feel that the comments by T. N. Khoshoo are unfortunate, since these may be used by those taxonomists of our country, who do not like to make use of modern tools in the field of taxonomy.

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T. N. Khoshoo replies:

Speaking in favour of taxonomy should not be construed as being against biotechnology. This is a totally wrong premise. Also, one does not have to recount at length the impact of molecular approaches on taxonomy; these approaches are now routine and known even to college students. However, these are particularly relevant to small taxonomic assemblages. One cannot write entire floras and faunas on the basis of biotech approaches. No country as large as India has such a flora or a fauna. As to experimental taxonomy of cultivated plants, one does not have to go abroad to do this work. In fact, M. S. Swaminathan, T. N. Khoshoo, R. P. Roy and others had flourishing schools in India and the initial papers were written in the 1950s. In an earlier paper (*Curr. Sci.*, 1994, **67**, 577–582), I have specially stressed the importance of upstream biotechnology for India together with its underlying scientific, technological, economic and even political implications. The paper was received well both in India and abroad. It became clear that biotechnology is critical for India's bioindustrial development. Both these papers were written after a thorough review of the biotechnological scene in the country. It revealed that there are only a few centres doing upstream biotechnology; the rest are involved in routine and repetitive work. The former is likely to lead to academic and/or commercial products, but one is not sure about the latter. The members of some Task Forces of the Department of Biotechnology, Scientific Advisory Committee-DBT and DBT-SAC-Overseas have often expressed concern about the state of India's taxonomy and urged that the same be strengthened particularly in the case of microorganisms (see also *Curr. Sci.*, 1995, **69**, 968–969).

Lastly, once in a while, self-introspection is necessary and one should be courageous to face facts. Excellence cannot remain hidden because such work stands out by itself, while mediocrity has to advertise and cry hoarse to be recognized.

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RESEARCH NEWS

Auto-catalysis as the possible origin of biomolecular chirality

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Existence presupposes origin! The mystery of the origin of optical activity is the chemist's formulation of this philosophical dictum. Chemists (perhaps unlike physicists), however, do not take easily to philosophy, and are content to chisel away at practical problems of direct relevance to human concerns. And even when, on the odd occasion, chemical problems take on a philosophical colouring, the chemist remains ingeniously practical. A recent example is discussed further below, but first some background.

All biomolecules are homochiral, i.e. of two possible mirror image forms (enantiomers), only one is consistently found to occur. The phenomenon flouts statistical common sense, which dictates that both forms be found in equal amounts. But such 'anti-Boltzmann' behaviour is redeemable if there is an appropriate input of free energy in the synthesis of these biomolecules. Enter the practical organic chemist. It has, of course, long been known that molecules can be produced largely in one enantiomeric form in a chemically chiral ('one handed') environment, such 'asymmetric synthesis' being quite efficient if one of a pair of reacting molecules is chiral. In fact, when the chiral partner is a catalyst, the arrangement is considered as perfect as can be.

The 'chicken-egg' situation is now apparent. Biomolecules can, of course, be produced using chiral catalysts, but where would these latter species come from? (This is the molecular incarnation of an ancient philosophical scourge.) There is a fascinating collection of impressive theories, but two broad categories may be discerned – determinate and chance (!). The determinate ones essentially shift chiral responsibility to a non-chemical agency, listing: polarized light, electric, magnetic and gravitational fields, α and β rays, and parity violating weak interactions[1–3]. The chance theories, too, commandeer concepts of noble lineage, and usually invoke small local perturbations of the global chiral symmetry, which are subsequently amplified (irreversibility, non-equilibrium thermodynamics)[1–3].

Interestingly, there is a point of convergence for the determinate and chance theories (chemistry demarcated from philosophy). Expectedly, the two theories have their strengths and weaknesses, and the *via media* combines the virtues of the two. Determinate processes are rather inefficient and produce

