Odum's Energy Systems Language & Combinatorial Species and Network Models

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Outline

- Toolbox
- Examples
- Combinatorial Species
- Network Models

Environment, Power, and Society by Howard T. Odum

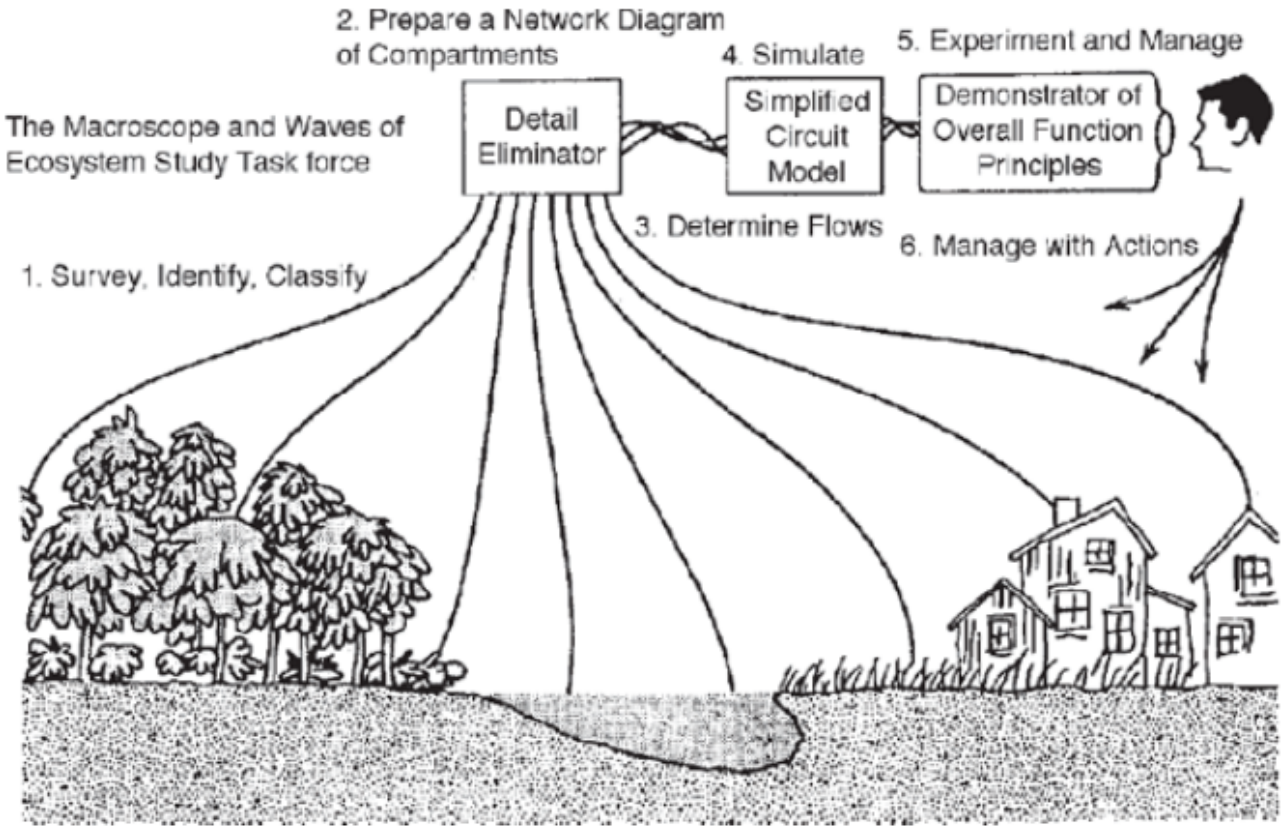
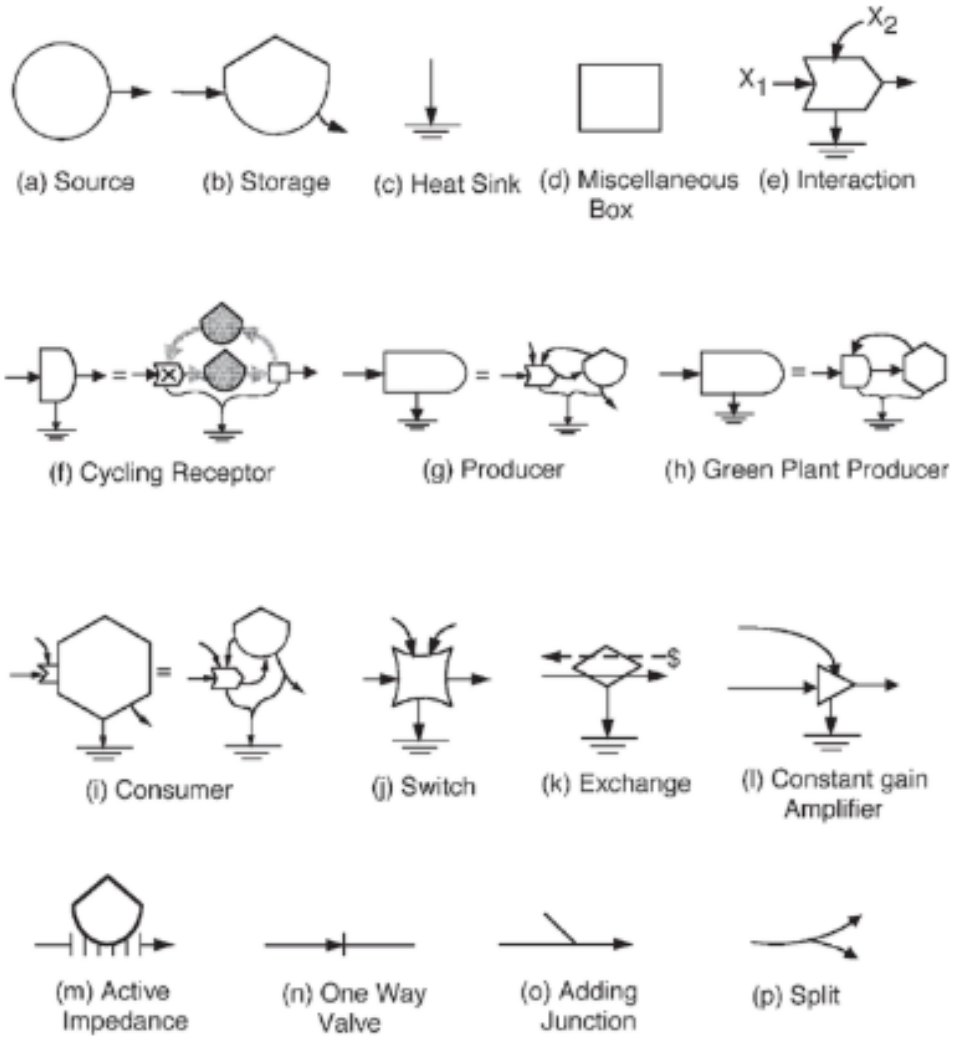
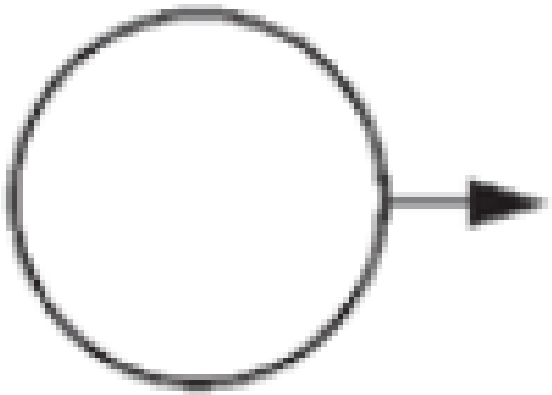


FIGURE 1.2 Cartoon of the macroscope and the steps in its use. The detail eliminator simplifies by grouping parts into compartments of similar function.

