30 included Price (*8*), PR-17 (*9*), and probably Giles (*10*).

Strains related to Caldwell (*11*) include the Copenhagen 4331-s strain (*12*) and the California strains (*13*).

Rhinovirus types	*Prototype strain*
(numbers to be assigned)	353 (*14*)
	1059 (*14*)
	1734 (*14*)
	11757 (*14*)
	33342 (*14*)

These new viruses were isolated by the investigators cited, who showed that each fulfilled all the criteria of a human picornavirus (*1, 3, 4*) but that it was distinct antigenically from all previously known types. As indicated, four of the prototype viruses (and related strains presently known) had the properties of echoviruses and five had those of rhinoviruses.

Primary reference antisera for the first 59 enteroviruses, including echovirus 29, are now or will soon be available to qualified research laboratories in small quantities for reference purposes. Specific announcement regarding the availability of these sera will be made by the National Institutes of Health in the very near future.

Panel for Picornaviruses:
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29 April 1963

Uranyl Ion Coordination

Abstract. *A review of the known crystal structures containing the uranyl ion shows that plane-pentagon coordination is equally as prevalent as plane-square or plane-hexagon. It is suggested that puckered-hexagon configurations of* OH^- *or* H_2O *about the uranyl group will tend to revert to plane-pentagon coordination. The concept of pentagonal coordination is invoked for possible explanations of the complex crystallography of the natural uranyl hydroxides and the unusual behavior of polynuclear ions in hydrolyzed uranyl solutions.*

In almost all compounds of hexavalent uranium the presence of the discrete molecular group UO_2 is recognized; this group is linear and has a formal charge of +2. The coordination of this linear group with other oxygen or fluorine atoms was, until recently, said to be generally either fourfold (as in the autunite structures) or sixfold (as in $NaUO_2Ac_3$) about the equator, as cited in most inorganic chemistry texts. Newer crystal-structure evidence indicates that fivefold coordination of UO_2^{+2} is also possible, and, in fact, may be the most common. It seems profitable now to summarize the structural evidence on uranyl coordination and estimate its bearing on certain, as yet unsolved, structure problems.

The classic work of Beintema (*1*) showing the occurrence of square configuration of oxygen around UO_2^{+2} in autunite, $Ca(UO_2PO_4)_2 \cdot nH_2O$, has now been confirmed in detail by precise crystal-structure analyses of the closely related abernathyite, $KUO_2AsO_4 \cdot 3H_2O$ (*2*), and metatorbernite $Cu(UO_2PO_4)_2 \cdot 8H_2O$ (*3*). The early study of the crystal structure of sodium uranyl acetate by Fankuchen (*4*) has been fully confirmed and refined by Zachariasen (*5*), showing an example of sixfold coordination. The first structure showing fivefold coordination with fluorine atoms was that of $K_3UO_2F_5$ (*6*), and with oxygen atoms, uranophane, $Ca(H_3O)_2(UO_2)_2(SiO_4)_2 \cdot 3H_2O$ (*7*). All of the well-established structure types are classified according to coordination in Table 1.

The fivefold coordination common for the uranyl ion is close to a flat pentagon in all the determined structures. The best measurements of the uranium-oxygen distances in the pentagon have been made in a recent refinement in this laboratory (*8*) of the crystal structure of cesium divanadatouranylate, $Cs_2(UO_2)_2V_2O_8$ (Fig. 1), an anhydrous structural analogue of the mineral carnotite, $K_2(UO_2)_2V_2O_8 \cdot 3H_2O$. The U-O distances in the pentagon are 2.28, 2.37, 2.30, 2.24, and 2.40 Å (all ± 0.03 Å) with an average of 2.32 Å. Deviations of the oxygen atoms from a plane perpendicular to the uranyl axis are not significant within the error of the determination (± 0.05 Å). A regular pentagon with a circumscribed radius of 2.32 Å has sides of 2.73 Å, which is a reasonable interatomic distance for two oxygen atoms that are moderately strongly attracted to the central uranium atom. The pentagonal coordination is, therefore, geometrically quite stable.

