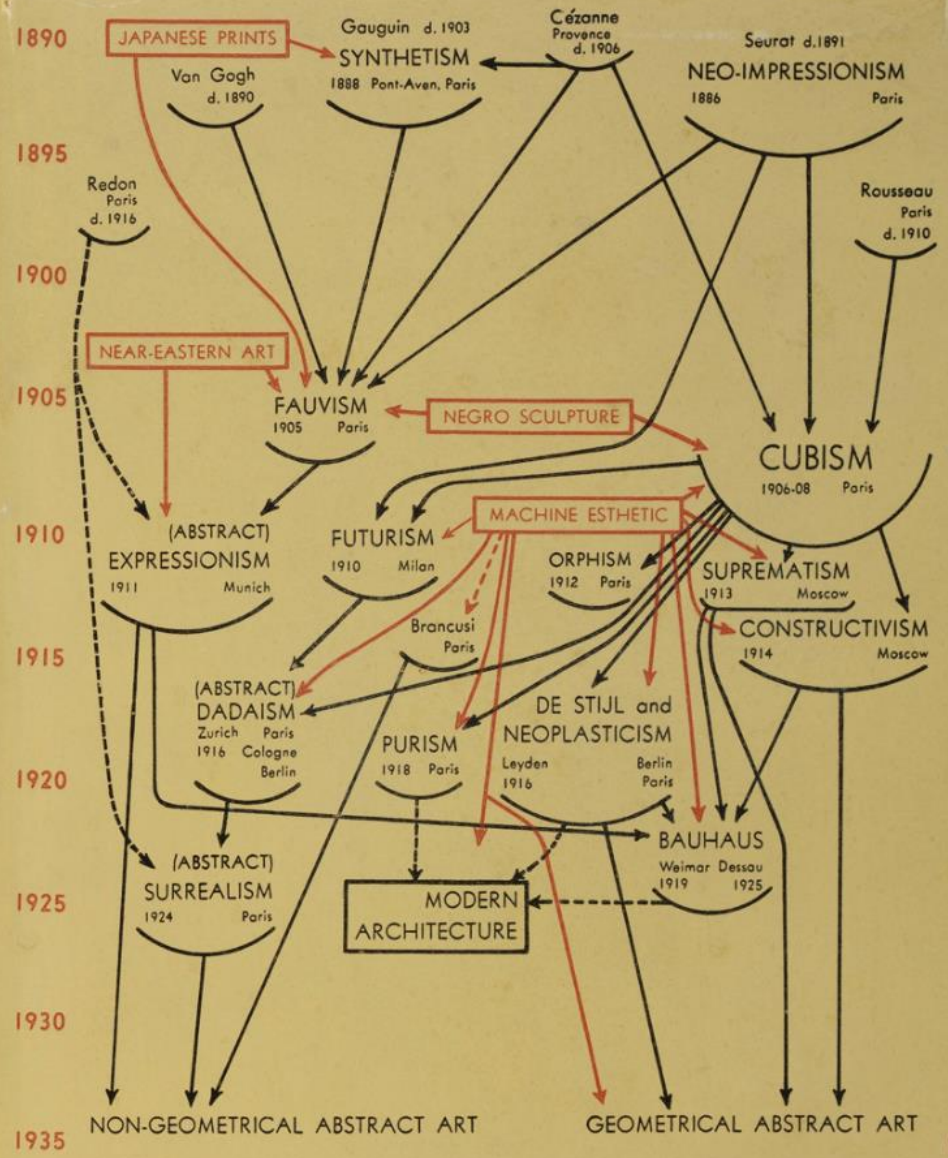


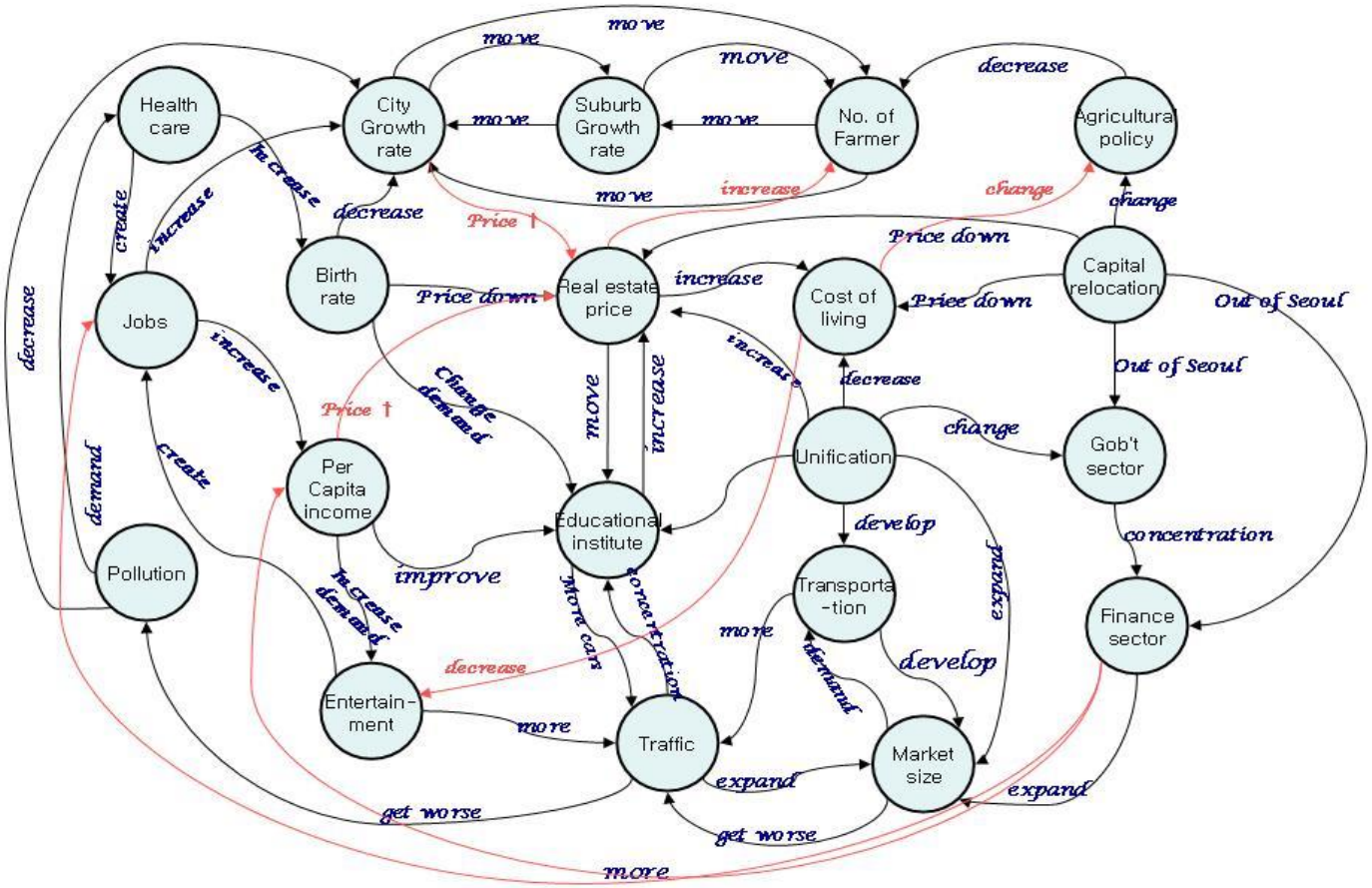
CUBISM AND ABSTRACT ART

THE MUSEUM OF MODERN ART

CUBISM AND ABSTRACT ART

CAUSAL LOOP DIAGRAMS

A city



A diagram like this may help to frame the existence of nexus, in terms of logical connections and cause-effect relationships, but what you need is a diagram that allows you to study and simulate quantitatively the behavior of the system at issue