Toolbox


X2
X1
(a) Source
(b) Storage
(c) Heat Sink
(d) Miscellaneous Box
(e) Interaction
(f) Cycling Receptor
(g) Producer
(h) Green Plant Producer
(i) Consumer
(j) Switch
(k) Exchange
$
(l) Constant gain Amplifier
(m) Active Impedance
(n) One Way Valve
(o) Adding Junction
(p) Split

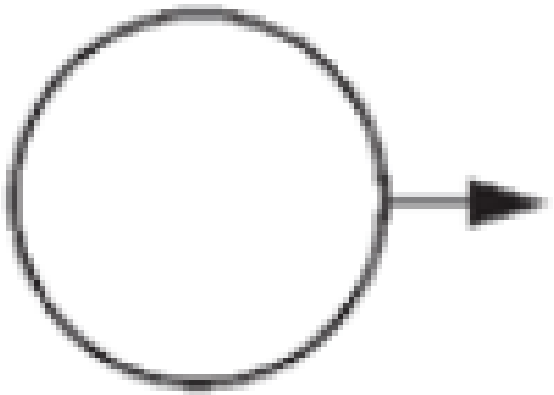
Source



(a) Source

- the sun
- fossil fuels
- water from a reservoir

Source

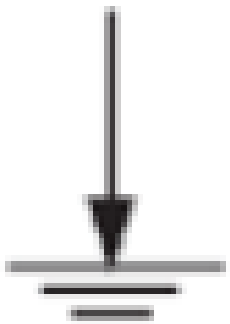


(a) Source

- the sun
- fossil fuels
- water from a reservoir

should come with data about whether its **constant force**, **constant flux**, or programmed in a particular sequence with, for example, a **square wave** or **sine wave**.

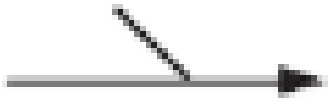
Heat Sink



(c) Heat Sink

"A sink is needed for all processes that are **real** and **spontaneous**, according to the second law of thermodynamics. All processes deliver some **potential energy** into heat. Heat is the random wandering of molecules that have kinetic energy, and it is this wandering from a less probable to a **more probable state** that pulls and drives real processes connected to such flows. **Energy degradation** is also required where storages are dispersing."

Adding Junction



(c) Adding Junction

the joining of two similar energy flows.

Split

(p) Split

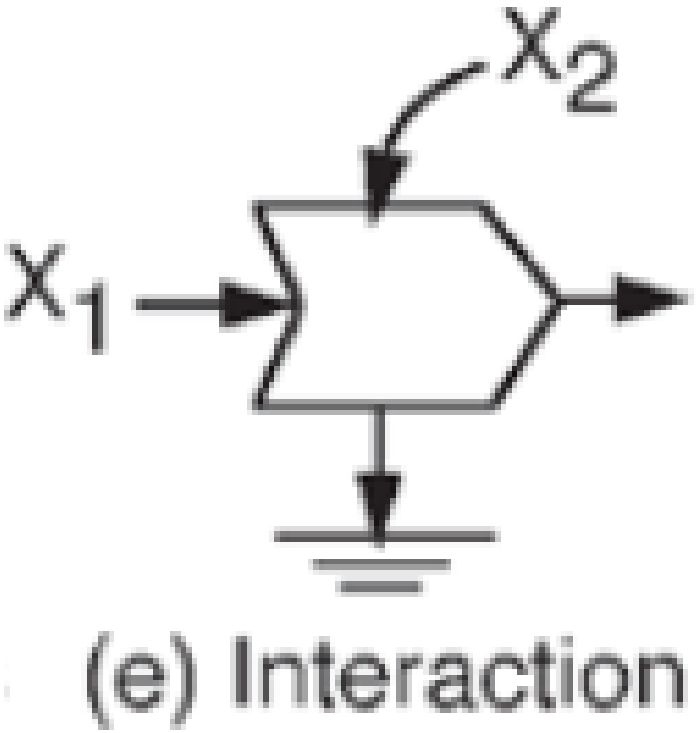
- One flow splits into 2 of the same kind.

Split

(p) Split

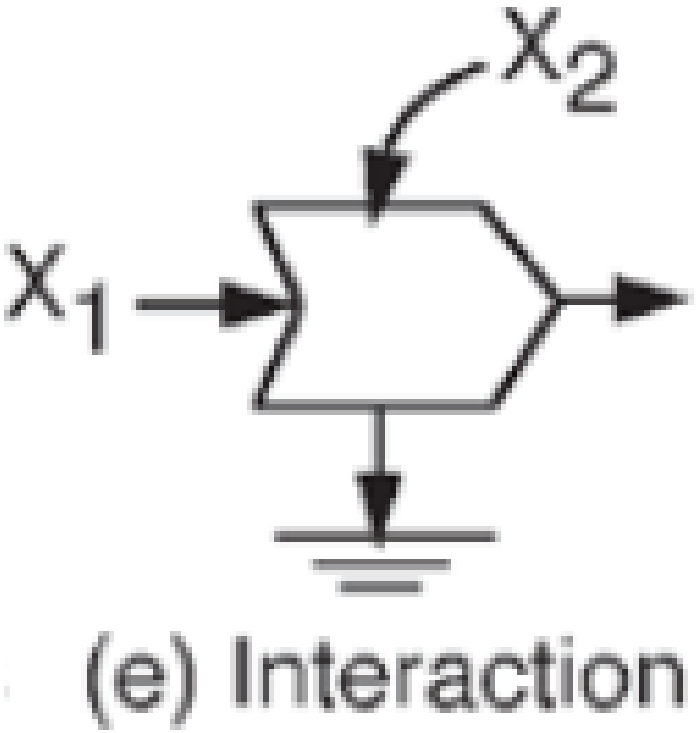
- One flow splits into 2 of the same kind.
- it isn't stated, but I don't think this has to be in a consistent way

Interaction



- X_1 and X_2 are forces
- their interaction generates a productive output

Interaction



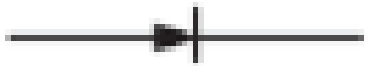
- X_1 and X_2 are forces
- their interaction generates a productive output
- a person turning a valve
- the interaction of limiting fertilizer with sunlight in photosynthesis

Misc. Box

(d) Miscellaneous Box

This can be used for any purpose but usually designates an important subsystem.