The uranium-oxygen distance in the flat hexagon coordination is 2.50 Å ($NaUO_2Ac_3$) and the corresponding hexagon edge is also 2.50 Å. This distance is considerably shorter than the usual oxygen-oxygen approach and might be expected to result in a displacement of the oxygen atoms from the equatorial plane. The several structures with the flat hexagon arrangement all have bidentate anion groups in which two oxygen atoms from one group forming one hexagon edge are already drawn very close together by the strong polarizing effect of the anion nucleus. Such short oxygen-oxygen distances are present in CO_3^{-2} (2.25 Å), in NO_3^- (2.10 Å), and in Ac^- (CH_3COO^-) (2.21 Å). A hexagon with threefold symmetry in which alternating edges are 2.2 Å will have the other three edges of length about 2.7 Å (circumscribed radius 2.50 Å). Thus, such groups will fit comfortably in a hexagonal plane about the uranyl group at the proper distance. When the oxygen atoms are not compressed as in an anionic group, they are forced out of the plane to form a "puckered" configuration, a situation found in all three examples of this type known. The fact that in complexes such as $UO_2Ac_3^-$ and $UO_2(CO_3)_3^{-4}$, where there are no significant external influences to prevent the complex from taking the most stable configuration with respect to the secondary uranyl bonding forces, the ligands lie strictly in the equatorial plane, strongly indicates that these secondary bonding forces will be weakened if they are forced out of this plane by steric conditions. Such weakening may result from the reduced overlap of ligand orbitals with (presumably) equatorial uranyl orbitals, and also merely from the proximity of the polar uranyl oxygen atoms.

Nine years ago, Zachariasen (*9*) reviewed the crystal chemistry of the uranyl ion, and illustrated the four types of coordination given in Table 1. At that time, pentagonal coordination was known only in one example, $K_3UO_2F_5$ (*6*). Zachariasen considered the hexagonal coordination to be preferred by the uranyl ion, and square and pentagonal configurations to be rare and unusual. Table 1 shows that plane 4-, 5- and 6-coordinations are equally prevalent, but that the puckered hexagonal arrangement is relatively uncommon. I believe that pentagonal coordination plays an important role in some situations where, heretofore, only hexagonal coordination has been considered.

Five general conclusions may be drawn from a study of the known structures. (i) The uranyl group will coordinate 4, 5, or 6 oxygen atoms about its equator, with a strong tendency to make these atoms coplanar. (ii) Fourfold and fivefold coordinations are geometrically stable, allowing oxygen atoms to approach at an optimum distance in a plane without overcrowding. (iii) Stable sixfold coordination can occur when the oxygen atoms are donated by highly polarized bidentate anionic groups which can draw them very close together. (iv) When isolated oxygen atoms (or hydroxyl groups) are brought into six-coordination with uranyl, they are forced out of the equatorial plane in a puckered configuration, thus tending to reduce the stability of the structure. (v) Bridges between two uranyl groups can be formed by one or two hydroxyl groups, fluoride or oxide ions, but not water molecules. Two or three uranyl groups (but not more) may be linked by one bridging atom.

Table 1. Crystal structure types containing uranyl groups in varying coordination.

Formula
Square, plane
$Ca(UO_2)_2(PO_4)_2 \cdot nH_2O$ (*1*)
$KUO_2AsO_4 \cdot 3H_2O$ (*2*)
$Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$ (*3*)
$MgUO_4$ (*25*)
β-$UO_2(OH)_2$ (*13*)
$BaUO_4$ (*26*)
Pentagon, plane
$K_3UO_2F_5$ (*6*)
$Ca(H_3O)_2(UO_2)_2(SiO_4)_2 \cdot 3H_2O$ (*7*)
$Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$ (*27*)
$Cs_2(UO_2)_2(SO_4)_3$ (*28*)
$Cs_2(UO_2)_2V_2O_8$ (*29*)
U_3O_8 (*8*)
Hexagon, plane
$NaUO_2Ac_3$ (*5*)
UO_2CO_3 (*30*)
$RbUO_2(NO_3)_3$ (*31*)
$UO_2(NO_3)_2(H_2O)_2 \cdot 4H_2O$ (*32*)
$UO_2(NO_3)_2(Et_3PO_4)_2$ (*33*)
$Ca_2UO_2(CO_3)_3 \cdot 10H_2O$ (*34*)
$NaK_3UO_2(CO_3)_3$ (*35*)
Hexagon, puckered
α-UO_3 (*36*)
α-$UO_2(OH)_2$ (*14*)
$CaUO_4$ (*37*)

