

of the alarm it caused. Forecasters were, however, instructed to predict 'severe local storms'. From 1938, however, the word 'tornado' has been permitted, and a strenuous effort has been made to specify more exactly the meteorological conditions favourable for the formation of tornadoes. The latest stage was the setting up by the United States Weather Bureau in 1952 of a research unit called the Severe Local Storms Centre, which formed at Washington and moved to Kansas City, in the heart of tornado country, in 1954.

The booklet under review is the first publication of the Centre. The climatology of tornadoes in time and space is described in some detail. Next are given the favourable air mass types in terms of the vertical distributions of temperature and water vapour. These are all naturally unstable in one way or another. The most important type of air mass is one with convective instability in which condensation begins at the bottom if the air mass is lifted. Once condensation has begun in the lower part, the upper part cools on lifting at the dry adiabatic rate compared with the smaller saturated adiabatic rate of the lower part so that the degree of instability quickly increases. Tornadoes are nearly always associated with thunderstorms and with the south-east sector of a depression. They seem to be associated with definite centres of low pressure and do not occur in sporadic 'air mass' or 'heat' thunderstorms. The instability has to be released by vertical ascent and the variations of wind speed with height favourable for convergence and vertical movement have been studied at the Centre. The forecast is formulated from consideration of the advection of heat and water vapour to produce a suitable vertical distribution and of the suitability of the wind structure for convergence. It is stated that in the first seven months of 1955, 1 in 3 of all areas for which tornadoes were forecast, each area averaging 20,000 sq. miles, contained at least one tornado during the period of the forecast. For so exceptional a phenomenon this seems a very useful proportion.

No mention whatever is made in the booklet of how a tornado actually forms; everything is devoted to determining the likelihood of convective overturning. This is certainly necessary, but is it sufficient? Lamb (Meteorological Office Geophysical Memoir 99, in the press) has suggested that surface features producing opposing winds are source points for tornadoes. The distribution of formation points of tornadoes might be worth examining for points of concentration.

MINERAL NUTRITION AND AMINO-ACIDS IN TOMATO

THE level and the quantitative composition of the free amino-acid fraction of tomato plants grown in full nutrient and in cultures deficient in zinc, copper, manganese, iron and molybdenum have been determined by J. V. Possingham (*Austral. J. Biol. Sci.*, 9, 539; 1956).

The methods used in the investigation include the quantitative estimation of amino-acids by a technique involving paper chromatography, and the culture of tomato plants in highly purified nutrient solutions. All the deficiencies investigated except that of molybdenum brought about increases in the free amino-acid fraction. In every case there was a

change in the quantitative composition of this fraction. Iron and zinc deficiencies were associated with large increases in the free levels of the two amides asparagine and glutamine, while with copper and manganese deficiencies many individual amino-acids increased in concentration, but not the two amides. The level of total free amino-acids and amides was low in molybdenum-deficient plants. The qualitative differences between deficient- and full-culture plants were not large, but included the accumulation of β -alanine with deficiency of zinc, copper or molybdenum, and of pipercolinic acid with deficiency of manganese or iron. Other differences were the absence of histidine with copper, manganese, iron and molybdenum deficiency, of phenylalanine with copper deficiency, and of lysine with copper, manganese and molybdenum deficiencies. Additionally many quantitative changes in amino-acid concentration were found. In the deficient plants there were changes in the concentration of most amino-acids relative to the levels in the controls. These changes were not uniform, and the relative amounts of the different amino-acids were altered with each deficiency.

The significance of these experimental results is discussed in relation to the known interactions between the mineral nutrition and the amino-acid composition of plants. Although a characteristic spectrum of free amino-acids is associated with each individual deficiency, the differences are not considered sufficiently large to make analysis for these compounds an additional method for the diagnosis of mineral deficiencies in this plant.

'L FORMS' OF BACTERIA

THE members of the "Réunion sur les Formes L et sur les formes évolutives des bactéries", held in Lausanne during May 17-18, 1956, have issued the following statement:

(1) Numerous cycles of different bacteria have been described under different names—L forms, filtrable invisible forms, evolution forms, etc. Often enough, all these bacterial forms have been described under the name of 'L cycle'. At the present state of our knowledge, it seems preferable to use different designations, in order to describe phenomena and appearances which are perhaps not the same.