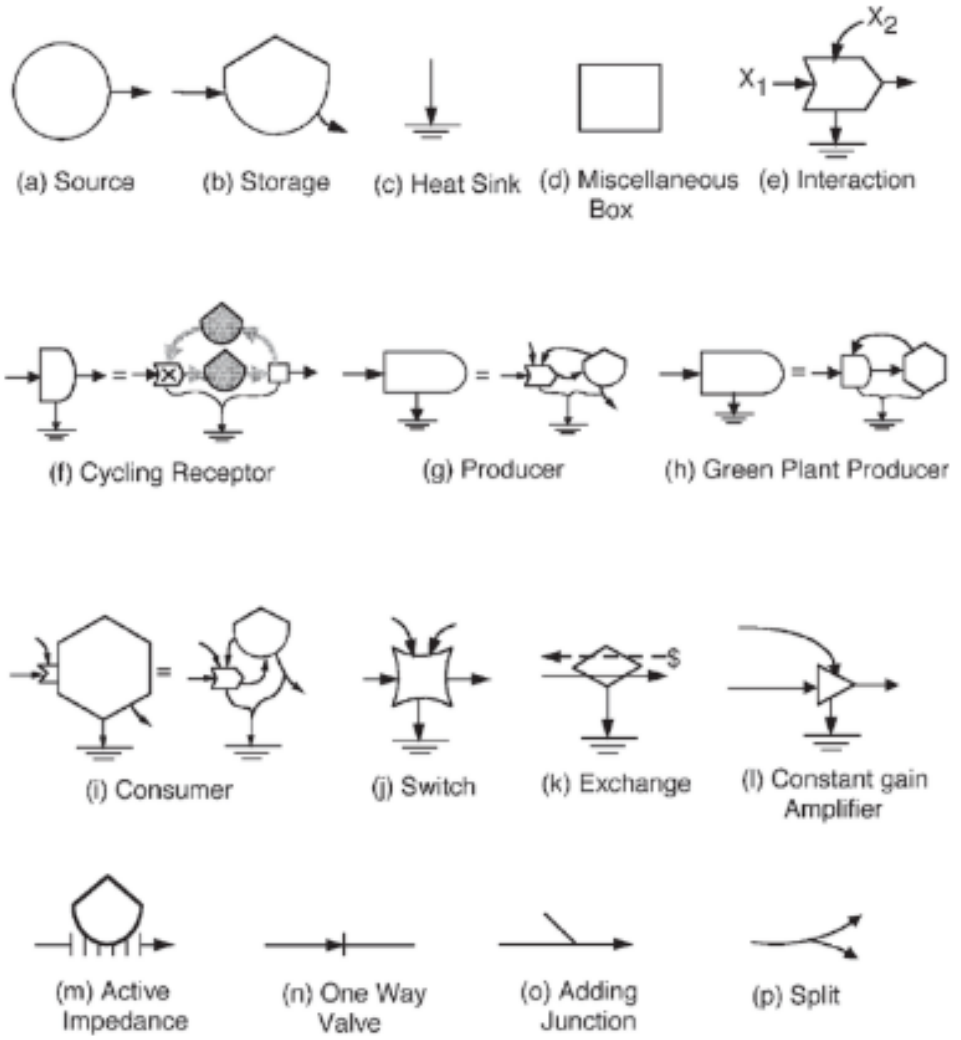
One-Way Valve



(n) One Way Valve

- allows flow to pass in one direction only
- Symbols (e–l) also have the one-way property because of energy losses and interactions with second flows.

Toolbox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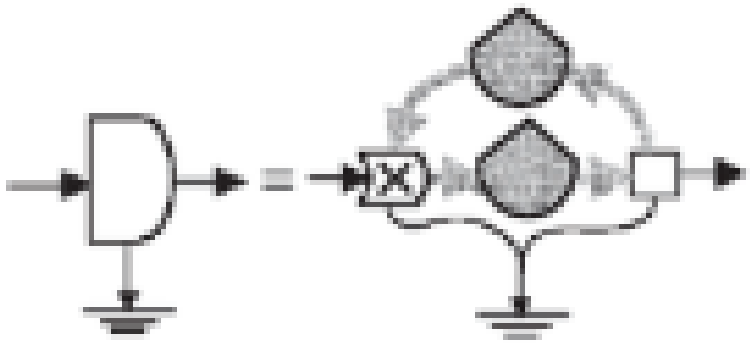
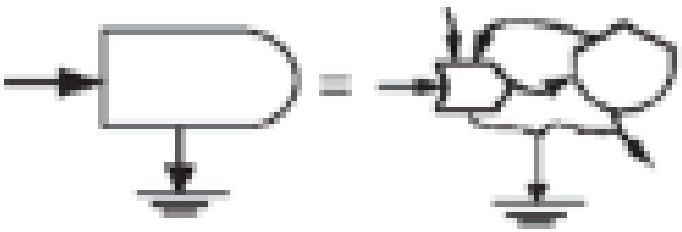
Cycling Receptor



(f) Cycling Receptor

This represents the reception of pure wave energy such as sound, light, or water waves. In this module energy interacts with some cycling material, producing an energy-activated state, which then returns to its deactivated state, passing energy on to the next step in a chain of processes. The kinetics of this module was first discovered in a reaction of an enzyme with its substrate and is called a Michaelis–Menten module.

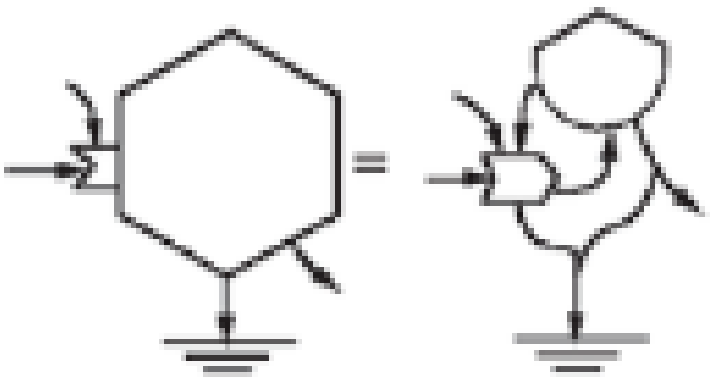
Producer



(g) Producer

The producer usually contains storages and interactions

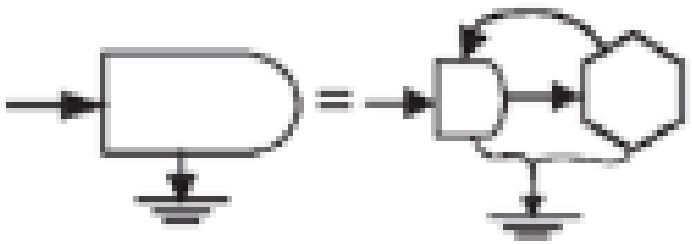
Consumer



(i) Consumer

- represents an interaction of 2 inputs and the autocatalytic coupling of storage that amplifies inflow
- The hexagonal consumer symbol usually implies the combination of **storage** and **interaction**, stored potential energy is fed back to processing the input.

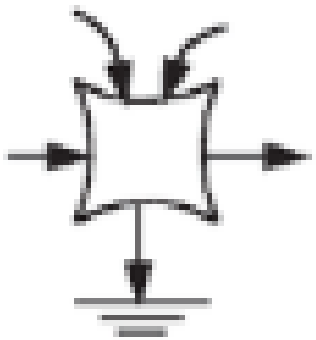
Green Plant Producer



(h) Green Plant Producer

- When this symbol is used for plants and vegetation, a **cycling receptor** and **consumer** unit are implied.
- Energy captured by a cycling receptor unit is passed to a consuming part, which feeds back to the left to keep the cycling receptor machinery working.
- photosynthetic cell

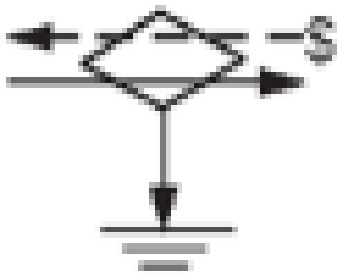
Switch



(j) Switch

- simple on or off, or
- a flow may be on when 2 or more energy flows are simultaneously on
- voting
- starting a car.