The compound $UO_2(OH)_2$ exists in several forms (*10, 11, 12*), two of which have been subjected to crystal-structure analysis. The β-form (*13*) has the hydroxyl groups arranged in nearly square rectangles about the uranyl groups. Each OH^- ion is shared between two UO_2^{+2} groups forming a fairly open sheet structure (Fig. 2). The α-form (*14*) is a more compact sheet arrangement in which each OH^- ion is shared by three UO_2^{+2} groups to form a hexagonal net, and the UO_2^{+2} group is surrounded by a puckered hexagon of 6 OH^- ions (Fig. 3). The orthorhombic II phase [β-$UO_2(OH)_2$] (*11*) has been shown (*12*) to be stable between 210° and 290°C (approximately), although Bergström and Lundgren (*13*) state that they obtained their crystals by hydrolysis of uranyl acetate in a sealed tube at 105° to 110°C. Zachariasen's orthorhombic $UO_3 \cdot H_2O$ (*10*) has been associated crystallographically by Bergström (*14*) with "α-$UO_2(OH)_2$" and by Dawson *et al.* (*11*) with their orthorhombic I phase, $UO_3 \cdot O \cdot 8H_2O$. According to Lundgren (personal communication), the simple α form is obtained only above 120°C; below this temperature a mixture of complex $UO_2(OH)_2$ phases is produced.

This behavior suggests a relationship with the natural uranium oxide hydrates, which are known in a bewildering variety. They have a very complex crystallography recently fully described by Christ and Clark (*15*), and include becquerelite, billietite, fourmarierite, masuyite, schoepite (phases I, II, and III) and vandendriesscheite (phases I and II). All have compositions approximating $UO_2(OH)_2 \cdot nH_2O$, but some contain small amounts of Ca, Ba or Pb. All have very large crystal unit cells, containing from 12 to 432 uranium atoms. Christ and Clark clearly demonstrate the pseudohexagonal nature of all these crystals, which is quite remi-

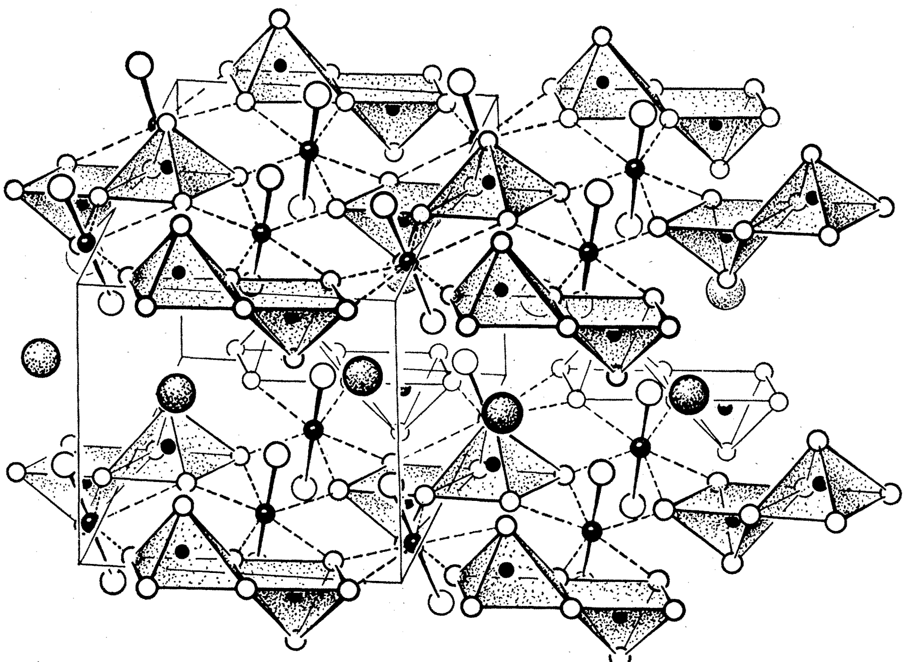

Fig. 1. The crystal structure of $Cs_2(UO_2)_2V_2O_8$, showing layers built of divanadate groups with vanadium in square pyramid coordination, joined to uranyl groups in pentagonal coordination (dashed lines).

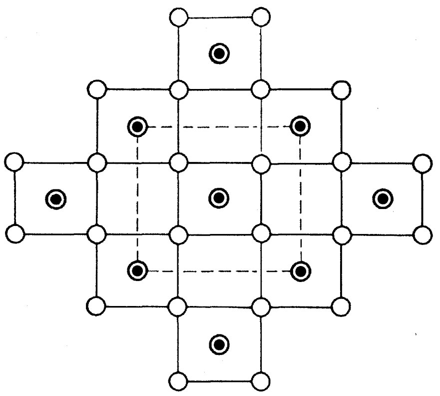

Fig. 2. The sheet structure of β-$UO_2(OH)_2$ (*13*), showing square coordination. Double filled circles are linear UO_2^{+2} groups in end view, open circles are OH^- groups. Dashed lines outline the orthorhombic unit cell.

niscent of the simple structure for α-$UO_2(OH)_2$, and they predict a similar puckered sixfold coordination of OH^- with UO_2^{+2} for the complex structures.