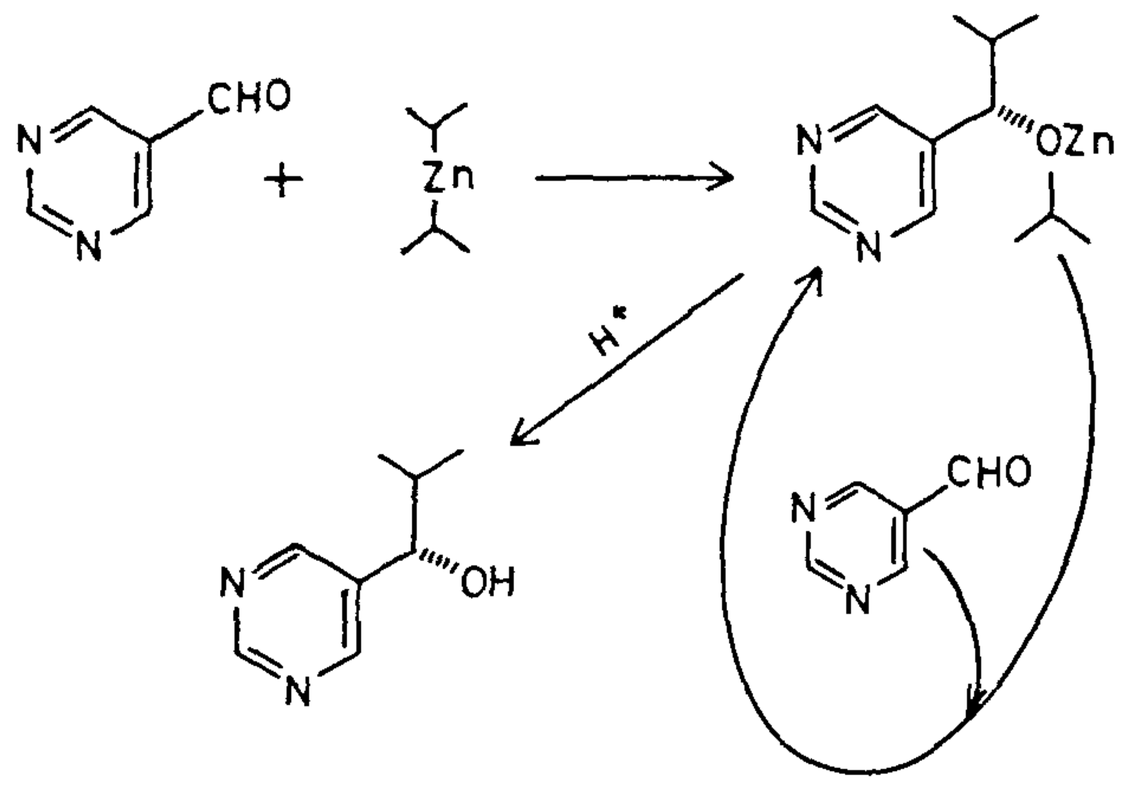

Figure 1. Asymmetric autocatalytic addition of diisopropylzinc to pyrimidine-5-carboxaldehyde (top left) to yield finally 2-methyl-1-(5-pyrimidyl)-propan-1-ol (bottom left). The closed loop involving the intermediate organozinc compound (top right) is the autocatalytic step.

only marginal levels of chirality, but are predictable and reproducible. The chance processes, although unpredictable and inefficient, incorporate excellent amplification strategies.

An amplification process at once immensely fascinating and efficient is 'autocatalysis'. In this eerie chemical phenomenon, the product of a reaction catalyses its own further production (molecules taking the first pretentious steps towards life, although not quite 'self-replicating'). Chiral autocatalysis is the obvious next step. But the simplicity of this conceptual juxtaposition can be misleading. The efficiency of chiral catalysis increases with increasing chiral purity of the catalyst, which, in autocatalysis, is itself continuously increasing during the reaction, a consequence of the 'self-feeding' nature of the process. 'Selectivity' is the critical element in modern organic chemistry and, because the enantioselectivity of each step is amplified, high selectivity is the quintessence of chiral autocatalysis. More of all this later, but one last point to set the scene. If it is possible not only to catalyse the required process but also to inhibit the unwanted one, we have the epitome of catalytic efficiency, at least on paper.

In chemistry (unlike in philosophy), setting the scene only brings up the half-way stage at best, with experimental design and execution yet to come. Japanese scientists elegantly deliver the latter part in a recent paper[4]. They have studied the addition of diisopropylzinc to pyrimidine-5-carboxaldehyde, in the presence of catalytic amounts of enantiomerically enriched product 2-methyl-1-(5-pyrimidyl)-propan-1-ol, the reaction being autocatalytic (Figure 1). They find impressive levels of chiral induction, even when the initial enantiomeric purity of catalyst is ridiculously low. The following are a typical set of values for the % e.e. of catalyst taken (x), the factor by which the enantiomer in excess has been increased relative to 'x' (y), and the % e.e. of newly formed final product (z) ('e.e.' is 'enantiomeric excess', a measure of the efficiency of chiral induction; 'x', 'y' and 'z' are in that order): 2, 2.5, 16; 10, 13, 74; 57, 61, 89; 81, 239, 90; 88, 942, 88. Among the trends: the absolute level of chiral induction in the final product ('z') is directly proportional to the initial chiral purity of catalyst ('x'), but the dependence is greater at lower values of 'x'. Thus, the overall dependence is logarithmic, as is to be expected (the % e.e. cannot exceed 100). The sharp decrease in linearity occurs around 'x' = 15. Note also, most importantly, that the above set of values was obtained from an initially low value of catalyst purity (2% e.e.), and by repeating the catalytic process after each run. In each run, the catalyst was used at a 20% molar ratio relative to reactants. An inhibitory process may well occur in parallel, but has not been proved.

This work does not solve the mystery of bio-chirality, but it is certainly an experimental verification of theoretical models proposed[5] to explain the mystery. Nor is it unprecedented, as the long list of references shows (relevant ones cited below)[5–8]. Particularly mentionworthy as a rival phenomenon is the spontaneous generation of chirality, for long a favourite explanation for the origin of bio-chirality. It is usually a crystallization-driven process[1], its attractive feature being the total absence of external chiral influence. However, it rarely delivers worthwhile e.e.'s, provides no control on the enantiomer obtained, and is generally of low practical utility. In contrast, strategies based on the amplification of small initial chiralities offer much to the practising chemist, and some food for thought to the philosophically inclined.

The problem of the origin of bio-chirality is intimately connected with that of the origin of life itself[1–3,9], and thus defines one of the ultimate frontiers of science. This reviewer cannot resist the temptation to relate an incident which occurred during a conference in the US a few years back, not least because it conveys the ambience of intellectual *hauteur* pervading this exciting field of human enquiry. Being seated next to one of the founders of the field, he engaged the eminence in scientific discussion and, perhaps impetuously, enquired whether the problem of the origin of life would ever be solved. The answer: the problem of the origin of life has been solved, what only remains is that of the origin of mind.

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