- 1 balancing + 1 reinforcing loop (Population model births and deats))
- 2 balancing loops (Furnace)

Two or multiple stocks Structures

- 1 renewable and 1 non-renewable resource (Oil market)
- 2 renewable resources (Fish Banks)
- Delays (supply or aging chains)
- Logistic or epidemic model (SI, or SIR)

The system herd: One stock basic structure 1) (reinforcing loop)





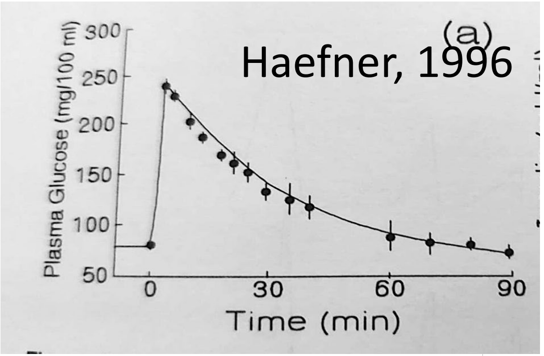
(Unlimited resources)

Reinforcing loop → exponential growth

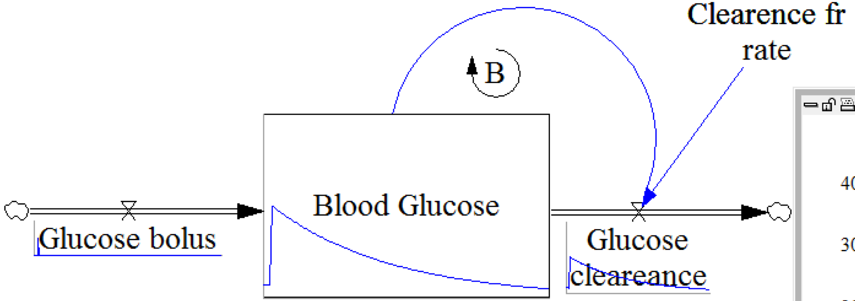
The system herd:
One stock basic structure 2)
(balancing loop)

