LESSONS ON STRUCTURE FROM THE STRUCTURE OF VIRUSES

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As the most primitive organisms, occupying the gray area between the living and nonliving, viruses are the least complex biological system. One can begin to think about them in a quantitative way, while still being at some level faithful to biochemical processes. We make some observations about their structure, formalizing in mathematical terms some rules-of-construction discovered by Watson and Crick and Caspar and Klug. We call the resulting structures objective structures. It is then seen that objective structures include many of the most important structures studied in science today: carbon nanotubes, the capsids and tails of many viruses, the cilia of some bacteria, DNA octahedra, buckyballs, actin and some microtubules, and certain severely bent and twisted beams. The rules defining them have rigorous quantum mechanical origins. One can also see that many of the simplifications people make about atomic calculations on crystal lattices - periodicity, the Cauchy-Born rule, the quasicontinuum method - have analogs for these more general structures, if only one accounts for the fact that different groups are involved. We develop a methodology for computing such structures. Some of the nonperiodic structures revealed by the formulas exhibit beautifully subtle relations of symmetry. This common mathematical structure paves the way toward many interesting calculations for such structures: the possibility of unusual electromagnetic and other collective properties, phase transformations between them, defects and failure, nonlinear elastic properties, and their growth by self-assembly.

References

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