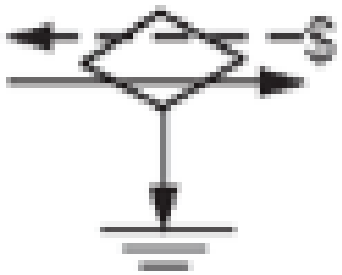
(Monetary) Exchange



(k) Exchange

- money is exchanged for real wealth
- flows of energy, goods, services, etc.
- money goes in the opposite direction

(Monetary) Exchange

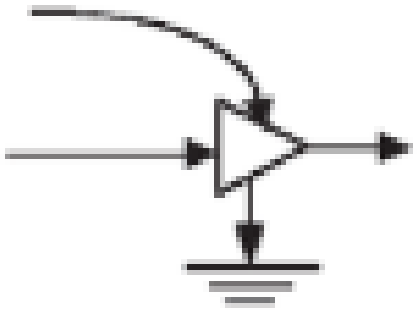


(k) Exchange

- money is exchanged for real wealth
- flows of energy, goods, services, etc.
- money goes in the opposite direction

- Human behavior adjusts prices, controlling the ratio of money flow to purchases
- a man purchasing groceries at a store receives groceries in one direction while paying money in the opposite direction
- The heat sink may be omitted when the work in the transaction is small

Constant Gain Amplifier

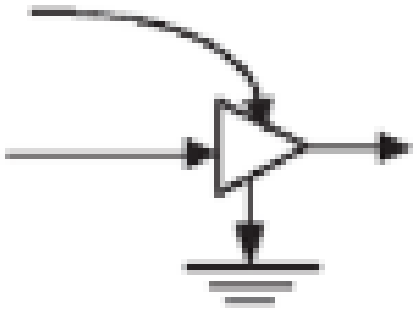


(I) Constant gain Amplifier

- Force from the left controls the amount of output and energy flow but contributes only a small energy input
- Whatever energy is required comes from the upper inflow

- The input force from the left causes an output force increased by a constant gain

Constant Gain Amplifier

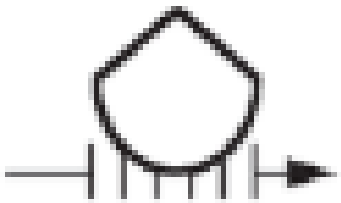


(I) Constant gain Amplifier

- Force from the left controls the amount of output and energy flow but contributes only a small energy input
- Whatever energy is required comes from the upper inflow

- The input force from the left causes an output force increased by a constant gain
- a reproducing species inputs effort from the left, generating an output of 10 offspring, as long as the energy supplies are more than adequate.

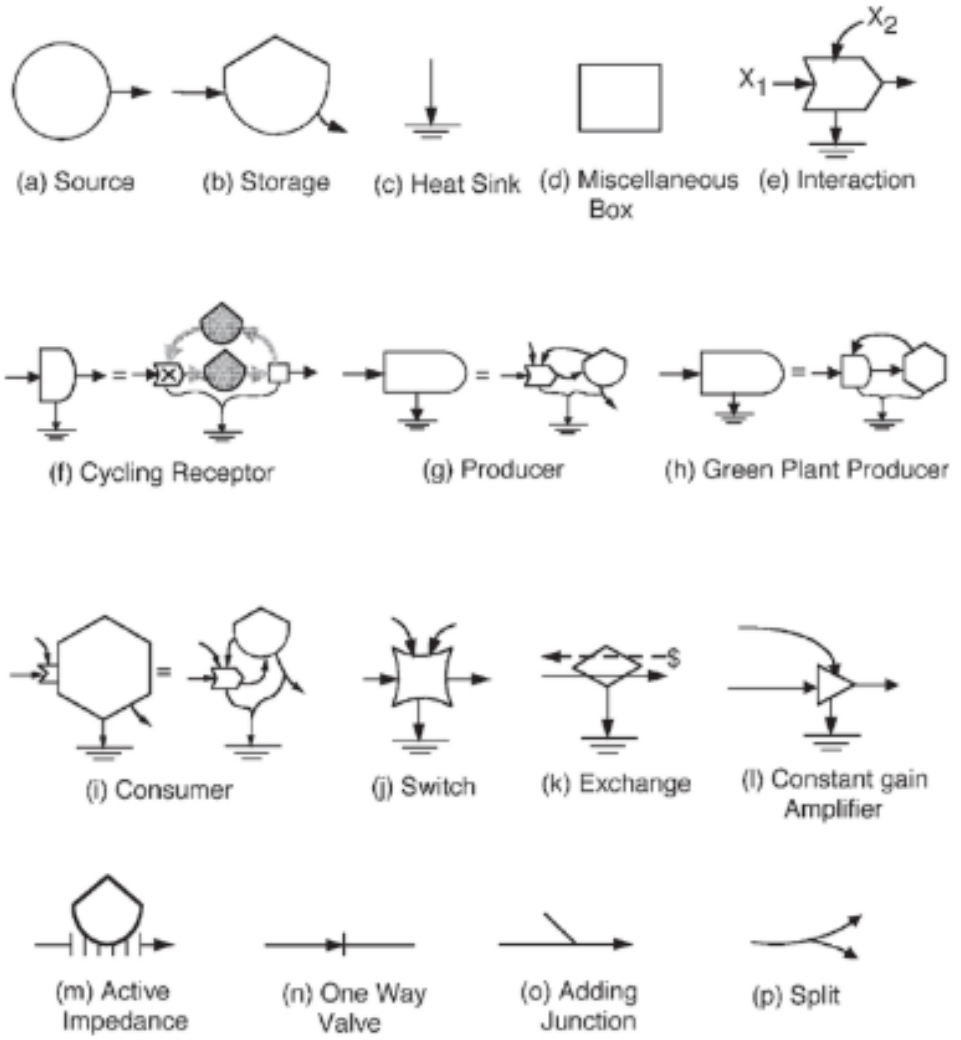
Active Impedance



(m) Active Impedance

- represents systems that develop a backforce against any input driving force as long as that force is increasing
- some energy storage is arranged so that when the forcing impetus ceases, the energy unit delivers a forward flow (from some storage or other source) in proportion to the earlier accumulation.
- Many organisms, human behavior programs, and

Toolbox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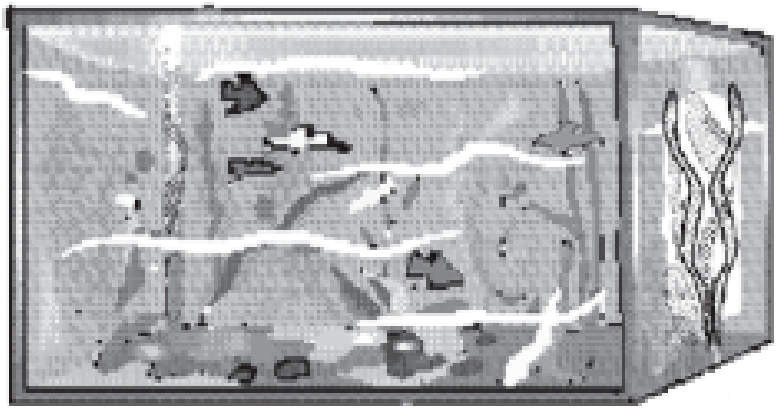
Aquarium