(2) E. Klieneberger-Nobel has used in all her papers published in English the expression 'L forms' in order to designate bacterial colonies of new appearance which occur *in vitro* spontaneously or by stimulation. It seems, however, that the English word 'form' has been interpreted incorrectly by a number of microbiologists using Latin languages. They have used this expression for the 'individual morphology of bacterial elements'. This incorrect interpretation manifests itself to-day when in the written or spoken language the following expressions are used: 'formes L naines', 'formes L globuleuses', etc. (Klieneberger-Nobel herself has occasionally made a similar mistake by using the expression 'L elements'.) E. Klieneberger-Nobel rejects completely the translation of the English 'form' into the French 'forme' and desires that it should be translated by the French word 'formation' and in German by 'Phase'. She is of opinion that one should designate as 'formation L' (L = Lister), 'L form', 'L Phase', the growth-form which can arise spontaneously or

by stimulation and is characterized by a colony of special appearance showing a dense centre and lighter periphery on media not containing stimulating substances. The micro-organisms composing this L form must not assume the morphology of the parent culture.

(3) So long as the mechanism of this development and the structure of the elements of the L form are not completely elucidated we must avoid designating the pleomorphic bacteria, the globular forms, the granulations and the filterable forms, etc., by the term 'L form'. These forms must keep their proper designations such as pleomorphic bacteria, globular forms, filterable forms, etc., in order to avoid confusion.

(4) P. Hauduroy has designated 'formes filtrantes et invisibles des bactéries' elements which he obtained

by means of bacteriophage action and which he also discovered in certain natural and pathological products. These elements reproduce the original bacteria when subcultured according to a special technique. Therefore, they are not stable forms but are stages probably of a developmental cycle.

Finally, it should be pointed out that differences exist between the PPLO (pleuropneumonia-like organisms) and L forms as they have been defined above, and at the present moment there is no point in mixing up what seems to represent two types of organisms. The terms which are liable to cause confusion should be avoided.

The members at the meeting were Dr. J. Basser-mann, Prof. L. Carrère, Prof. R. Fasquelle, Prof. P. Hauduroy, Mme. E. Klieneberger-Nobel, Prof. G. Penso, Prof. J. Roux and Dr. Z. M. Tunçman.

STEREOCHEMISTRY OF CUPRIC COMPOUNDS

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THE stereochemistry of cupric compounds is unusual in that a regular octahedral environment of the cupric ion rarely, if ever, occurs. Three types of environment are encountered: (1) distorted octahedral with four short and two long bonds; (2) square coplanar; (3) tetrahedral. The tetrahedral compounds are few in number. They have been discussed recently by Felsenfeld¹ and will not be mentioned further here. Types (1) and (2) comprise the vast majority of cupric compounds and, since the planar compounds can be regarded as a limiting case of (1) with two ligands removed completely, they can be considered together as a single class. Some examples of distorted octahedral coordination are presented in Table 1.

According to Pauling's valence-bond theory of metal complexes², the planar compounds involve dsp^2 hybridization of the orbitals on the cupric ion. Since only four $3d$ -orbitals are left available for occupancy by nine electrons, the extra electron is regarded as occupying the $4p_z$ -orbital. Pauling did not discuss the distorted octahedral compounds, but

Wells³ suggests that the odd $4p$ electron may be responsible for the two additional weak bonds. The presence of an unpaired $4p$ -electron is, however, incompatible with recent evidence from paramagnetic resonance⁴ and optical studies^{5,6}, and is in any event difficult to reconcile with the marked resistance of cupric copper to further oxidation. Alternative suggestions, that they are derived from $4s4p^34d^3$ hybridization, or that they are simple ionic complexes, do not explain the marked deviations from octahedral symmetry.

