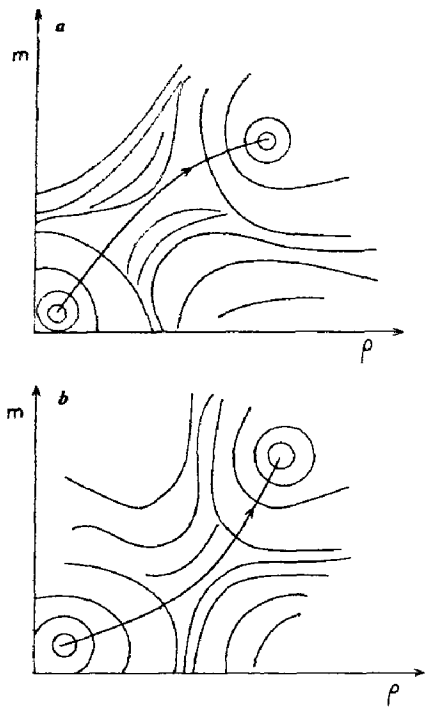

Figure 2. Free energy contour diagrams showing the fluid and the solid minima for the fluid (the circle at the left corner) and the crystalline (circle at the right corner) phases for simple molecules (*a*) and for colloids (*b*). Here ρ denotes the density and m the order of the system. The arrow shows the preferred pathway. For simple systems, the pathway is such that incipient order forms before the density build up occurs while for colloids (and presumably also for proteins), the density build up occurs before the order formation.

Thus, these new studies could at least partly explain the great sensitivity of protein crystallization to the experimental conditions. In the narrow temperature-density range near the critical point, large scale density fluctuations make the association of the proteins relatively easy.

This model of protein crystallization has certain similarities with Dill's model of protein folding where also a critical point was assumed to help the collapse of the coiled protein to the globular state – the proper connections required for the native state takes place later[9]. The same kind of model also appears in the analysis of Bryngelson and Wolynes[10]. All these models are separate applications of a general two-order parameter model. The underlying free energy surface determines the reaction pathway. The possible free energy surfaces are shown in Figure 2. Both in the Dill's model of protein folding and in the ten Wolde–Frenkel model of protein crystallization, the minimum energy pathway lies along the collapse or association direction, leading to first an increase of density which is then followed by the build up of order. This is shown by an arrow in Figure 2 *a*. For simple liquids, the situation seems to be reverse, as shown by the arrow in Figure 2 *b*.

The computer simulation and the density functional theory studies raise as many questions as they answer. Because of the favourable interactions among the hydrophobic patches between different proteins, one expects the association to be highly directional, that is like a polymerization or gelation process. Protein association is also expected to be highly dependent on electrical interactions between proteins. While it certainly helps to think in terms of the free energy surface, it is not clear how important these specific effects in protein crystallization are. In particular, while electrostatic interactions are long-ranged, the hydrophobic interactions are again rather short-ranged.

The analyses of ten Wolde and Frenkel and of Talanquer and Oxtoby are mainly for colloid systems. To what extent they can be extended to understand protein crystallization is not clear yet. The general picture suggested may still be true but for different reasons. As protein association may very well be guided by the hydrophobic patches and as the association itself may very well be the rate-determining stage, it is not surprising that the crystallization of proteins can be different from that of small molecules. In fact, earlier studies[11] had already discussed protein crystallization (such as nucleation and growth of orthorhombic form of hen egg-white lysozyme) as a self-assembly. The work of ten Wolde and Frenkel, however, seems to provide a thermodynamic explanation of the anomalous enhancement of protein crystallization observed in some systems. It may be useful to develop a kinetic version of this model and compare the results with the self-assembly models.

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Progress in interstellar chemistry

A key problem in modern astrophysics is the formation of galaxies. Considerable progress has been made on this problem in recent times, primarily because technological development has vastly enhanced the capabilities of astronomical instruments, giving us a glimpse into hitherto unseen eras in the history of the Universe.

