

**P. W. Anderson (1972). *More Is Different*. Science, New Series, Vol. 177, No. 4047, pp. 393-396**

[http://robotics.cs.tamu.edu/dshell/cs689/papers/anderson72more\\_is\\_different.pdf](http://robotics.cs.tamu.edu/dshell/cs689/papers/anderson72more_is_different.pdf)

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| <p>(P1, C1) What is the reductionist hypothesis?</p>   | <p>That we can reduce science to the study of the most fundamental ideas.</p>   |
| <p>(P1, C1&amp;2) What areas of physics would you consider to be 'intensive research' and which would be 'extensive research'? Why?</p>                      | <p>Intensive: particle physics, some aspects of theoretical physics, cosmology, nuclear physics<br/>         Extensive: materials science (an application of quantum mechanics), you could argue that chemistry is the application of quantum mechanics to systems of many atoms (but chemists will frown at you). You can go right through the hierarchy of science and say anything that is not intensive, by definition, is extensive.</p> |
| <p>(P1, C2) What is the constructionist hypothesis?</p>  | <p>That we can start from the fundamental laws and construct the universe.</p>  |
| <p>(P1, C3) According to the hierarchy presented in the third column of the first page, what would be the 'most' and 'least' fundamental areas of study?</p> | <p>Most: elementary particle physics<br/>         Least: social sciences</p>  |
| <p>(P1, C3) Why might the constructionist hypothesis not be valid?</p>   | <p>Because the behaviour of complex systems is not simply an extrapolation of the behaviour of simpler sub units. Molecules don't behave as if they are simply a few atoms together, but have properties that couldn't simply be extrapolated from an atom alone.</p>   |
| <p>(P2, C1) What laws govern the universe on the cosmological scale and what laws govern the universe on the atomic scale?</p>                               | <p>General relativity on the cosmological scale and quantum mechanics on the atomic scale.</p>  |
| <p>(P2, C1) What is the chemical formula for ammonia?</p>  | <p>NH<sub>3</sub></p>   |

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| <p>(P2, C1) Why does Anderson say that the Nitrogen in Ammonia is negatively charged and the Hydrogens in Ammonia are positively charged?</p> | <p>Because Ammonia is covalently bonded, the Hydrogen atoms are sharing their electron with the Nitrogen, this means that there are more electrons in the vicinity of the Nitrogen nucleus than Nitrogen has protons, making that region of the molecule negatively charged. Equally, from Hydrogen's point of view, by sharing its electron, the region around the Hydrogen nucleus has less electrons than there are protons in the nucleus, leading to a positive charge. This is a polar molecule for this reason.</p> |
| <p>(P2, C1) What is an electric dipole moment?</p>  | <p>A measure of the separation of positive and negative charges.</p>   |
| <p>(P2, C1&amp;2) Why is it said that there's no such thing as an electric dipole moment in a stationary system of ammonia?</p>               | <p>A stationary system is an average of the states that the system can take. As the dipole of ammonia is inverted (due to the Nitrogen tunnelling through the triangle of Hydrogen atoms) very frequently between a pyramid (negative N on top, positive Hs on bottom) and a reversed pyramid (negative N on bottom, positive Hs on top), the average of this is zero.</p>   |
| <p>(P2, C2) What does Anderson mean by symmetry when discussing ammonia?</p>  | <p>He's discussing parity – the equivalence of left- and right-handed states. In the case of ammonia, he means that the pyramid and the inverted pyramid are equally likely and therefore the system is symmetrical.</p>   |
| <p>(P2, C2&amp;3) Why does Anderson say that sugar breaks the parity symmetry?</p>  | <p>Because it is a complex molecule of 40 atoms, and nature makes them in one orientation of spiral (clockwise or anticlockwise) and not the other. There's no way to simply invert it to the other orientation of spiral.</p>   |
| <p>(P2, C3) What is different about sugar molecules that are produced by humans?</p>  | <p>Human-made sugar molecules have no preference for the orientation of their spiral, we see an equal mix of both. Only nature has a preference for one 'handedness' of sugar molecule.</p>  |
| <p>(P2, C3) What is Anderson's definition of symmetry?</p>  | <p>Viewpoints from which a system appears the same.</p>  |

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| <p>.(P2, C3) What is Anderson trying to explain in the last paragraph on P2?</p>   | <p>That the fundamental laws of physics alone can't be built up to predict the complex behaviour of larger systems. If we put one nitrogen atom and three hydrogen atoms through the fundamental laws of physics, it won't spit out a pyramid structure. But once we know it does have a pyramid structure, the laws do fit with this idea.</p>                                |
| <p>.(P3, C1) Draw a diagram of an atom (a circle) and a molecule (two circles joined by a line) to prove that a 'crystal' has less symmetry than the underlying structure.</p> | <p>A circle has infinite lines of symmetry, but two circles joined by a line only has two (in 2D).</p>   |
| <p>.(P3, C2) New properties come, according to Anderson, from broken symmetries. What macroscopic examples does he give?</p>   | <p>Superconductivity, superfluidity, antiferromagnetism, ferroelectricity.</p>   |
| <p>.(P4, C1) Why does decreasing symmetry imply increasing complication? Are they synonymous?</p>  | <p>With more symmetry, rules tend to be simpler. For example kicking a football is a fairly simple process and very easily predictable, owing to the symmetry of the ball. But kicking a rugby ball is much more complicated, as the ball is less symmetrical, and kicking a rugby ball can have many different outcomes depending on whereabouts on the ball you kick it.</p> |
| <p>.(P4, C2) Given the first few paragraphs of the article, why does Anderson talk of the 'arrogance of the particle physicist'?</p>   | <p>As they study the fundamental laws, which from a constructionist point of view would allow them to say that they can explain everything above them in the hierarchy.</p>  |

## Summary

Why do you think Anderson chose to call the piece "More Is Different"?

How would you summarise this paper in:

1 paragraph:

1 sentence:

(Optional) Do you have any criticisms of this article?