A different theory has been outlined by one of us⁷, wherein all cupric compounds are regarded as retaining their full complement of nine $3d$ -electrons. The unusual stereochemical effects are related to the distortions discussed by Jahn and Teller⁸. It will not be necessary to discuss their rather abstract presentation here, since the relevant issues can be dealt with in a fairly simple fashion. We give below an elementary account of this theory and apply it both to the published data and to some new experimental evidence.

The physical basis of the theory is explained as follows. In an octahedral field the set of d -orbitals is split into two groups, a lower triplet t_{2g} , and an upper doublet e_g (Fig. 1). The e_g -orbitals are the $d_{x^2-y^2}$ and d_{z^2} -orbitals, the former pointing towards the ligands in the xy -plane and the latter towards those along the z -axis. The t_{2g} -orbitals are d_{xy} , d_{xz} and d_{yz} , which have a high density between the lines joining the central ion to the ligands. The splitting arises from the tendency of the metal electrons to avoid those regions where the field due to the attached ligands is greatest and hence to concentrate in regions where this field is least. For the cupric ion in an octahedral field, the lower triplet of orbitals is completely filled and the remaining three electrons must be placed in the upper doublet either as $(3d_z^2)^2(3d_{x^2-y^2})^1$ or as $(3d_{x^2})^1(3d_{y^2})^2$. The cupric ion in a regular octahedral field thus has an orbitally degenerate electronic ground state. Now Jahn and Teller have shown⁸ that if the electronic state of a non-

Table 1. INTERATOMIC DISTANCES IN SOME CUPRIC COMPOUNDS

| Crystal | Distances to nearest neighbours (in Å.) | Ref. |
|--|--|--------------|
| Copper oxide | 4O at 1.95 | (a) |
| $\text{Cu}_2(\text{OH})_2\text{CO}_3$ (malachite) | 4O(OH) at 1.98, 2O at 2.71 4O(OH) at 2.01, 2OH at 2.41 | (b) |
| Cu bis-dimethylglyoxime | 4N at 1.92 | (c) |
| Copper chloride | 4Cl at 2.30, 2Cl at 2.95 | (16) |
| Copper bromide | 4Br at 2.40, 2Br at 3.18 | (d) |
| CsCuCl_4 | 4Cl at 2.30, 2Cl at 2.65 | (18) |
| Copper chloride.2H ₂ O | 2H ₂ O at 2.01, 2Cl at 2.31, 2Cl at 2.98 2H ₂ O at 2.01, 2Cl at 2.26, 2Cl at 2.92 | (12) (13) |
| $\text{K}_2\text{CuCl}_4 \cdot 2\text{H}_2\text{O}$ | 2H ₂ O at 1.97, 2Cl at 2.32, 2Cl at 2.95 | (17) |
| Copper acetate.H ₂ O | 4O at 1.97, H ₂ O at 2.20, Cu at 2.64 | (e) |
| Copper formate.4H ₂ O | 4O at 2.00, 2H ₂ O at 2.36 | (f) |
| Copper proline.2H ₂ O | 2N at 1.99, 2O at 2.03, 2H ₂ O at 2.52 | (g) |
| $\text{CuCl}_2 \cdot 2\text{-pyridine}$ | 2N at 2.02, 2Cl at 2.23, 2Cl at 3.05 | (14) |

Numbered references are mentioned in the text. Lettered references are:

- (a) Tunell, G., Posnjak, E., and Ksanda, C. J., *Z. Krist.*, **90**, 120 (1935).
 (b) Wells, A. F., *Acta Cryst.*, **4**, 200 (1951).
 (c) Bezzl, S., Bua, E., and Schiavinato, G., *Gazzetta*, **81**, 856 (1951).
 (d) Helmholtz, L., *J. Amer. Chem. Soc.*, **69**, 886 (1947).
 (e) Van Niekerk, J. N., and Schoening, F. R. L., *Acta Cryst.*, **6**, 227 (1953).
 (f) Kiriyama, R., Ibamoto, H., and Matsuo, K., *Acta Cryst.*, **7**, 482 (1954).
 (g) Mathieson, A. McL., and Welsh, H. K., *Acta Cryst.*, **5**, 599 (1952).