

## M. ENTROPY AND ORDER: MAXWELL'S DEMON

### 1. Order and Probability

If several truckloads of bricks were dumped onto one location, they would probably fall into a jumbled pile. It is highly unlikely that they would fall into place to make an orderly structure such as a building. This is because there are more ways to make a jumbled pile of bricks than a building. In other words, a disorderly arrangement is more probable. (Similarly, it is more likely that a student's dormitory room will be disorganized because there are many more ways to be "sloppy" than to be neat.)

Returning to the kinetic-molecular theory of matter, when a substance such as water is in a solid state (ice), its molecules are arranged in a very definite regular geometric pattern. As heat is added to the solid, the entropy increases. The molecules, although maintaining almost the same average pattern as before, are moving about much more at any instant of time. The entropy increase is therefore described as an increase of disorder on the molecular level. When the ice melts, the water molecules are moving about even more, and in fact the previous regular geometric pattern has been almost entirely broken, making the system much more disorganized and its entropy, therefore, much larger. Still, on the average, the molecules are about as close together as before. As more heat is added and the temperature rises well above the melting temperature, the average distance between molecules increases, and the range of the momentum values of the molecules increases. When the water evaporates, the molecules become quite separated, and their range of momentum values increases even further. The molecules are now in a very disorganized arrangement, and as a result the entropy of the system is much larger.

The ideas of order and disorder (or organization or lack of it) include not only arrangements of molecules in space, but also the energy distribution functions as well. The mixing of hot and cold molecules discussed above in connection with the approach to equilibrium (section K3) can also be described as a loss of organization in their energy distributions. Initially, half the molecules were clustered in a distribution with a low average temperature (less energy per molecule) and the other half in a distribution with a high average temperature. This represents a discernible grouping or ordering of the molecules—those with low energy and those with high energy. After they have mixed and reached equilibrium, there is only one distribution, and there is no longer organization or spatial segregation according to energy.

To sum up, the principle that the entropy of an isolated system cannot decrease simply means that a system by itself will not separate its molecules into groups of different average energy (or spacing or both), because such a separation would represent the acquisition of some higher degree of orderliness or organization—which, statistically, is quite improbable. Furthermore, microscopically, entropy is a measure of the disorder of a system. When the entropy of a system has increased, it has become less orderly.

### 2. Maxwell's Demon

Many schemes have been proposed to circumvent the principle of no entropy decrease for an isolated system. One of the most famous and fanciful of these schemes was considered by the great Scottish theoretical physicist, James Clerk Maxwell (1831–1879). He imagined a box containing a gas of molecules in thermal equilibrium. A wall was mounted across the middle of the box, dividing it into two parts. In the wall there was a trapdoor, which was initially open, so that molecules from both halves of the container could pass through. Maxwell then



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## Poems

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### A Life

There is an extravagance in the means my sanity took  
to rescue their madness that makes the one look  
uncommonly like the other.

Rebecca West, "Parthenope"

I remember the sister who fed me soap saying it was food.  
I remember falling heavy against the child I said I loved.  
I remember amnesiac fists of electricity at my temples.  
I remember the chalky powdered diet drinks, change was  
simple.  
I remember an eye of red wine in an arid household.  
I remember his deceptive chest, the way his arms pulled.  
I remember my voice deep in a well of bed clothes.  
I remember the breath-held Sundays, the way the sun rose.  
I remember the juggle of accounts, the Christmas sewing-  
machine.  
I remember his heart exploding, the way my children screamed.  
I remember parties where I was scalded with coffee.  
I remember adulthood like work in a munitions factory.  
I remember letters I wrote about the facts he altered.  
I remember the smell of bolting awake. I remember darkness.  
I remember insisting "I am just like everyone else,"  
I remember thinking much later that maybe I was.

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Wendy Bishop