(a) Balanced Aquarium



P = Photosynthetic Production

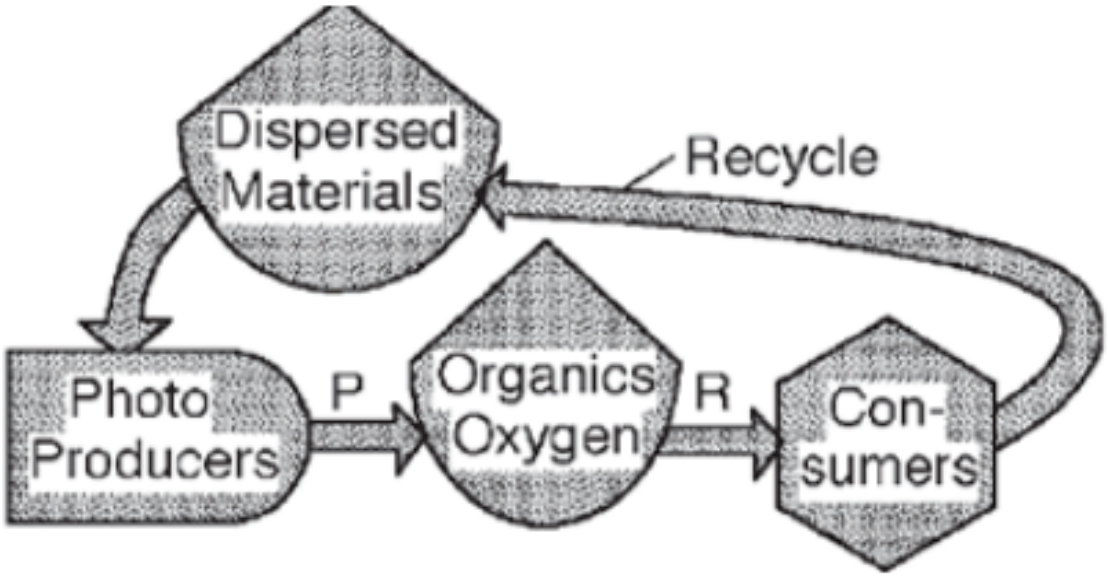
$$\text{Light} + CO_2 + H_2O + \text{Mineral elements} \longrightarrow \text{Organic Matter} + O_2 + \text{Heat}$$

$$\text{Heat} + CO_2 + H_2O + \text{Mineral elements} \longleftarrow \text{Organic Matter} + O_2$$