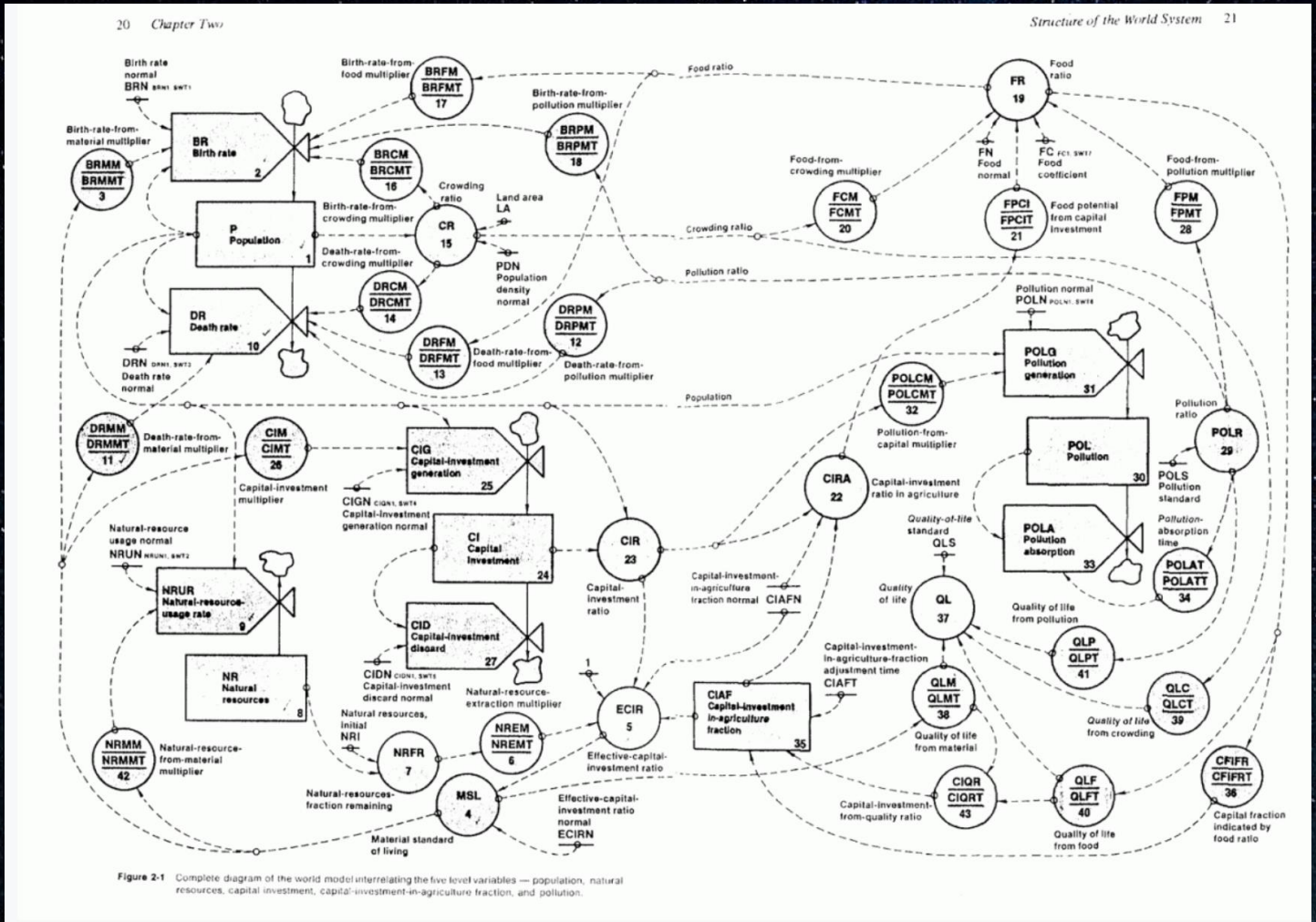
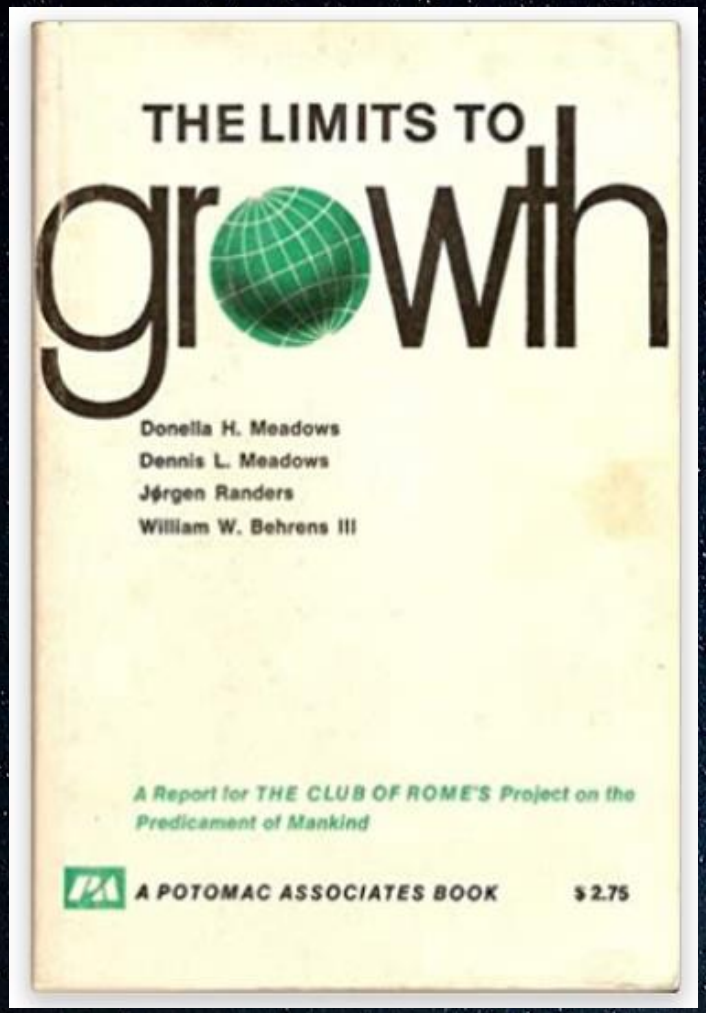
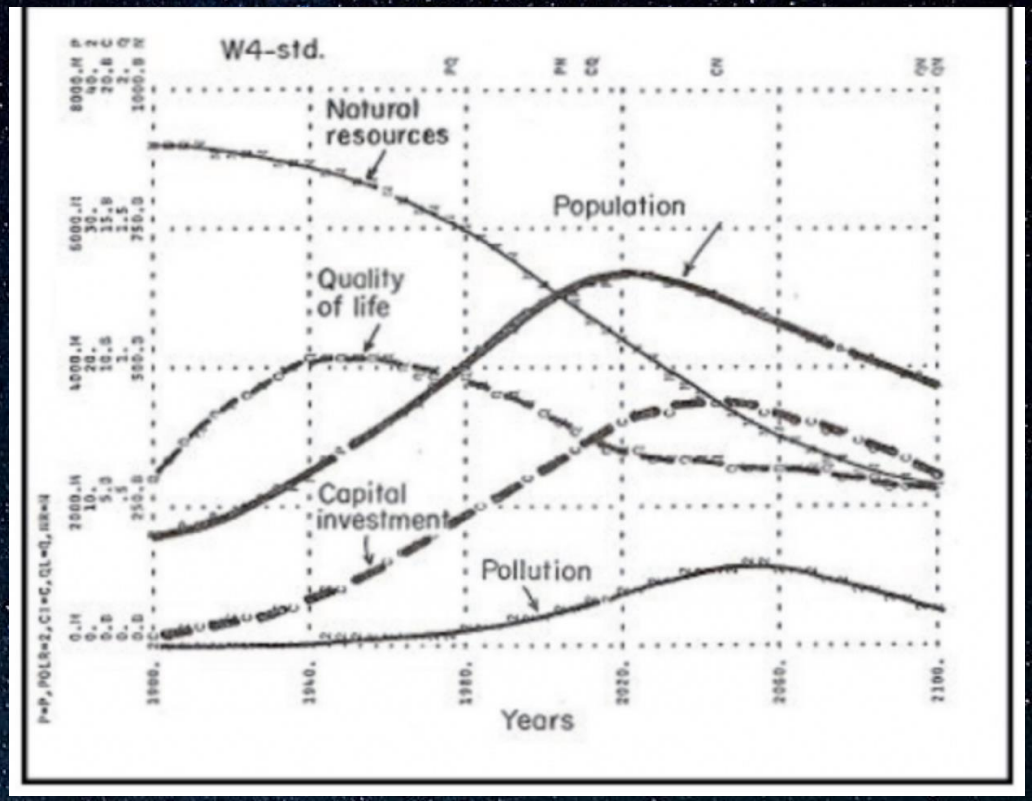


Figure 2-1 Complete diagram of the world model interrelating the five level variables — population, natural resources, capital investment, capital-investment-in-agriculture fraction, and pollution.

Jay Forrester's World Model from World Dynamics, 1971

Jay W. Forrester


THE LIMITS TO
growth
Donella H. Meadows
Dennis L. Meadows
Jørgen Randers
William W. Behrens III
A Report for THE CLUB OF ROME'S Project on the Predicament of Mankind
A POTOMAC ASSOCIATES BOOK
$2.75


W4-std.
Natural resources
Population
Quality of life
Capital investment
Pollution
Years

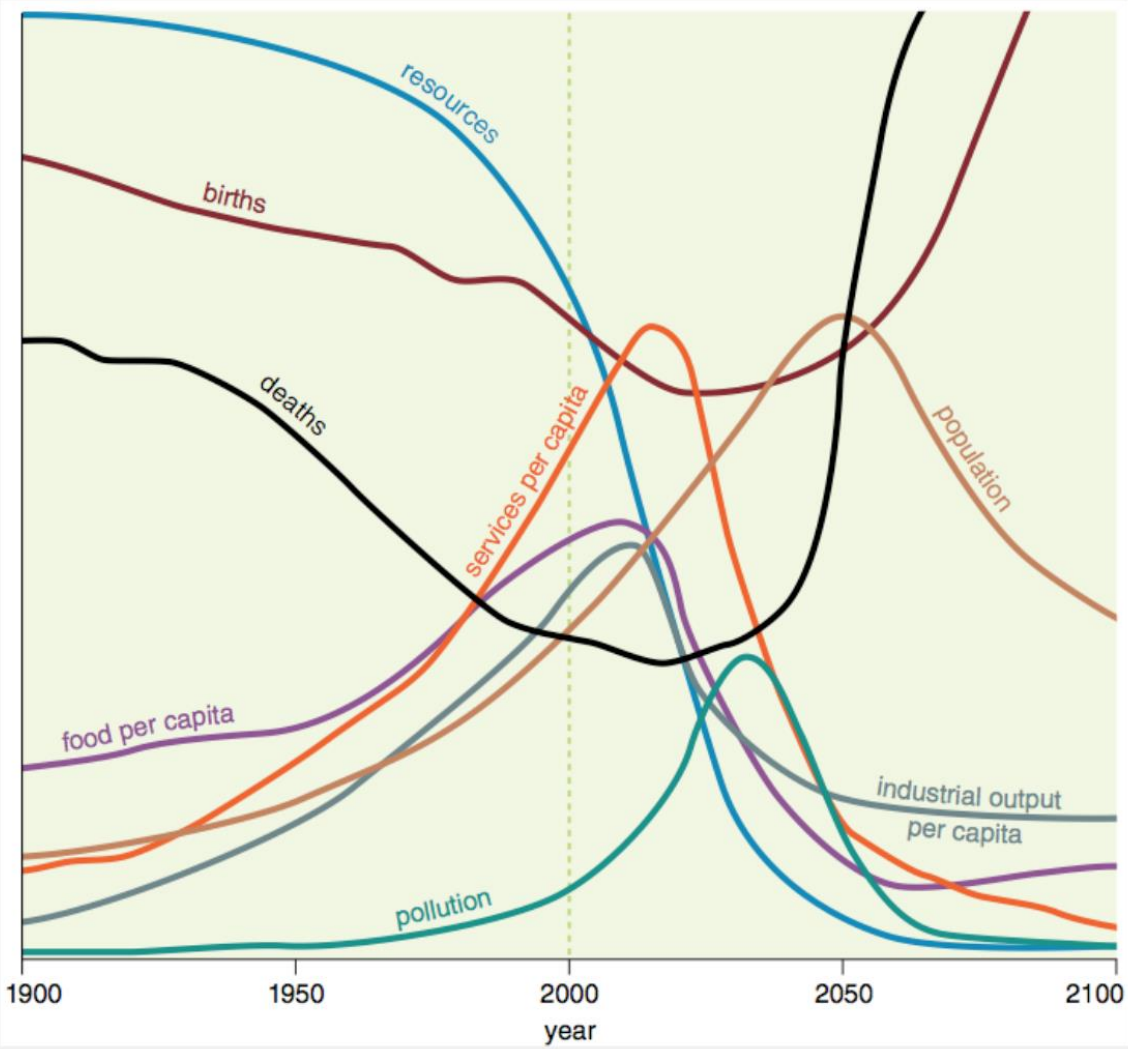


Figure 1. Base scenario from 1972 Limits to Growth, printed using today's graphics by Charles Hall and John Day in "Revisiting Limits to Growth After Peak Oil"
http://www.esf.edu/efb/hall/2009-05Hall0327.pdf