The principles of coordination stated suggest another explanation. If the puckered hexagon coordination is relatively unstable, there will be a strong tendency for the hexagonal units in the α-$UO_2(OH)_2$ sheet to revert in some way to pentagonal units. For example, if a pair of OH^- ions between two UO_2^{+2} groups is replaced by a single O^{-2} ion (dotted circle in Fig. 3), the adjacent UO_2^{+2} groups both become five-coordinated. The problem then arises of finding a suitable arrangement of pentagons which can satisfy a crystallographic symmetry group. The well-known incompatibility of fivefold symmetry axes with crystallographic lattice translations implies that a considerable amount of complication and adjustment will be necessary to preserve the layer fabric while incorporating pentagonal units. I have felt for some time that the complex crystallography of uranium oxide hydrates results not so much, as might be supposed, from the interlayer atomic arrangements, but rather from readjustments within the uranyl hydroxide layer itself to accommodate pentagonal $(UO_2)O_5$ units in crystallographic order.

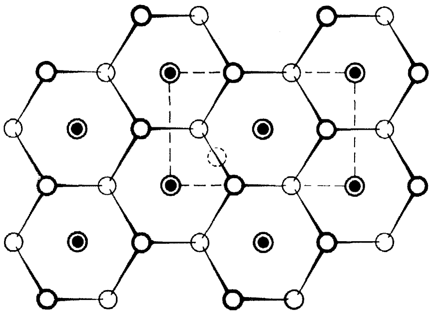

Fig. 3. The sheet structure of α-$UO_2(OH)_2$ (*22*). The puckering of the hexagonal OH^- layer is shown by the light and dark circles.

Clark and Christ of this laboratory as long ago as 1956 established by Fourier methods the exact locations of the uranium atoms in the simplest of these mineral compounds, billietite. Their results have just been confirmed by Protas and Rérat (*16*), who also found the uranium locations in becquerelite.

As predicted by Christ and Clark, the uranium atoms lie near the nodes of a regular hexagonal net, but the deviations are appreciable and highly significant. The uranium-uranium distances, which in the regular net are all 4.1 Å, are now divided into two groups, one between 3.75 and 4.05 Å and the other 4.54 to 4.69 Å (the latter shown by dotted lines in Fig. 4). Although no reliable x-ray evidence has yet been obtained to establish the oxygen positions, an oxygen arrangement is easily postulated (Fig. 4) by placing some near the centers of uranium triangles bounded by the short distances (as in the regular structure) and others near the centers of the lines corresponding to the long distances. In this way, in a rectangular repeat unit which contains six uranium atoms, ten oxygen atoms are placed producing an elegant pattern of pentagons which conforms neatly with the space group symmetry (*Pnmn* for billietite, *Pnma* for becquerelite). Also, the pentagons are nearly plane and the uranium-oxygen distances are all about 2.35 to 2.40 Å.

Such a rearrangement requires a revision of the chemical formula. The change from the α-$UO_2(OH)_2$ sheet to the billietite sheet may be represented by the reaction $6UO_2(OH)_2 \rightarrow (UO_2)_6O_2(OH)_8 + 2H_2O$, indicating a new sheet structure which is still uncharged. The relation between O^{-2} and OH^- ions in the billietite and becquerelite structures is not definite as far as the structure is known now, and the sheet could as well be formulated as $(UO_2)_6O_4(OH)_6^{-2}$ or $(UO_2)_6O_6(OH)_4^{-4}$. To account for the cations in billietite and becquerelite, their formulas may be written as $Ba[(UO_2)_6O_4(OH)_6]\cdot 8H_2O$ and $Ca[(UO_2)_6O_4(OH)_6]\cdot 8H_2O$, respectively.