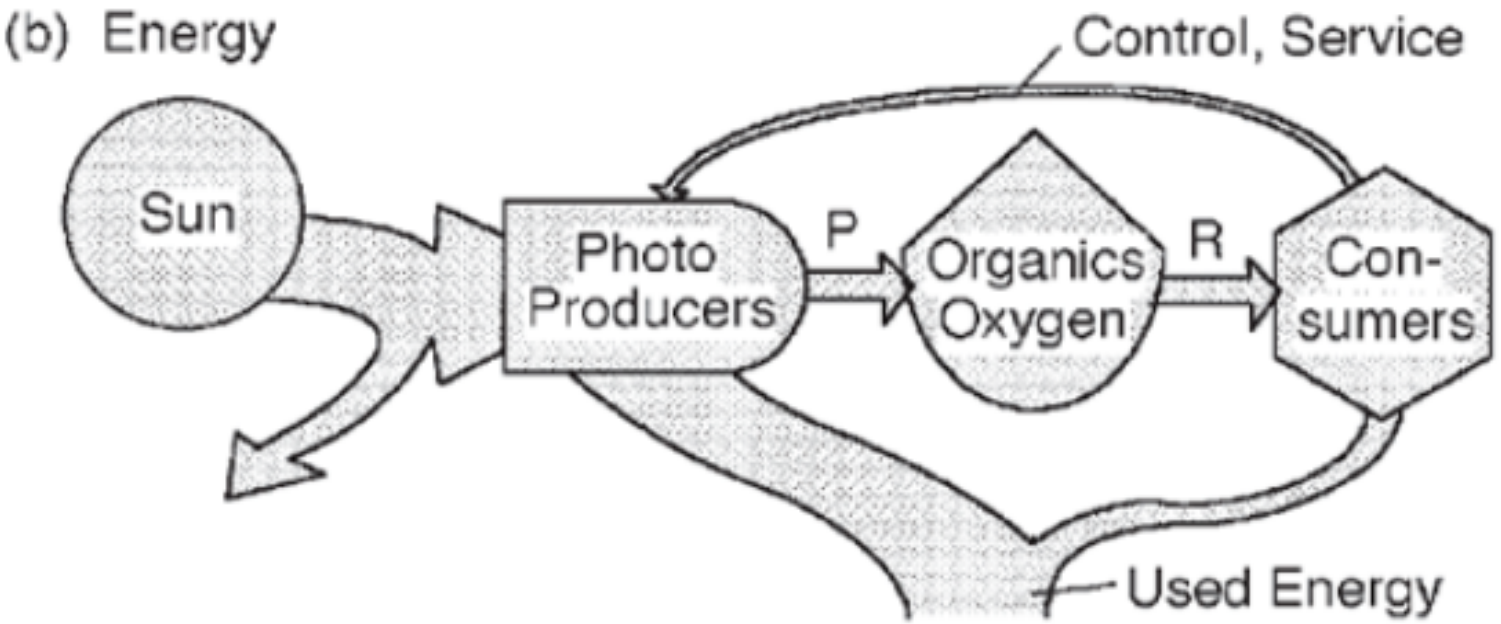
R = Respiratory Consumption

Aquarium

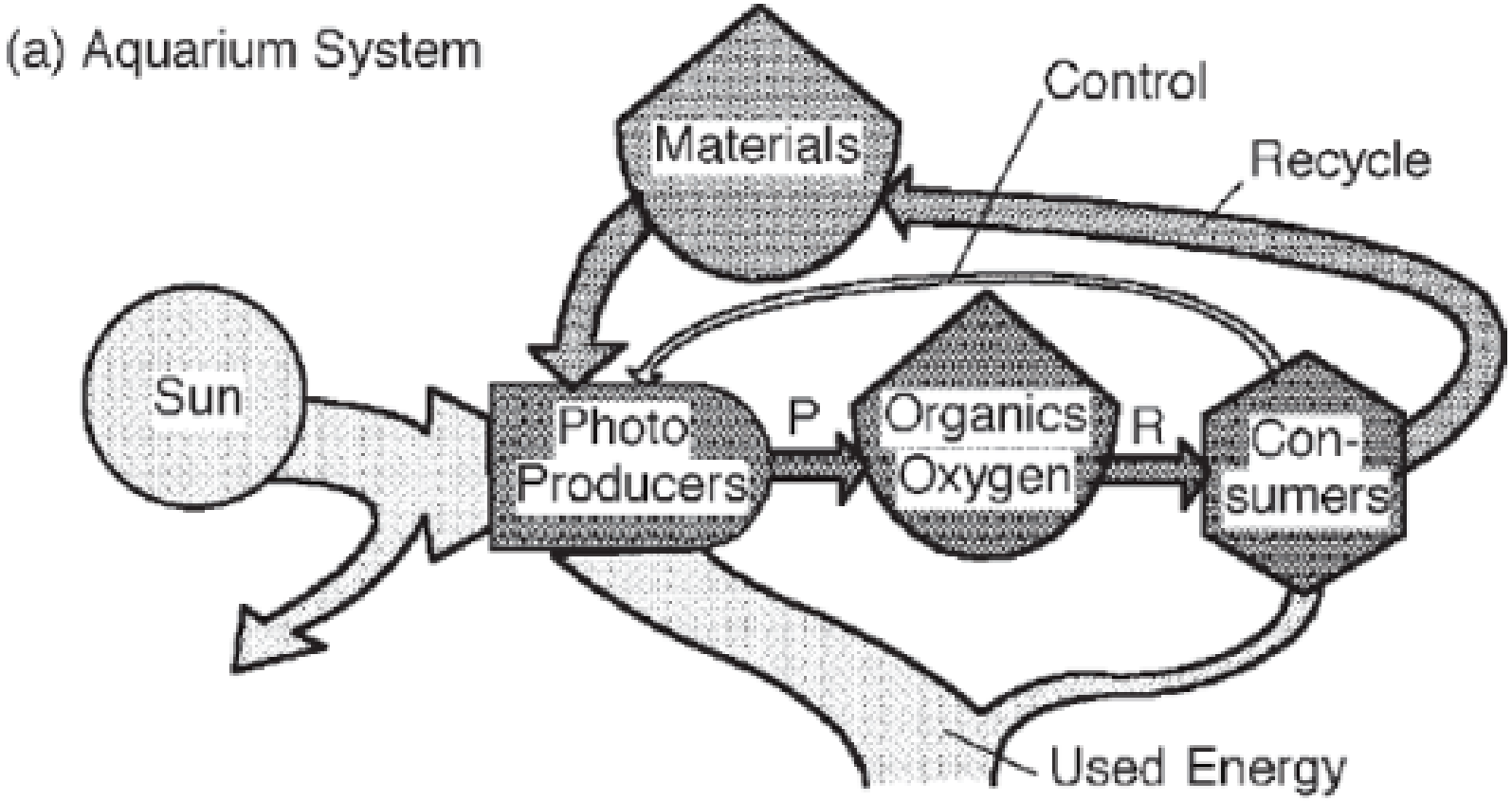
(c) Materials



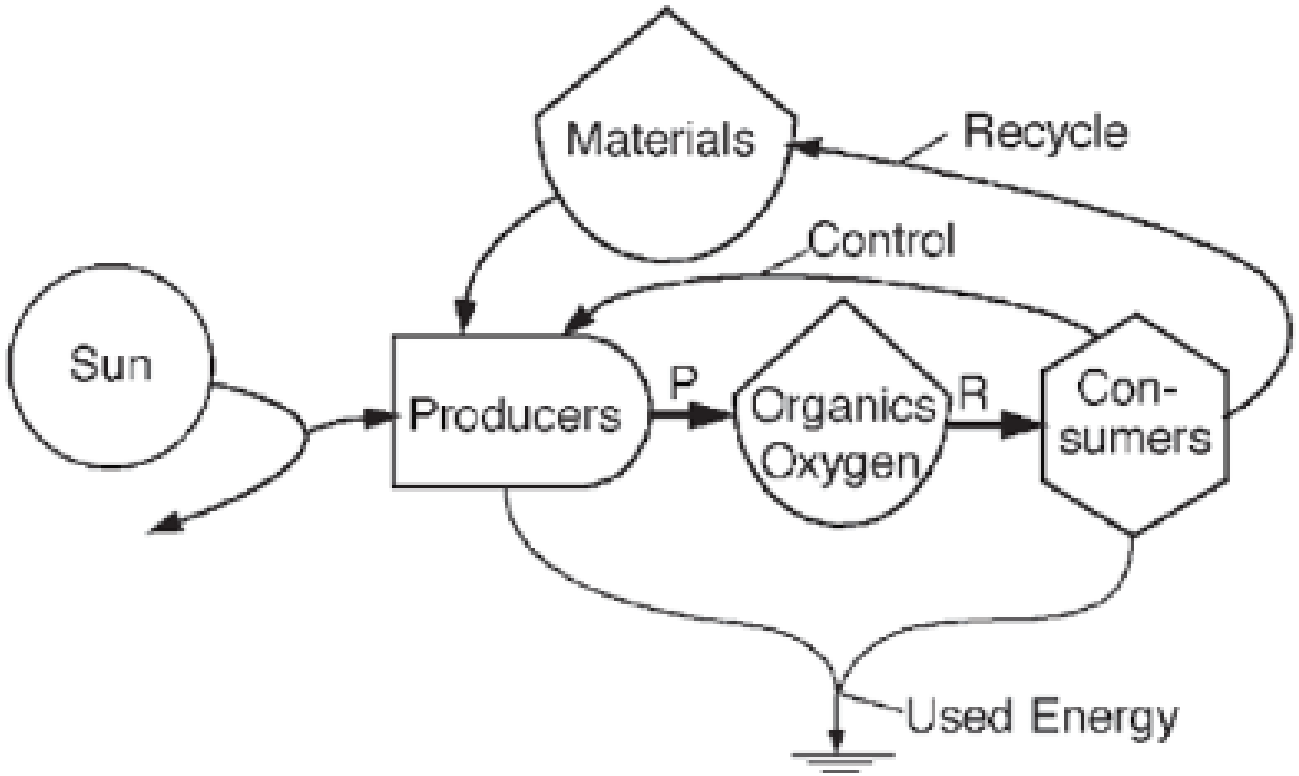
Aquarium


(b) Energy
Control, Service
Sun
Photo Producers
P
Organics Oxygen
R
Con-sumers
Used Energy

Aquarium


(a) Aquarium System
Materials
Control
Recycle
Sun
Photo
Producers
P
Organics
Oxygen
R
Con-
sumers
Used Energy