System - a set of entities comprising a whole where each component interacts with or is related to at least one other component and they all serve a "common objective"

Three kind of things:

- stocks
- flows
- processes

STOCK

element containing a quantity of countable something. Stocks are extensive state variables, that constitute tuple of numbers $\{Q_1, Q_2, \ldots Q_n\}$ that at any time represent the state of the system

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- *The number of the stocks should be the minimum necessary to describe the state of the system for the prescribed purposes.*
- *Any system change (either detectable from the external or not) must correspond to some change in the tuple of state variables.*

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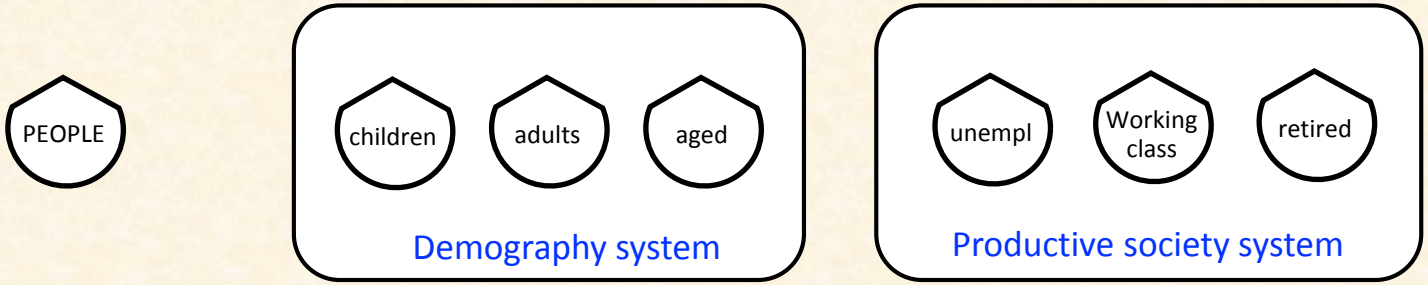
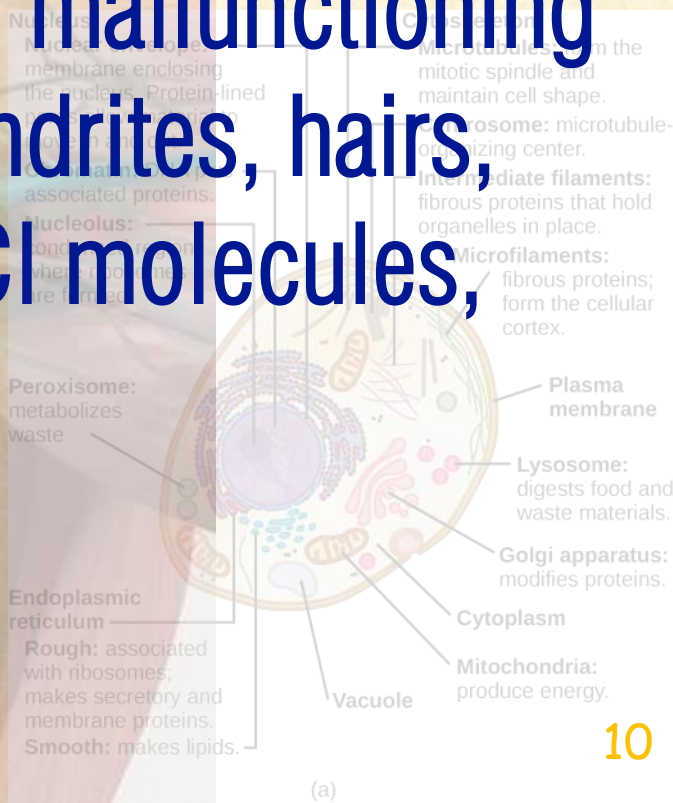


Cells, DNA, nutrients, aminoacids, proteins, molecules, atoms, tissues mass, oxygen, energy, ATP, glucose, microbes, living "guests", leucocytes, water, water within cells, water in the eyes, healthy cells, malfunctioning cells, cations, metal atoms, dendrites, hairs, bones, blood vessels, nails, HCl molecules, radioactive nuclei….

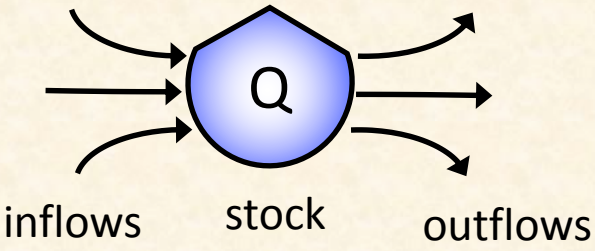


Cells, DNA, nutrients, aminoacids, proteins, molecules, atoms, tissues mass, oxygen, energy, ATP, glucose, microbes, living "guests", leucocytes, water, water within cells, water in the eyes, healthy cells, malfunctioning cells, cations, metal atoms, dendrites, hairs, bones, blood vessels, nails, HCl molecules, radioactive nuclei....

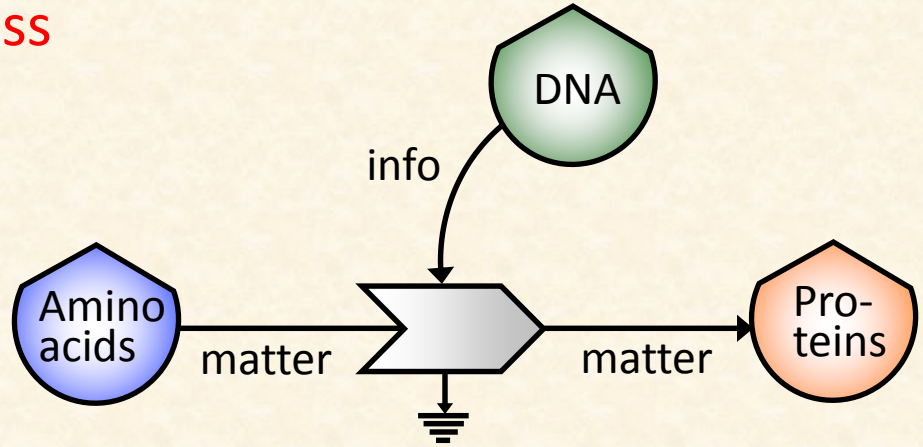
THE CHOSEN SET OF STOCKS IS NOT A "PHOTOGRAPH" OF THE SYSTEM

FLOW

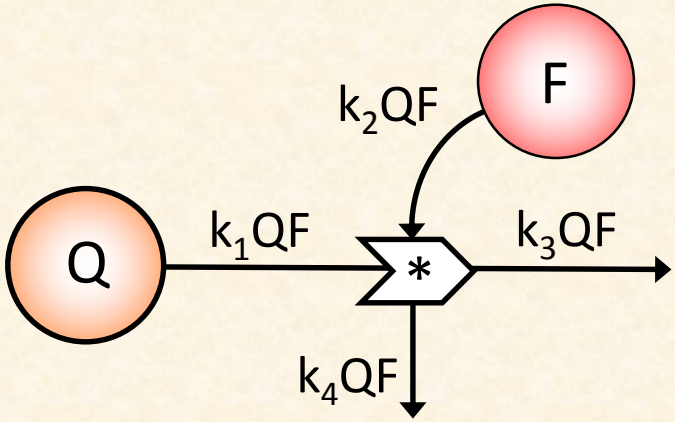
<u>What makes a stock change over time</u>

