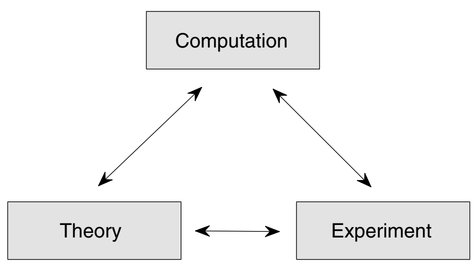
3. *Develop a taste for the random.* Science and engineering is populated with processes that have a random component. Having a sense of probability and the ability to gather and interpret statistics with the computer is vital.

4. *Develop a nose for dimension.* Simulation is much more computationally intensive in three dimensions than in two dimensions—a hard fact of life that is staring many computational scientists right in the face. An accurate impression of how computers assist in the understanding of the physical world requires an appreciation of this point. Moreover, being able to think at the array level is essential for effective, high-performance computing.

5. *Develop a touch for what is finite, inexact, and approximate.* Rounding errors attend floating point arithmetic, computer displays are granular, analytic derivatives are approximated with divided differences, a polynomial is used in lieu of the sine function, and the data acquired in a lab may only be correct to three significant digits. Life in computational science is like this and the practitioner must be resolute enough to face such uncertainties. Steady footwork is required on the balance beam that separates the continuous and the discrete.

While the development of these five senses is an explicit priority, our overarching ambition is to communicate the excitement of computing together with an appreciation for its constraints and its connections to other methodologies. The interplay between computing, theory, and experimentation is particularly important.




Each vertex represents a style of research and provides a window through which we can view science and engineering in the large. The vibrancy of what we see inside the triangle depends upon the ideas that flow around its edges. A good theory couched in the language of mathematics may be realized in the form of a computer program, perhaps just to affirm its correctness. Running the program results in a simulation that may suggest a physical experiment. The experiment in turn may reveal a missed parameter in the underlying mathematical model, and around we go again.

There are also interesting dynamics in the other direction. A physical experiment may be restricted in scope for reasons of budget or safety, so the scene shifts to computer simulation. The act of writing the program to perform the simulation will most likely have a clarifying influence, prompting some new mathematical pursuit. Innovative models are discovered, leading to a modification of the initial set of experiments, and so forth.

In thinking about these critical interactions we are reminded of the great mathematical scientist Richard Hamming, who stated in the 1960s that "the purpose of computing is insight, not numbers." We are in obvious agreement with this point of view. The takeaway

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message from a first programming course should be "Insight Through Computing" instead of just "Output Through Computing." The next generation of computational scientists and engineers needs to think broadly and creatively, and we hope that our book is a contribution in that direction.

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More generally, we are fortunate to have our academic home defined by two of Cornell's great academic units: the College of Engineering and the Faculty of Computing and Information Science. Location is everything if you want to be energized by both colleagues and students. We have the best.

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