The COBE-DMR mission, and several subsequent experiments, have successfully detected anisotropy in the cosmic microwave background on a range of angular scales; these have been interpreted as views of the extremely small fractional density inhomogeneities at an epoch when

the cosmological expansion scale factor was a thousandth the present value. This spectrum of density perturbations is believed to gravitationally grow to form the galaxies of today. Simulations of the assemblage of matter into galaxies and clusters of galaxies have been fairly successful in evolving initial matter perturbation spectra consistent with the CMB anisotropy observations into galaxies and clusters with abundances and correlation scales consistent with observations of the nearby universe.

However, it is often forgotten that these simulations of the dissipationless dark matter dynamics tell us little about the astrophysics that forms the visible galaxies in the gravitational potential wells. The infall of baryonic matter and its subsequent dissipative collapse or fragmentation involve complex physical mechanisms that are often regulated and sometimes evolve catastrophically through feedbacks. Recent discovery of sub-mm bright galaxies at high redshifts, by SCUBA, and its potential discordance with 'standard' galaxy formation scenarios that have been in vogue for some years now, has served to bring back attention on our lack of understanding of the basic astrophysics in galaxy formation.

The dynamical evolution of a gaseous inhomogeneity, irrespective of whether it is a protogalaxy or an interstellar cloud, is determined by the relative time scales for gravitational collapse and for dissipation. While dissipation is small, the collapse is quasi-static; however, as the gas density rises beyond a threshold and dissipation is sufficiently high, the cloud is no longer quasi-statically supported by gas pressure and, consequently, will catastrophically collapse and hierarchically fragment until some other physics like, for example, opacity within the cloud, comes into play. The crucial astrophysical input required for understanding this process is the heat loss rate. With the exception of the very first protogalactic clouds that had extremely low metallicities, most protostellar clouds predominantly cool via molecular emission. The bottom line is that the cooling rate, and therefore the star formation efficiencies, ought to be determined by the molecular abundances.

To summarize, it has been believed for over a decade that the basic unknown in the astrophysical evolution of cool gaseous clouds is the chain of mechanisms that lead to the formation of stars. Recent observations of the H_3^+ molecule in interstellar space, first by Geballe and Oka[1] and subsequently by McCall *et al.*[2], have perhaps detected the key link in this chain.

Whereas molecular hydrogen forms on the surfaces of grains, it is believed that almost all other trace molecules and radicals, including species like H_2O, CO, OH and CN, are formed by reactions involving H_3^+. In the extremely cold interstellar clouds, cosmic ray ionization is the dominant mechanism that ionizes molecular hydrogen, leading to the formation of H_3^+; however, the cosmic ray flux may be inferred only indirectly. Laboratory measurements of the IR spectrum of H_3^+ were obtained almost two decades ago, but its detection in dense and diffuse clouds and towards the Galactic centre had to await recent improvements in sensitivity and resolution made possible by IR spectrometers using CCD detectors.

Demonstration of the capability of detecting H_3^+ in the interstellar space represents a significant step towards understanding the interstellar chemistry that leads to the formation of the molecules that dominate cooling in the clouds, and hence the formation of stars in cool clouds.

Once again we have a demonstration of how the application of the state-of-the-art has opened new windows and opportunities in our quest for unravelling the mysteries in the Universe.

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OPINION

On recommending students: The curious case of all students being in the top ten per cent

V. Sitaramam

Recommending students for higher studies and research is apparently a simple job of saying a few good things about each student to help them with their careers. There is certainly some merit in that view. That is what we do by and large. What are the minimum statements/data required to justify the recommendations? If the subsequent employers are consumers of our products, how much transparency is required in parceling out our products? Entry–performance–exit triad of institutionalized learning at any level has comparable problems and these are quite inter-linked. Isolationism does not protect us against long-term decay in standards and performance.

The examination fever is on. The grades are being finalized. The CSIR-UGC results, just announced, leave much to be desired. GRE... let us not mention it. For the students, the M Sc is over. What lies ahead? This time, a season for the poetry of recommendations[1], requires reminiscing things that matter to the student, to the teacher, and to the system. Will some order emerge?

In the period between March to June, each one of us sends out a few to a few dozen recommendations[1]. I had the occasion to ask many faculty members at Pune and elsewhere, how they coped with this work. Some universals, nearly axiomatic, emerge: (i) it is our duty to recommend students to wherever they wish to apply; (ii) the choice where the