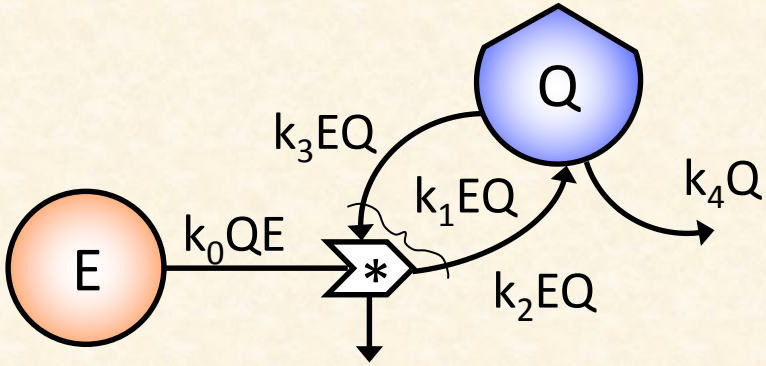


Interaction process



PROTEIN SYNTHESIS

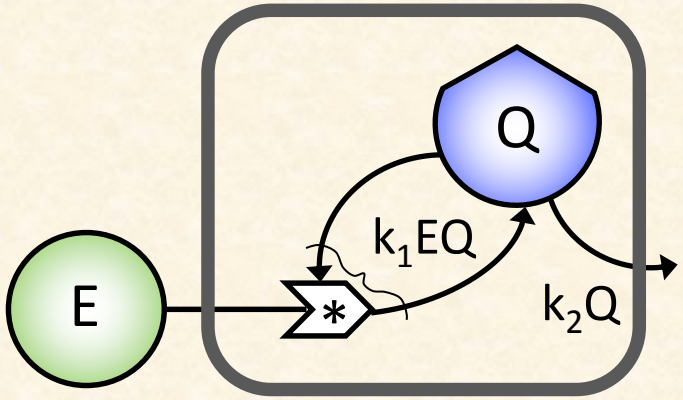




$$\dot{Q} = k_2EQ - k_3EQ - k_4Q = k_1EQ - k_4Q$$

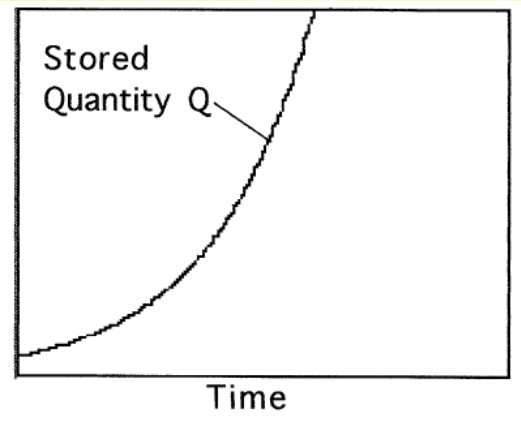
$$k_1 = k_2 - k_3$$

Growth on an unlimited source

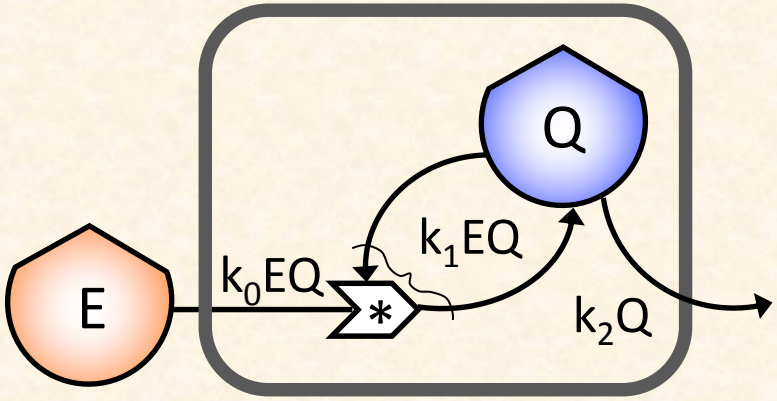


unlimited source

$$\dot{Q} = k_1EQ - k_2Q$$

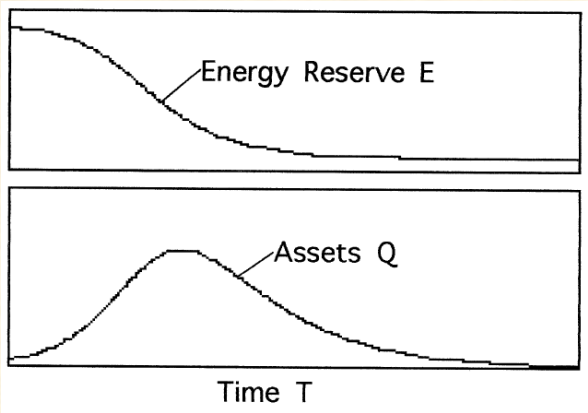


Growth on a non-renewable source

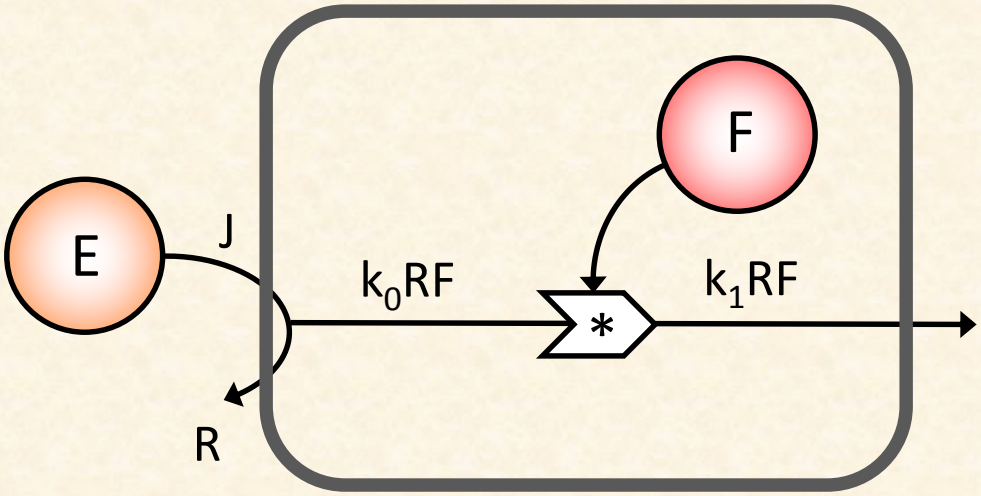


finite source

$$\dot{E} = -k_0EQ$$
$$\dot{Q} = k_1EQ - k_2Q$$



Flow-limited source



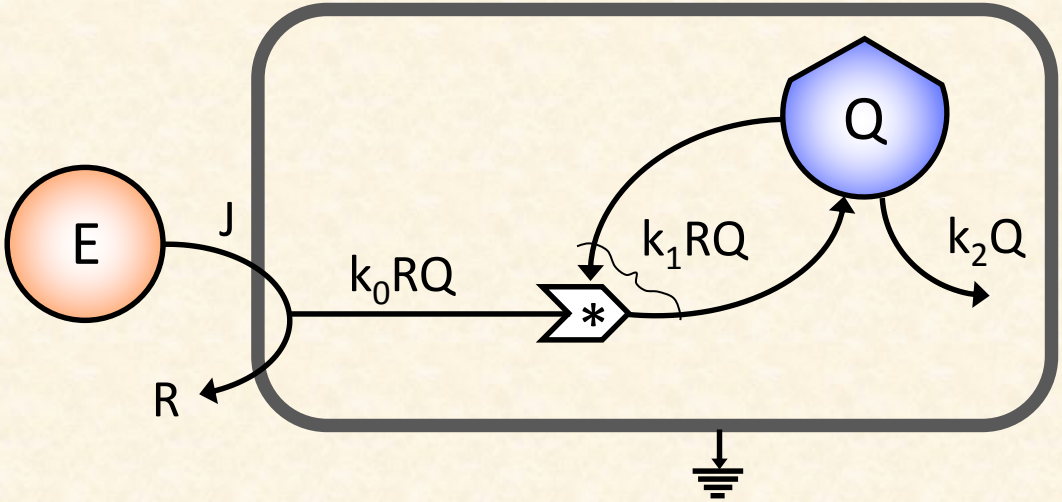
$$R = J - k_0RF$$

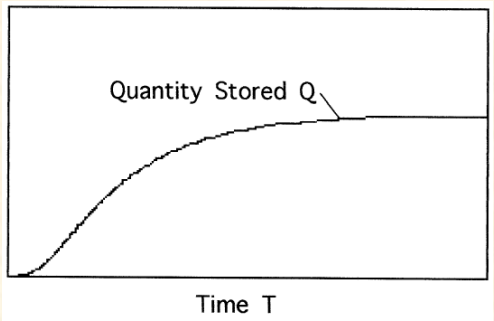
$$\rightarrow \quad R = J/(1+k_0F)$$

The flow of resource ***E*** that can be actually used is limited

The "pumping" by ***F*** will be effective proportionally to the unutilized quantity of resource, that is, ***R***, which therefore must be regarded as the actual source