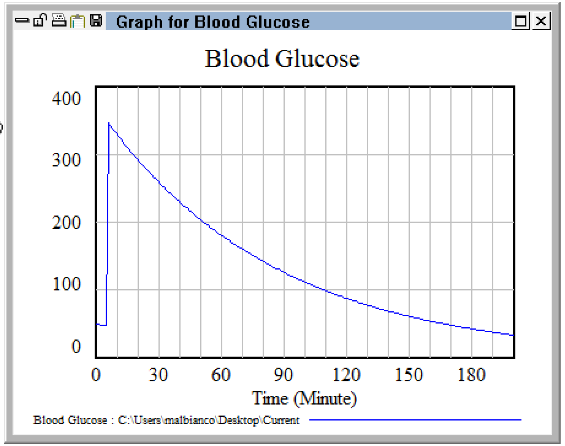
Exponential decay

Insulin and glucose challenge



Passage rate





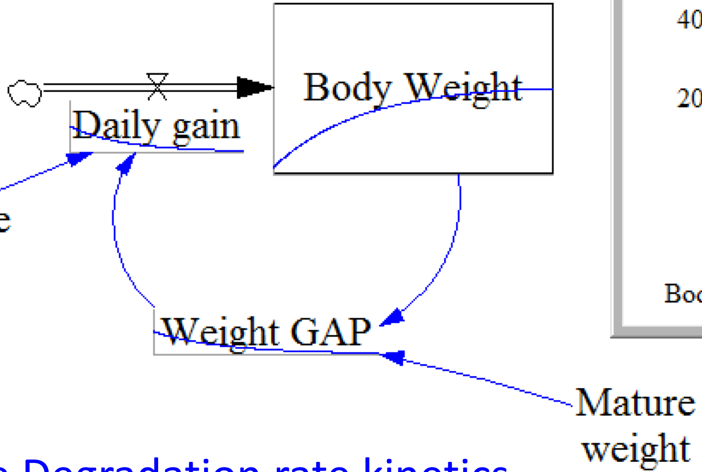
Simple Degradation rate kinetics

Haefner, 1996

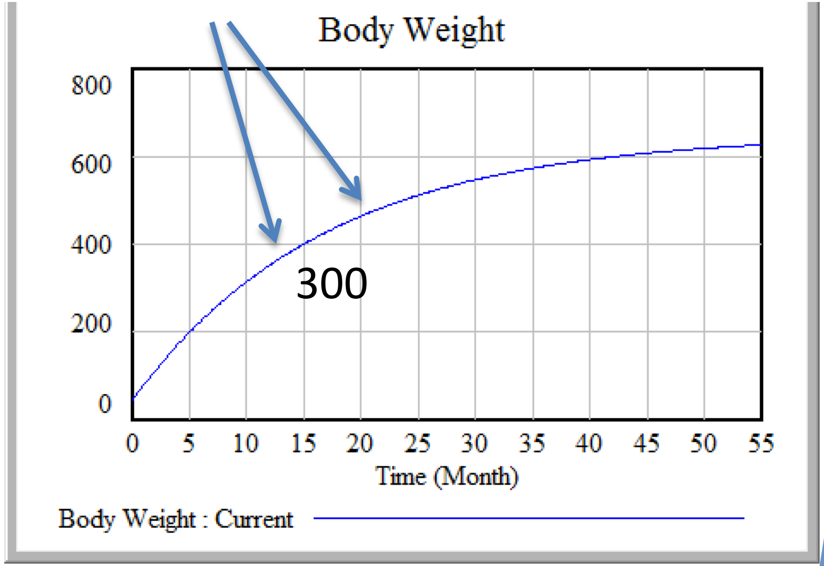
The system herd:
One stock basic structure 3) (balancing loop)

Explicit goal
Goal Seeking

HEIFER GROWTH

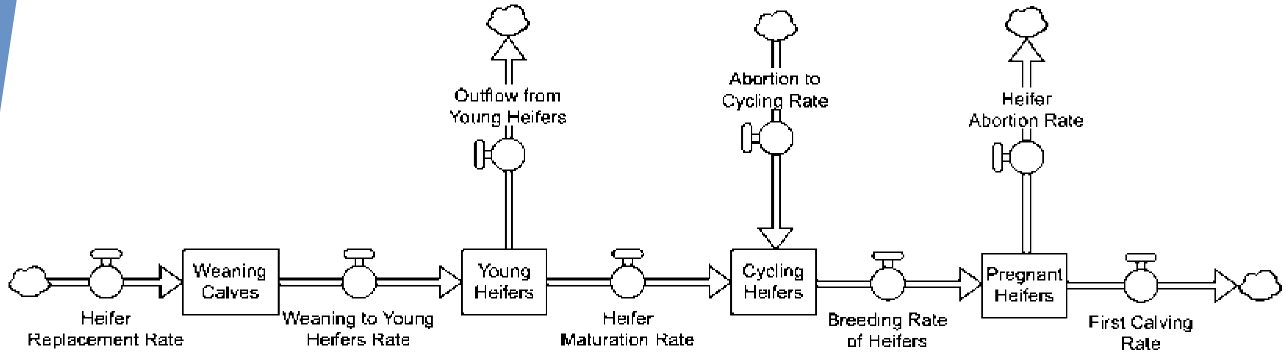


Target weights?



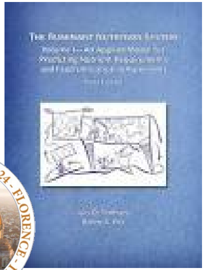
Other: Simple Degradation rate kinetics

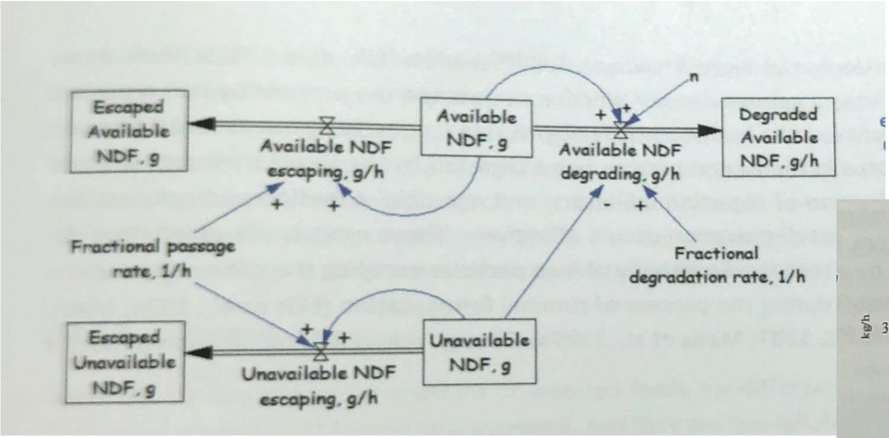
The system herd: Multiple stocks: time delays (aging chains)