Aquarium


Materials
Recycle
Control
Sun
Producers
P
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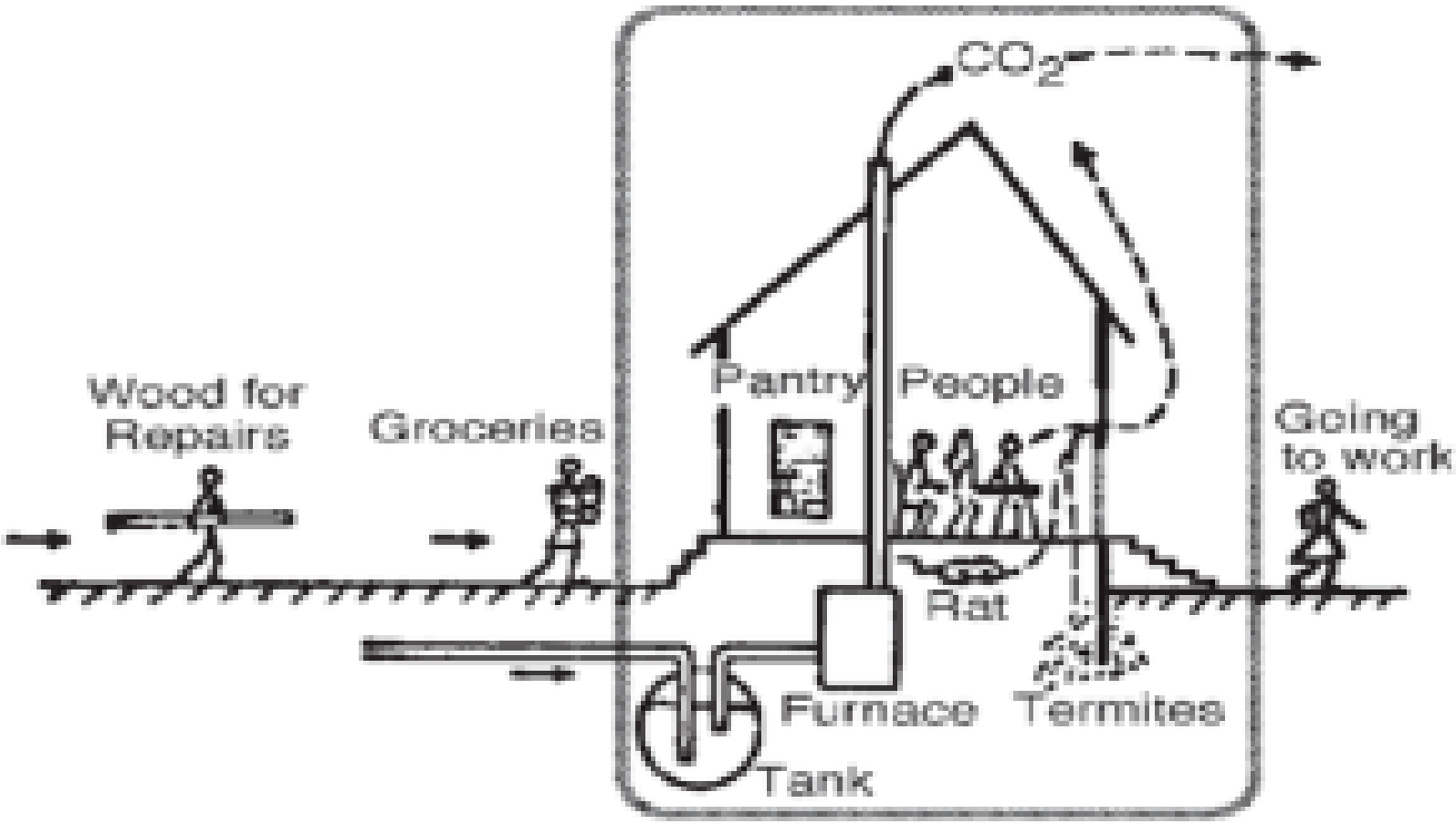
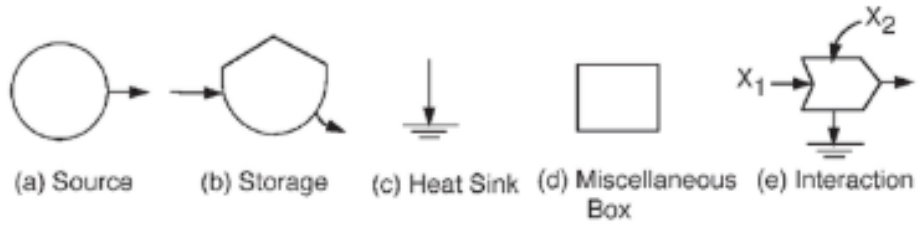
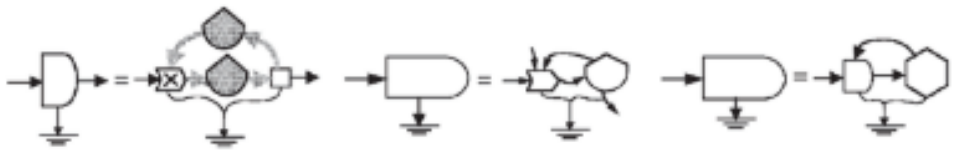
Human Residence



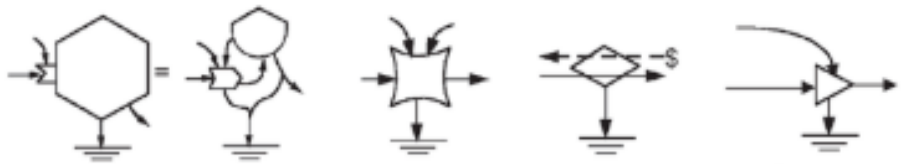
Toolbox



(a) Source (b) Storage (c) Heat Sink (d) Miscellaneous Box (e) Interaction



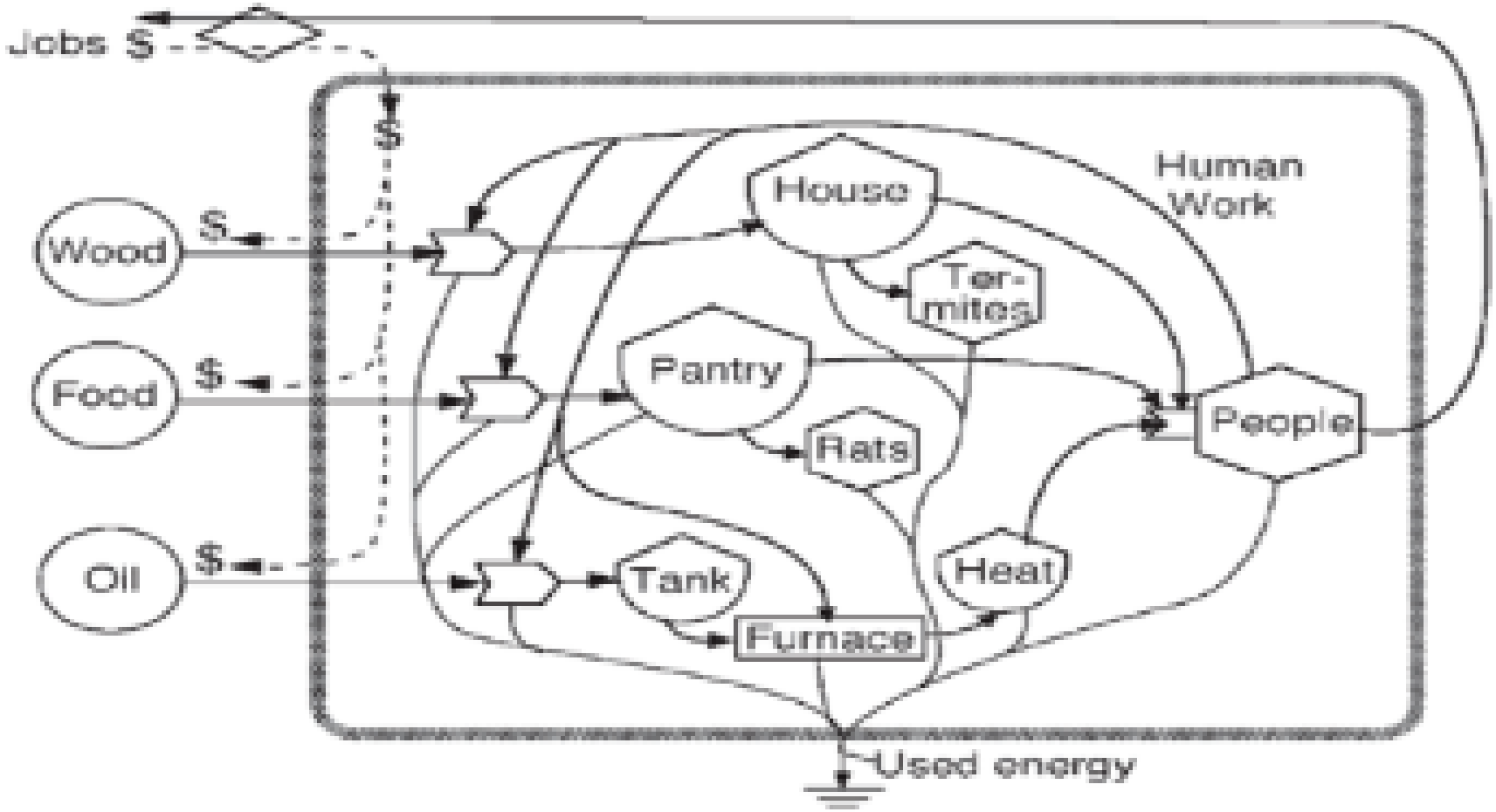
(f) Cycling Receptor (g) Producer (h) Green Plant Producer