Flow-limited renewable resource

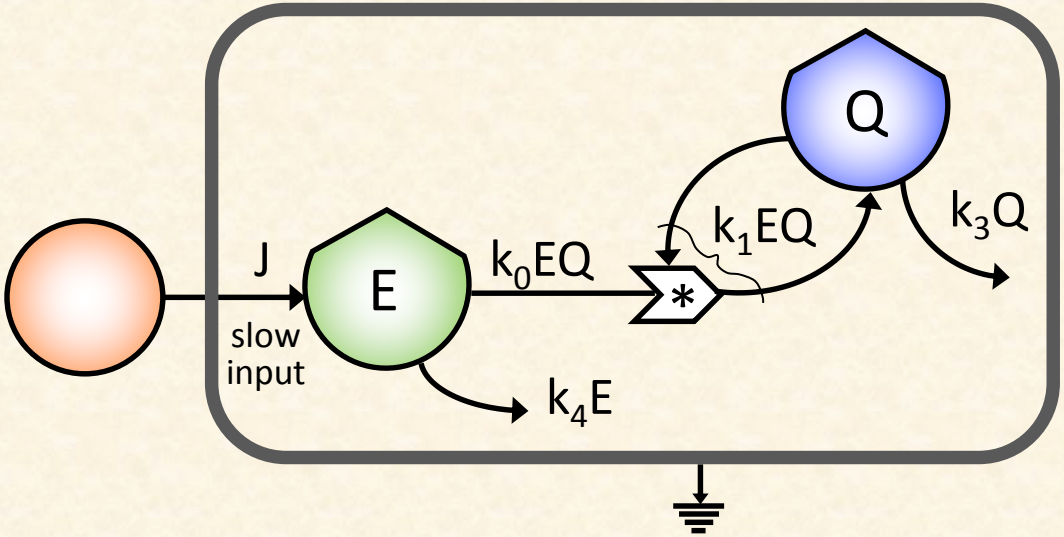


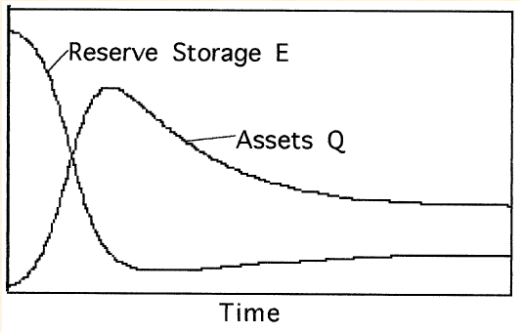


$R = J - k_0RQ \rightarrow R = J/(1+k_0Q)$

$\dot{Q} = k_1RQ - k_2Q$

Slowly renewable

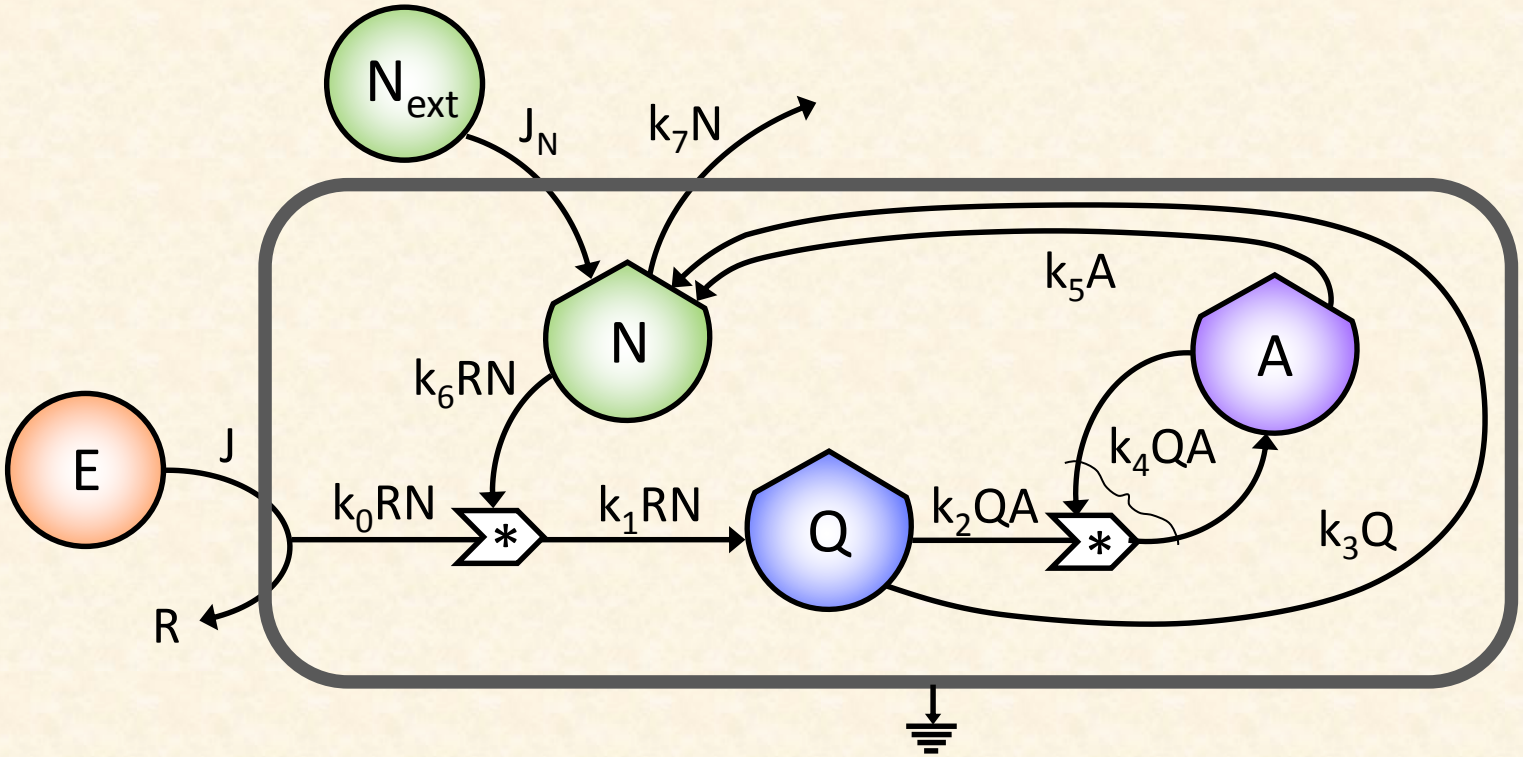




$\dot{E} = J - k_4E - k_0EQ$

$\dot{Q} = k_1EQ - k_3Q$

Ecosystemic unit



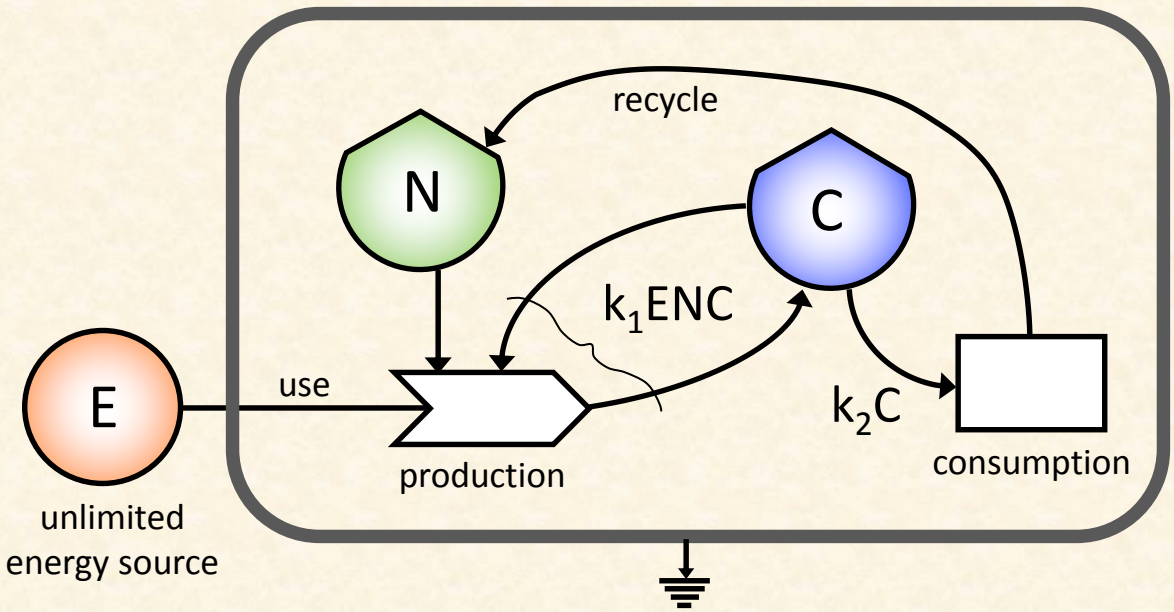
$$R = J - k_0RN \rightarrow R = J/(1+k_0N)$$

$$\dot{N} = J_N + k_3Q + k_5A - k_6RN - k_7N$$

$$\dot{A} = k_4QA - k_5A$$

$$\dot{Q} = k_1RN - k_3Q - k_2QA$$

Autocatalytic growth with limiting material cycle

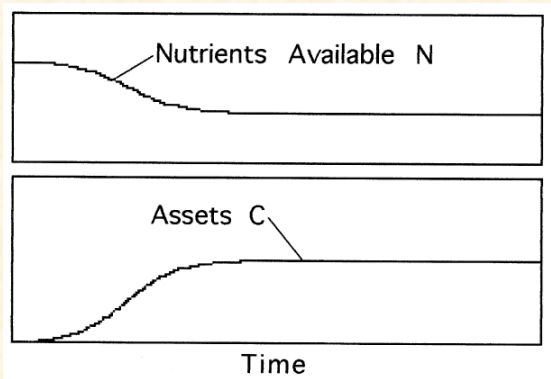


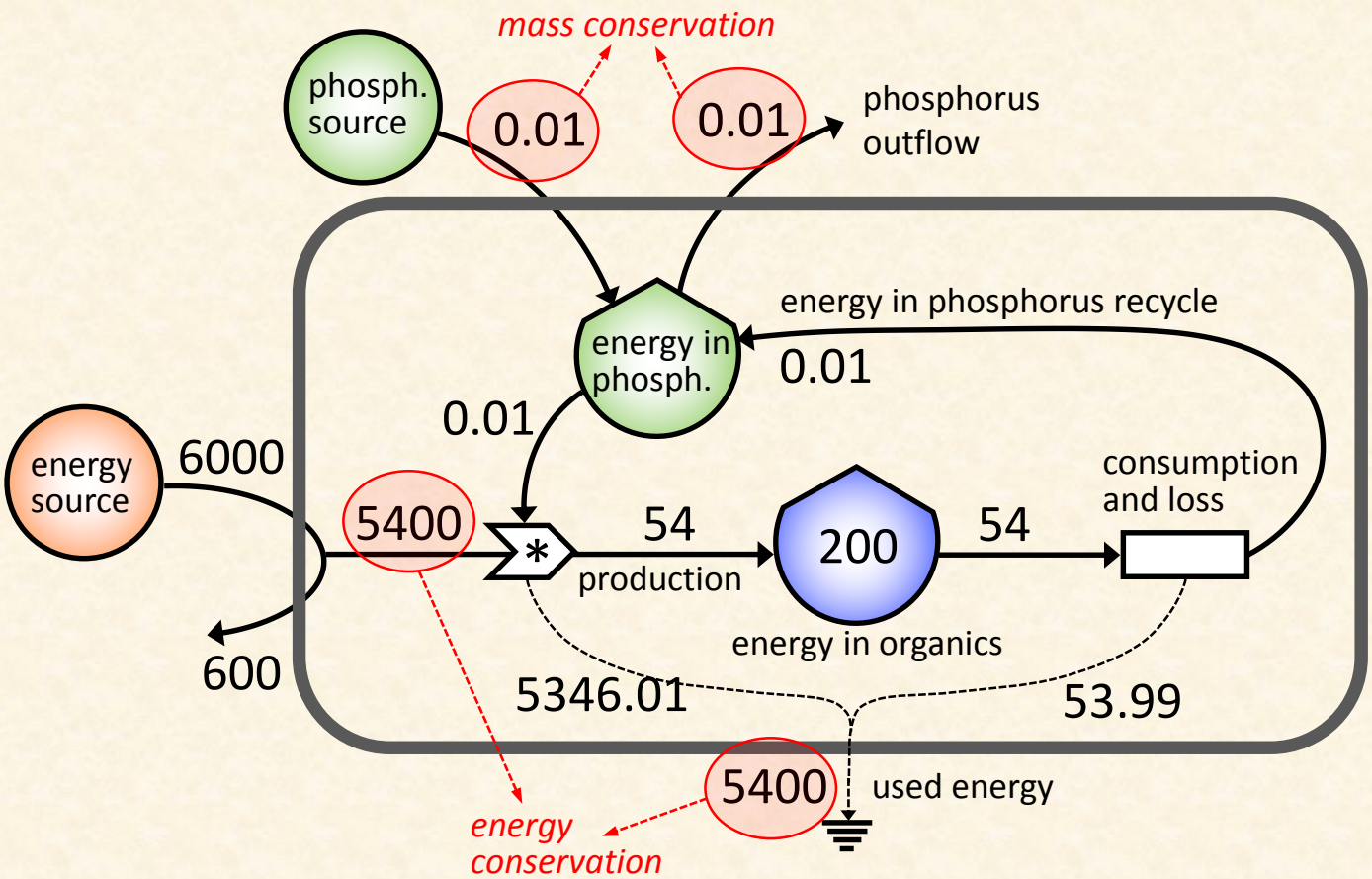
$$N = T_N - fC$$

(N=nutrients available, T_N=total nutrients, f=fraction in C)

$$\dot{C} = k_1ENC - k_2C$$

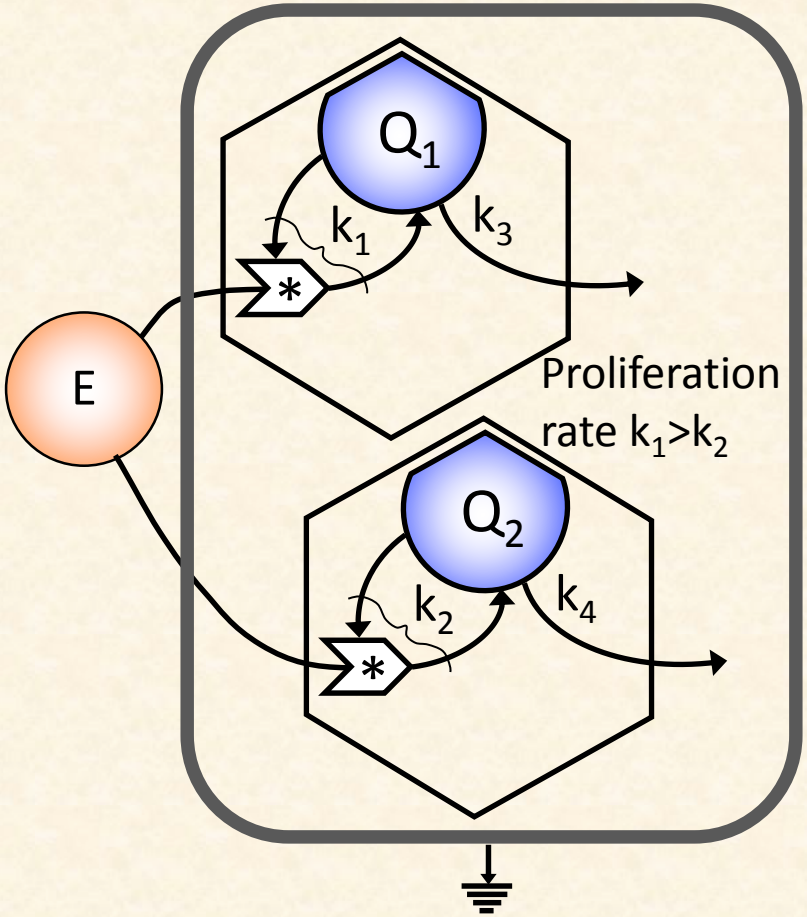
$$= (k_1ET_N - k_2)C - k_1EfC^2 \quad \text{(logistic)}$$

