Physical Relationships among Matter, Energy, Information

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Basic elements of the universe

- Greeks – earth, air, fire, water
- Chinese – metal, wood, water, fire, earth
- Physicists – space and time
- General systems theorists – matter, energy, information

Miller’s living systems theory

- Miller suggested there are seven levels of systems – cells, organs, organisms, groups, corporations, nations, and supranational organizations.
- All process matter, energy and information.

Information is a recent concept

- Shannon – a reduction of uncertainty
- Bateson – that which changes us, or the difference that makes a difference
- Von Foerster – information is a function of the observer

Connections

- Einstein connected matter and energy in 1905 (E = mc**2)
- Szilard connected energy and information in 1929 (Maxwell's demon)
- Bremermann connected matter and information in 1962 (E = mc**2 = hf)

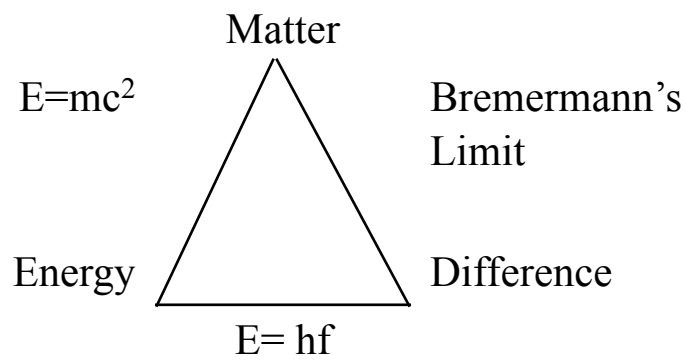

Figure 1. A triangle of relationships

Planck’s constant

- The energies of quanta are proportional to the frequency of radiation (E= hf)
- Planck’s constant also appears in the Heisenberg uncertainty principle (h < Dm Dp)

Maxwell's demon

- The demon sorts high energy and low energy particles.
- Szilard recognized that the demon would require information in order to sort the particles.
- He showed that the act of measuring the velocity of gas molecules would produce more entropy than the sorting process would remove.

Matter and information

- Bremermann suggested that there is a upperbound on the rate at which symbols can be processed by matter.
- They can be processed at speeds not exceeding 10**47 bits/gram/sec.

Pattern recognition

- Ashby showed the dramatic impossibility of some pattern recognition strategies.
- A grid of 20 by 20 lights that can be only on or off presents a variety of 2**400 patterns or more than 10**100.
- If the pattern recognition strategy is to match a pattern with one of the possibilities, a computer as large as the earth operating for centuries would fail.

From information to difference

- Szilard and Bremermann and Miller used the term “information”.
- But information is a function of the observer and hence is not an elementary concept.
- “Difference” is probably a more appropriate concept when dealing with physical foundations.

On the relationship between matter and information

- Bremermann's limit applies only at the atomic level.
- Differences, and hence information, can be observed at the level of atoms (where Bremermann's limit applies), molecules (DNA), cells (neurons), organs (brains), organisms (skills), groups (norms), and societies (culture or laws).

Attention to information

- Agricultural societies are concerned with producing and storing matter.
- Industrial societies are concerned with producing and using energy.
- Post industrial societies seek to understand and manage information.

Reflection

- Observers, and the distinctions they make, are the means whereby the substance of the universe becomes aware of itself.