(i) Consumer (j) Switch (k) Exchange (l) Constant gain Amplifier

(m) Active Impedance (n) One Way Valve (o) Adding Junction (p) Split

Human Residence



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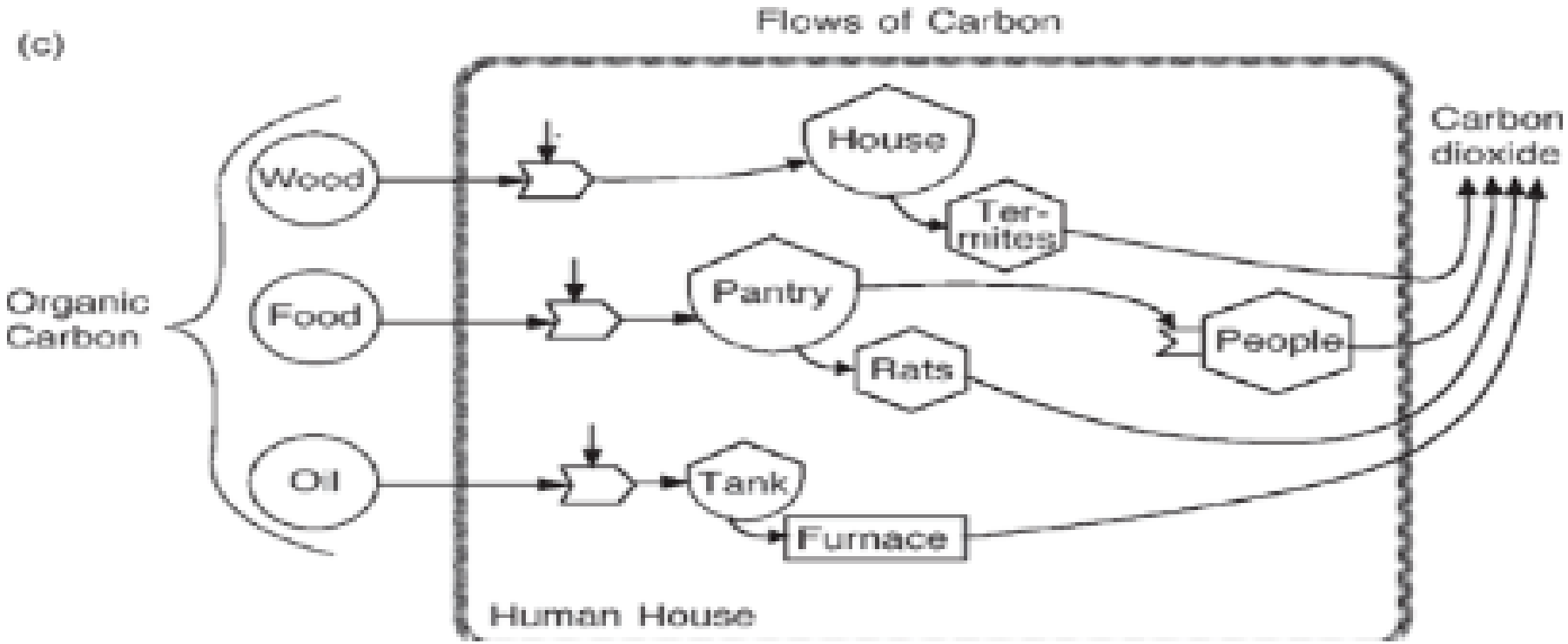


Combinatorial Species

The theory of combinatorial species was originally developed by André Joyal

Definition

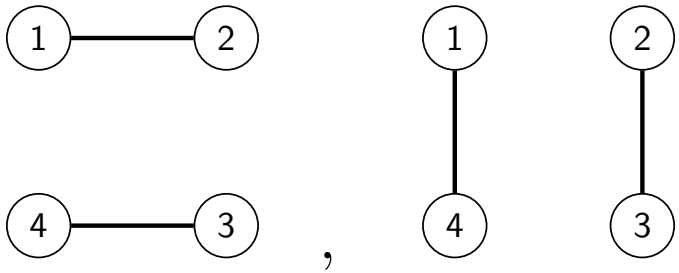
A **combinatorial species** *is a functor*

$$F : \mathrm{FinBij} \to \mathrm{Set}$$

To a finite set X, F assigns a set of structures on X, with a group action of $S_{|X|}$.

Example: Simple Graphs

For finite set X, let Simple$[X]$ be the set of simple graphs with vertex set X.



Example: (Directed, multi) Graphs

For finite set X, let $\mathrm{Grph}[X]$ be the set of isomorphism classes of graphs (kinda) with vertex set X.

Sum of Species

Given species F, G : FinBij $\to$ Set, define

$$(F + G)[X] = F[X] + G[X]$$

Sum of Species

Given species F, G: FinBij $\to$ Set, define

$$(F + G)[X] = F[X] + G[X]$$

either an F structure on X, or a G structure on X

Day Convolution

Given species $F, G : \mathrm{FinBij} \to \mathrm{Set}$, you get an element of $(F \otimes G)[X]$ by partitioning X into two chunks, putting an F structure on one chunk, and a G structure on the other.

Another Product of Species

Given species F, G : FinBij $\to$ Set, define

$$(F \times G)[X] = F[X] \times G[X]$$

Another Product of Species

Given species F, G: FinBij $\to$ Set, define

$$(F \times G)[X] = F[X] \times G[X]$$

an F structure and a G structure on X together

Other Operations on Species

- Hadamard product / inner product
- Cauchy product
- Plethysm / composition

Network Models

Definition

A **network model** *is a lax symmetric monoidal functor*

$$(F, \phi) \colon (\mathsf{S}, +) \to (\mathsf{Mon}, \times)$$

Network Models

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A **network model** *is a lax symmetric monoidal functor*

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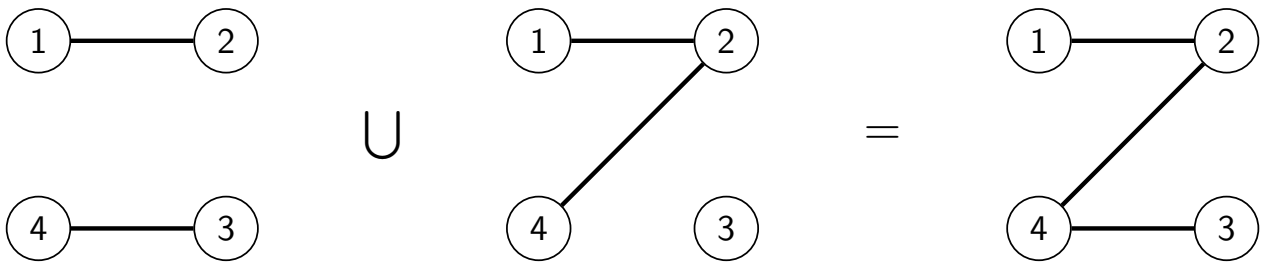
Network models are used to construct operads where the operations are "networks" as described by F

Example: Simple Graphs



$$(\mathsf{Simple}, \sqcup) \colon (\mathsf{S}, +) \to (\mathsf{Mon}, \times)$$

Thank You!