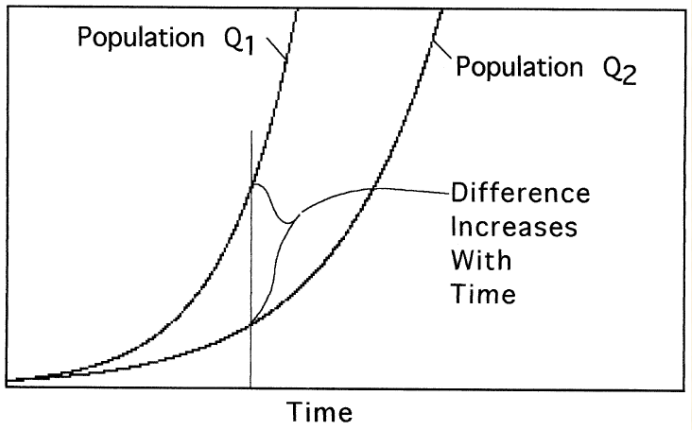




Mass and energy conservation in a stationary state

Two populations growth

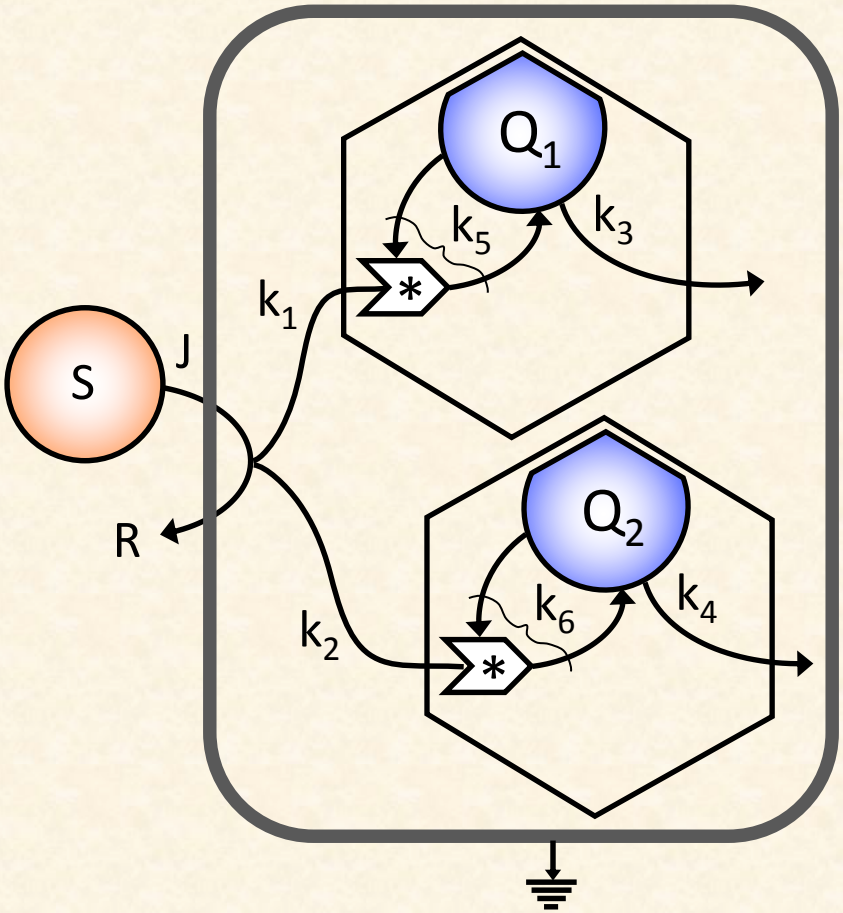


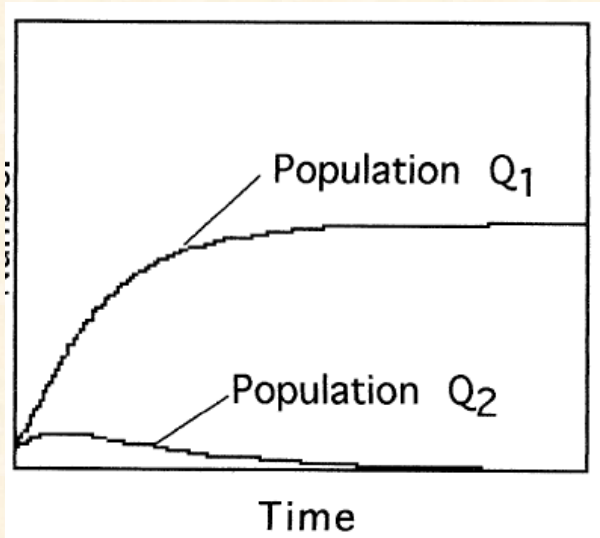


$$\dot{Q}_1 = k_1 E Q_1 - k_3 Q_1$$

$$\dot{Q}_2 = k_2 E Q_2 - k_4 Q_2$$

Competition for a flow-limited source



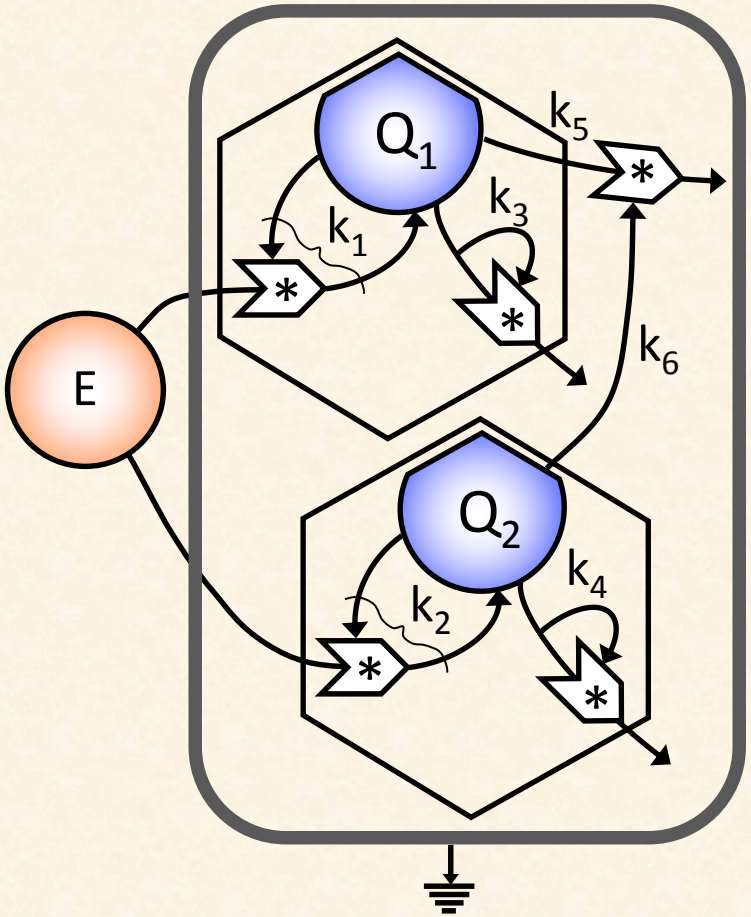


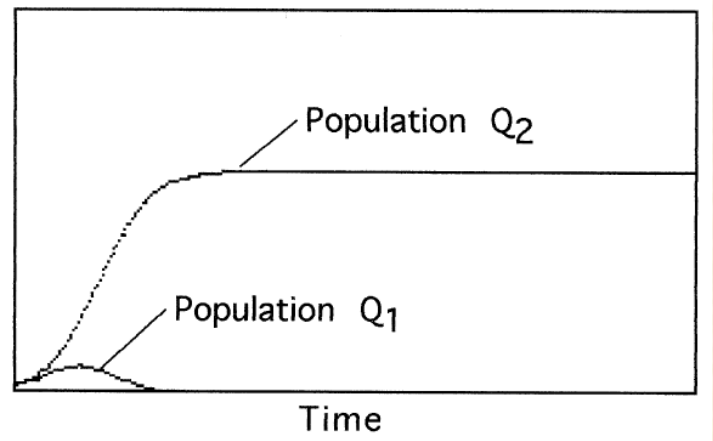
$$R = J - k_1RQ_1 - k_2RQ_2 \rightarrow$$
$$R = J/(1 + k_1Q_1 + k_2Q_2)$$