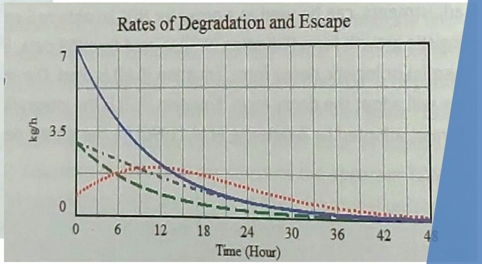


Heifer Dynamics (Atzori et al., 2023)

Digestive dynamics (Tedeschi and Fox 2018)

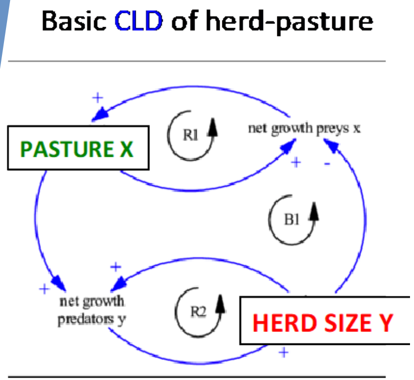


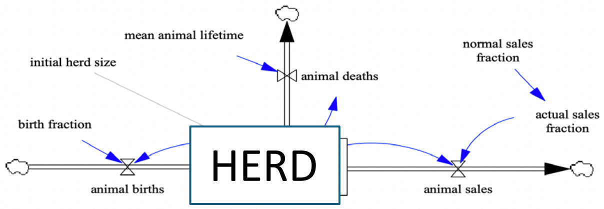


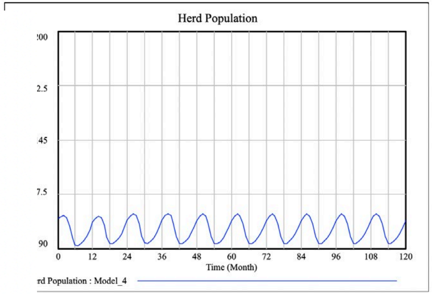


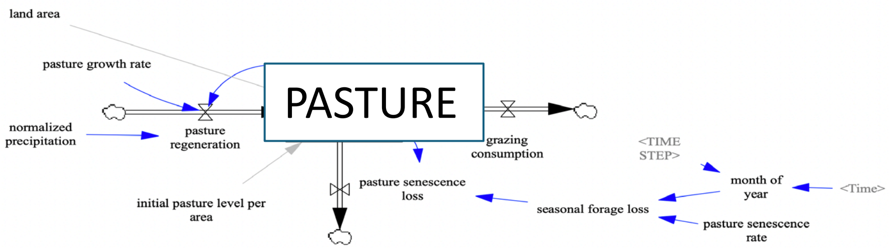
The system herd: Two stocks (renewable)

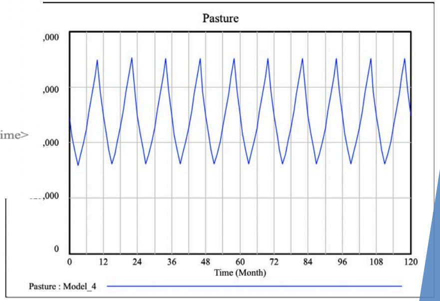
Herd – Pasture as predator-prey model (Lotka Volterra)











Intake – Body Reserves (Tedeschi et al, 2012)

Feeding Behavior (Fiorbelli et al., 2023; Eaap)

ASAS-NANP Symposium 2023: (Atzori et al., 2023)
Mathematical Modeling in Animal Nutrition

Conclusions

- Systemic applications requires understanding of feedback thinking and stock dynamics
- Qualitative archetypes can be useful to enhance insightfulness for ST and management actions (technical, policy)
- Simple models of basic stock structures might support stock and flows dynamics in digestive or livestock systems
- More examples can be built and listed to increase the size of "The system Herd".

Aknowledgements

South Dakota State University

The math model will come at the right time (Yaman Barlas)

Questions?

System Dynamics Italian Chapter

www.systemdynamic.it

the System Dynamics Society
st groups bring together people with shared interest in specific topics

Agriculture & Food

Approved in March 2016

https://systemdynamics.org/agriculture-and-food/