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.
Jay W. Forrester's World Model from World Dynamics, 1971
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

[Graph showing trends over time with labels: 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"

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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![Diagram of Stock System]

**Demography system**
- children
- adults
- aged

**Productive society system**
- unempl
- Working class
- retired
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.....
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THE CHOSEN SET OF STOCKS IS NOT A “PHOTOGRAPH” OF THE SYSTEM
FLOW

What makes a stock change over time
Interaction process

PROTEIN SYNTHESIS

Amino acids → DNA → Proteins

QF

\[ \dot{Q} = k_2 EQ - k_3 EQ - k_4 Q = k_1 EQ - k_4 Q \]

\[ k_1 = k_2 - k_3 \]
Growth on an unlimited source

\[ \dot{Q} = k_1 EQ - k_2 Q \]

Growth on a non-renewable source

\[ \dot{E} = -k_0 EQ \]
\[ \dot{Q} = k_1 EQ - k_2 Q \]
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

\[ R = J - k_0 R Q \Rightarrow R = J/(1+k_0 Q) \]

\[ \dot{Q} = k_1 R Q - k_2 Q \]

Slowly renewable

\[ \dot{E} = J - k_4 E - k_0 E Q \]

\[ \dot{Q} = k_1 E Q - k_3 Q \]
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

\[ N = T_N - fC \]
\[ \dot{C} = k_1 ENC - k_2 C \]
\[ = (k_1 ET_N - k_2)C - k_1 EfC^2 \] (logistic)
Mass and energy conservation in a stationary state
Two populations growth

\[ \dot{Q}_1 = k_1 EQ_1 - k_3 Q_1 \]
\[ \dot{Q}_2 = k_2 EQ_2 - k_4 Q_2 \]
Competition for a flow-limited source

\[
R = J - k_1 R Q_1 - k_2 R Q_2 \quad \rightarrow \\
R = J/(1 + k_1 Q_1 + k_2 Q_2)
\]

\[
\dot{Q}_1 = k_5 R Q_1 - k_3 Q_1 \\
\dot{Q}_2 = k_6 R Q_2 - k_4 Q_2
\]
Competitive populations

\[
\dot{Q}_1 = k_1 EQ_1 - k_3 Q_1^2 - k_5 Q_1 Q_2 \\
\dot{Q}_2 = k_2 EQ_2 - k_4 Q_2^2 - k_6 Q_1 Q_2
\]
Cooperative populations

\[ R = J - k_1 R Q_1 Q_2 - k_2 R Q_1 Q_2 \]
\[ R = J/(1 + k_1 Q_1 Q_2 + k_2 Q_1 Q_2) \]

\[ \dot{Q}_1 = k_5 R Q_1 Q_2 - k_3 Q_1 - k_7 R Q_1 Q_2 \]
\[ \dot{Q}_2 = k_6 R Q_1 Q_2 - k_4 Q_2 - k_8 R Q_1 Q_2 \]
Prey-predator

\[ \dot{H} = k_1EH - k_2H - k_3CH \]
\[ \dot{C} = k_4CH - k_5C \]

Alfred J. Lotka
& Vito Volterra
Double prey-predator

\[
\begin{align*}
\dot{P} &= k_1 J - k_2 P - k_3 PH \\
\dot{H} &= k_4 PH - k_5 H - k_6 HC \\
\dot{C} &= k_7 HC - k_8 C
\end{align*}
\]
Systems at war

\[ R = J - k_0 RA - k_1 QRB \rightarrow R = J/(1+k_0A+k_1B) \]

**Assets:**
\[
\dot{A}_1 = k_2 RA_1 - k_3 A_1 - k_6 A_1 - k_{11} A_1 B_2 \\
\dot{B}_1 = k_4 RB_1 - k_5 B_1 - k_8 B_1 - k_{10} B_1 A_2 
\]

**Defense:**
\[
\dot{A}_2 = k_6 A_1 - k_7 A_2 - k_{14} A_2 B_1 - k_{13} A_2 B_2 \\
\dot{B}_2 = k_8 B_1 - k_9 B_2 - k_{12} B_2 A_1 - k_{15} A_2 B_2 
\]
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

Knowledge → Stocks & flows

Stocks & flows → Diagram

Diagram → Equations

Equations → Simulator

Simulator → Validation

Validation → Knowledge
THE CONCEPT OF LEVERAGE POINT

How Wolves Change Rivers

HOW WOLVES CHANGE RIVERS