$$\dot{Q}_1 = k_5RQ_1 - k_3Q_1$$

$$\dot{Q}_2 = k_6RQ_2 - k_4Q_2$$

Competitive populations

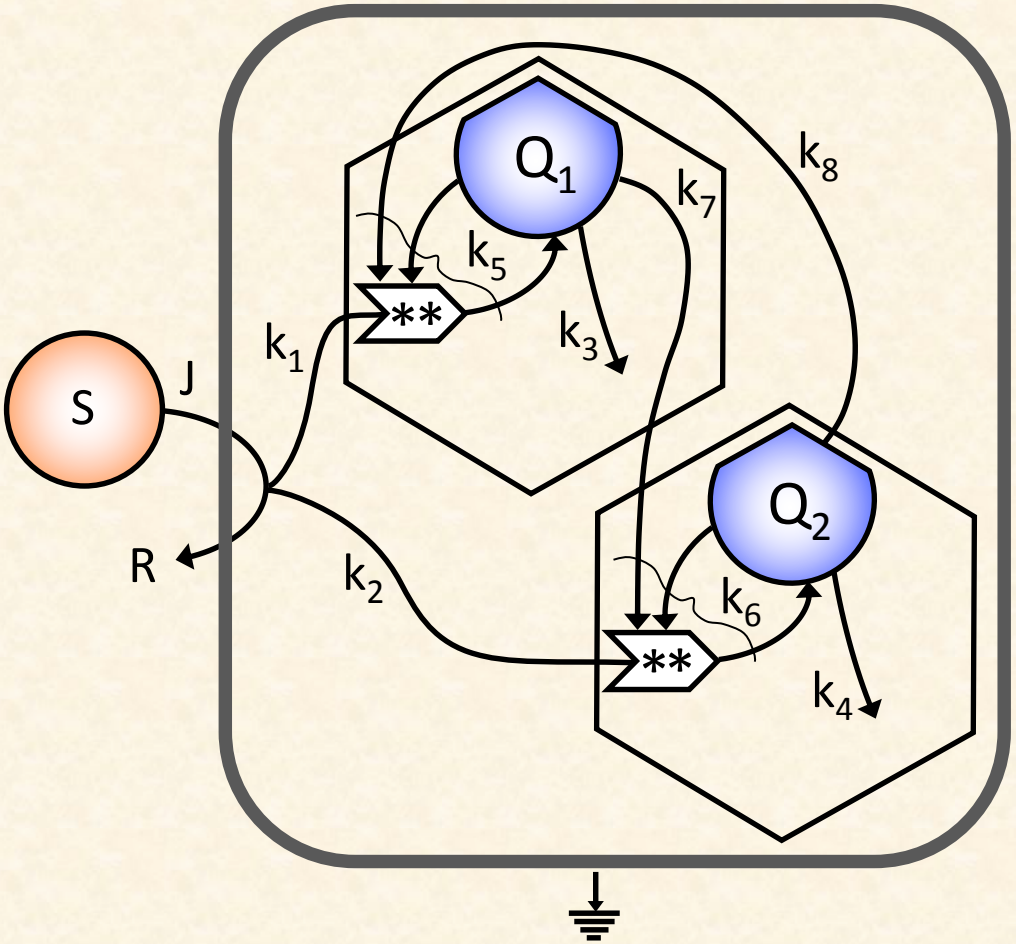


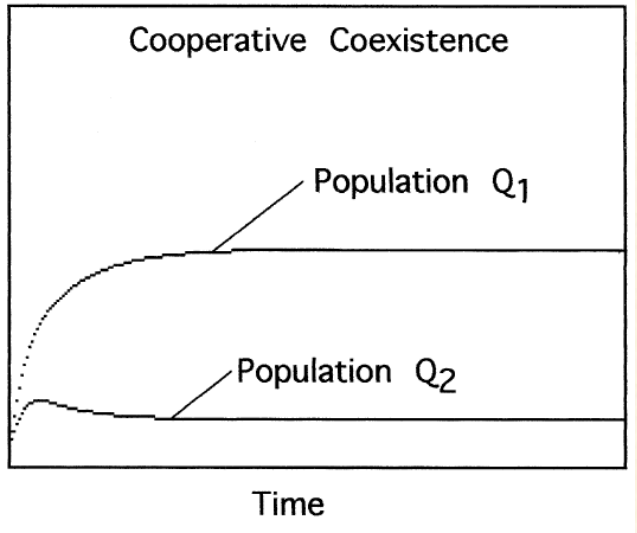


$$\dot{Q}_1 = k_1 E Q_1 - k_3 Q_1^2 - k_5 Q_1 Q_2$$

$$\dot{Q}_2 = k_2 E Q_2 - k_4 Q_2^2 - k_6 Q_1 Q_2$$

Cooperative populations



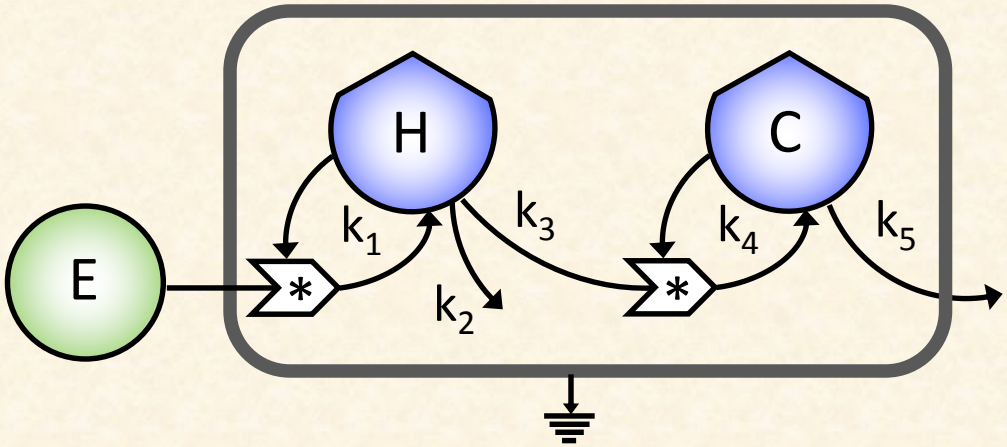


$$R = J - k_1RQ_1Q_2 - k_2RQ_1Q_2 \rightarrow$$
$$R = J/(1 + k_1Q_1Q_2 + k_2Q_1Q_2)$$

$$\dot{Q}_1 = k_5RQ_1Q_2 - k_3Q_1 - k_7RQ_1Q_2$$

$$\dot{Q}_2 = k_6RQ_1Q_2 - k_4Q_2 - k_8RQ_1Q_2$$

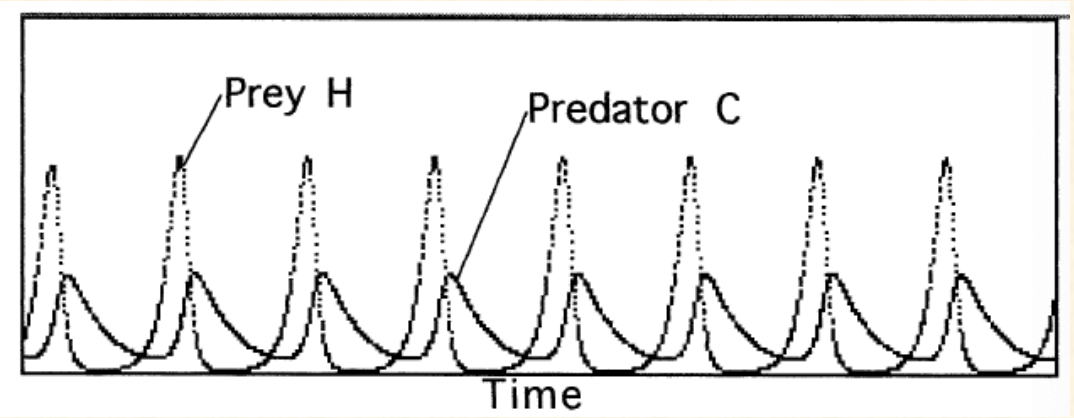
Prey-predator



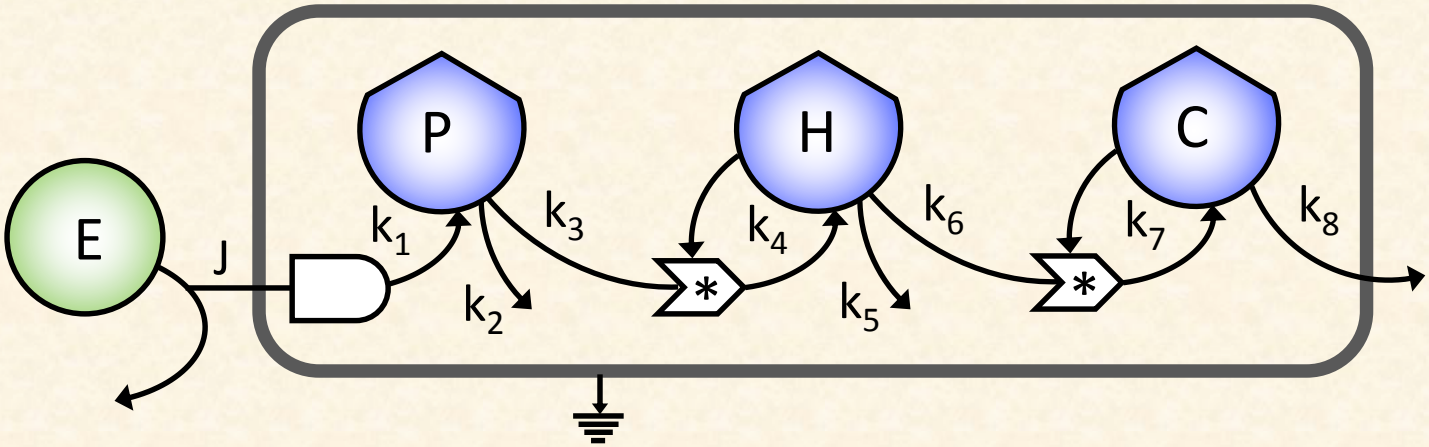
$$\dot{H} = k_1EH - k_2H - k_3CH$$

$$\dot{C} = k_4CH - k_5C$$

Alfred J. Lotka
& Vito Volterra



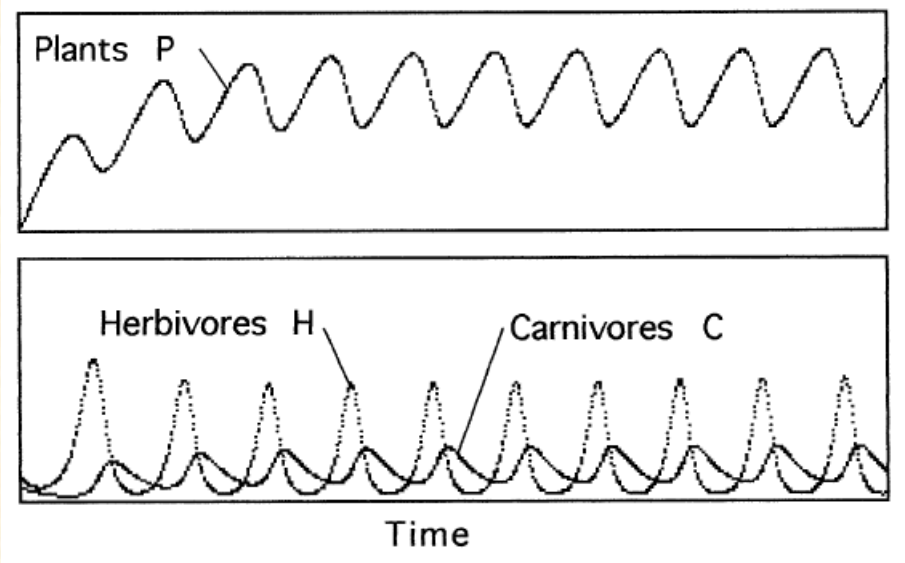
Double prey-predator



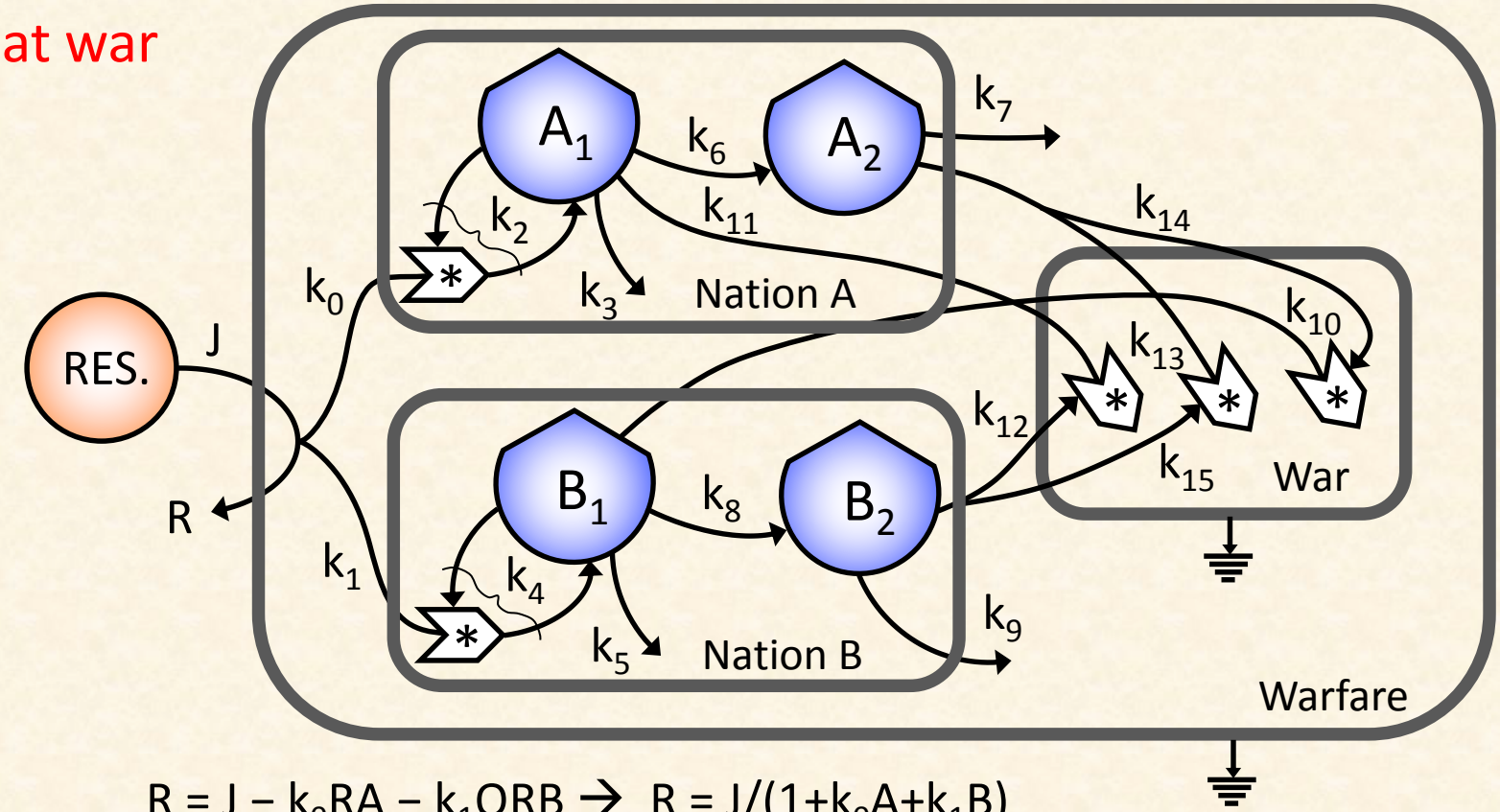
$$\dot{P} = k_1 J - k_2 P - k_3 PH$$

$$\dot{H} = k_4 PH - k_5 H - k_6 HC$$

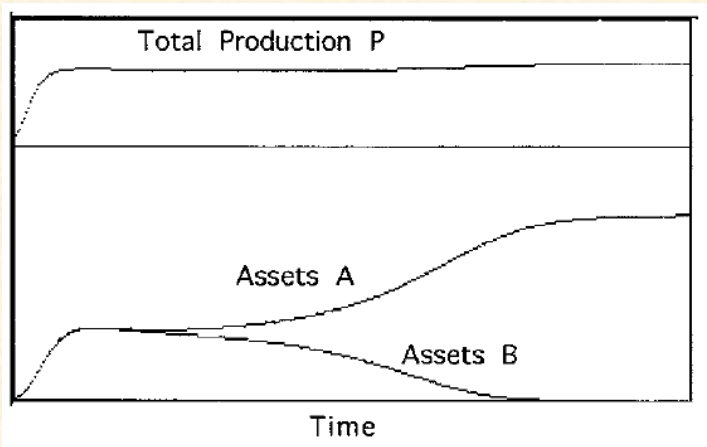
$$\dot{C} = k_7 HC - k_8 C$$



Systems at war



$$R = J - k_0RA - k_1QRB \rightarrow R = J/(1+k_0A+k_1B)$$



Assets:

$$\dot{A}_1 = k_2RA_1 - k_3A_1 - k_6A_1 - k_{11}A_1B_2$$

$$\dot{B}_1 = k_4RB_1 - k_5B_1 - k_8B_1 - k_{10}B_1A_2$$

Defense:

$$\dot{A}_2 = k_6A_1 - k_7A_2 - k_{14}A_2B_1 - k_{13}A_2B_2$$

$$\dot{B}_2 = k_8B_1 - k_9B_2 - k_{12}B_2A_1 - k_{15}A_2B_2$$

WORKPLAN

1. Definition of the system

2. Identification of its main inputs and outputs, and definition of its boundary

3. Identification of the set of variables necessary to describe the system

4. Identification of the flows connecting the stocks, one each other and with the external environment

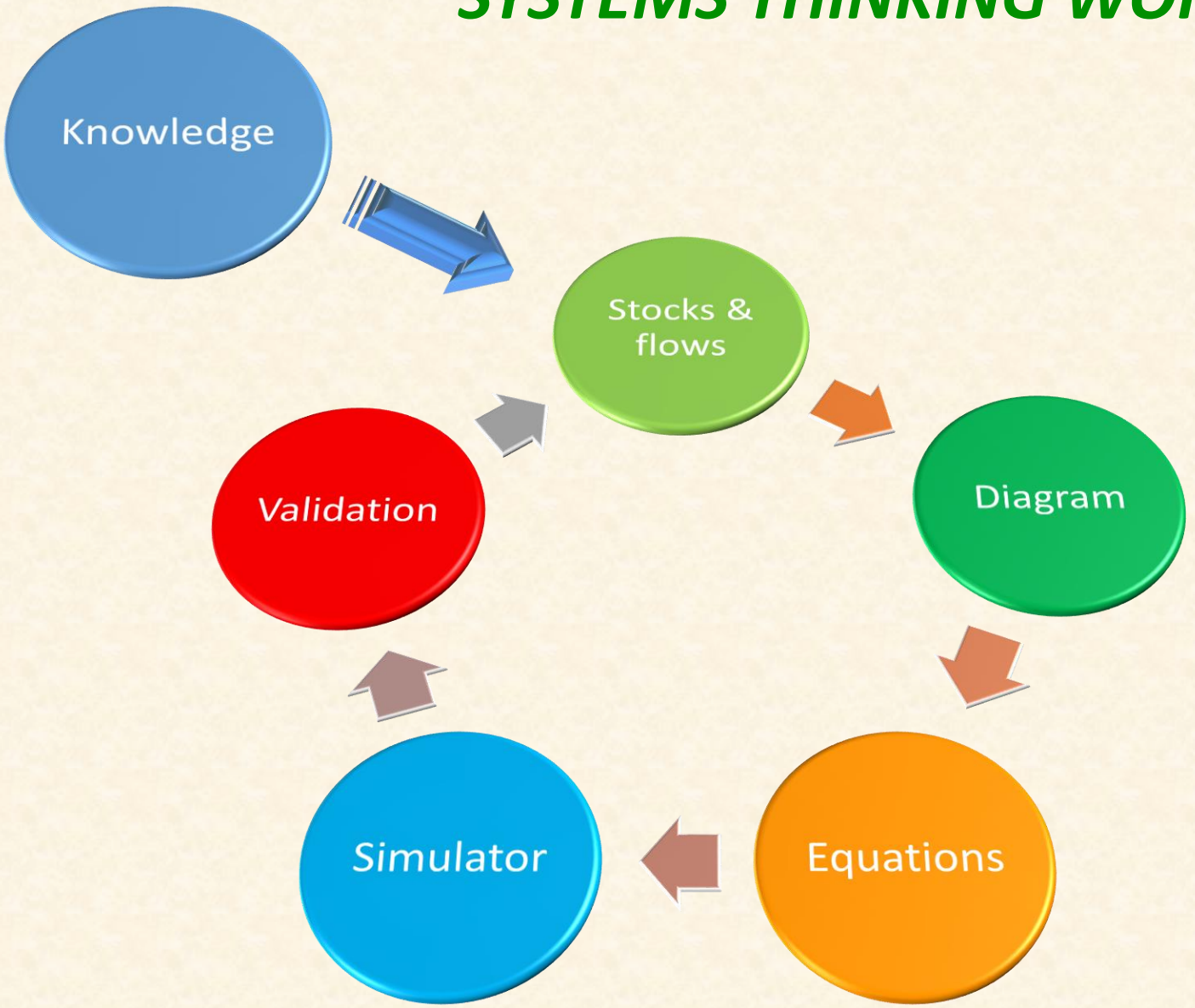
5. Identification of the processes occurring within a system

7. DRAWING THE DIAGRAM

8. SETTING UP OF EQUATIONS

9. CREATING A SIMULATOR

SYSTEMS THINKING WORKPLAN



THE CONCEPT OF LEVERAGE POINT

https://www.yellowstonepark.com/things-to-do/wolf-reintroduction-changes-ecosystem