In summary, it is suggested that the compound $UO_2(OH)_2$ can assume a simple hexagonal layer structure (α-form, Fig. 3) at intermediate temperatures where greater thermal motion may permit higher coordination, but at lower temperatures a structural arrangement based on pentagonal coordination becomes more stable. Confirmation of this proposal will, of course, require a full three-dimensional crystal-structure analysis in order to

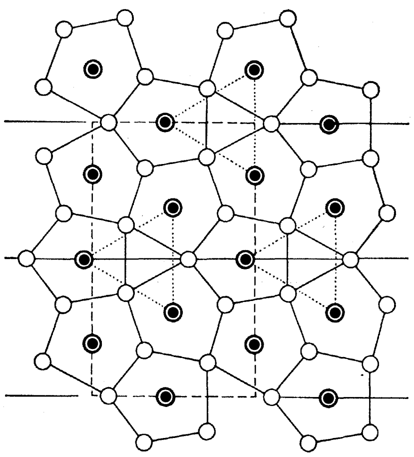

Fig. 4. The proposed sheet structure of billietite and becquerelite based on uranium positions (*16*) and pentagonal coordination. Horizontal lines are mirror planes; dashed lines outline the orthorhombic unit cell of billietite.

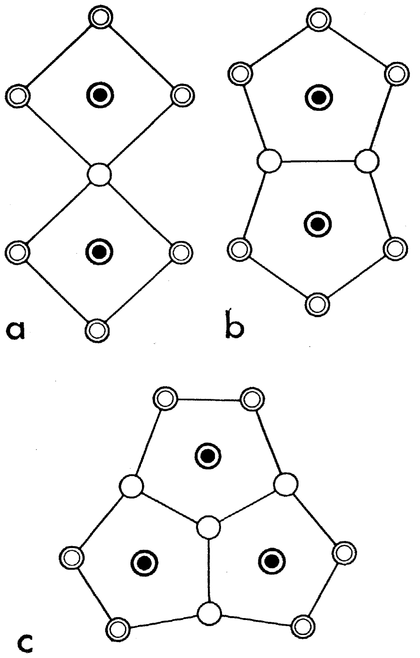

Fig. 5. Proposed structures for polynuclear complexes in hydrolyzed solutions of uranyl ion based on square and pentagonal coordination. Single open circles are OH^- groups, double open circles are H_2O molecules. The complexes are: (*a*) $(UO_2)_2OH(H_2O)_6^{+3}$; (*b*) $(UO_2)_2(OH)_2(H_2O)_6^{+2}$; and (*c*) $(UO_2)_3(OH)_4(H_2O)_6^{+2}$.

resolve the oxygen atoms clearly in the presence of the heavy uranium x-ray scatterers.

The relation of these coordination principles to the nature of the hydrolysis products of uranyl ion in solution is interesting. Ahrland, Hietanen and Sillén (*17*) applied modern electromotive titrations to uranyl solutions to determine the polynuclear species in the solution and their ionic charges. Their data could be explained fairly well by the step-wise formation of a series of complexes of general formula $UO_2[UO_2(OH)_2]_n^{+2}$. They devised a structural hypothesis for the formation of these polynuclear complexes on the basis of the crystal structure work on α-$UO_2(OH)_2$ (*13*). According to this view, hexagonal $UO_2(H_2O)_6^{+2}$ groups add $UO_2(OH)_2(H_2O)_4$ "links" by replacing two H_2O ligands in the mononuclear "core" with the two bridging $(OH)^-$ groups, building up at each step a larger segment of the hexagonal sheet structure of α-$UO_2(OH)_2$ (for which *n* in the general formula would be infinite). It was suggested, in accord with Sillén's core-links hypothesis (*18*), that each link could be added with equal ease, and the equilibrium constants for the reactions

$$UO_2[UO_2(OH)_2]_n^{+2} + UO_2(OH)_2 \rightarrow UO_2[UO_2(OH)_2]_{n+1}^{+2}$$

would be the same for all values of *n*. More refined measurements (*19*) show that the three species $(UO_2)_2(OH)^{+3}$, $(UO_2)_2(OH)_2^{+2}$, and $(UO_2)_3(OH)_4^{+2}$ predominate in the solution, and that higher complexes, if present, occur only in very small amounts. This result is not expected from the earlier structural hypothesis, but can be more easily understood if one does not assume hexagonal coordination. In the absence of crystal-lattice stabilization, free uranyl hydroxide complexes in solution would not be expected to have the puckered hexagonal coordination of H_2O and OH^- groups around the uranyl ion, but rather, by principle ii (above), either plane-square or plane-pentagon coordination. If we assume that only $(OH)^-$ can form bridges between two uranyl groups, two types of dimeric complexes can be predicted, one with one link and one with two. The additional coordination ligands are supplied by H_2O, to form squares in the one-link complex (Fig. 5*a*), and pentagons in the two-link complex (Fig. 5*b*). It is clear that when only one link is involved, pentagonal coordination cannot be accommodated. The formulas of these complexes may be written $(H_2O)_3$-$UO_2(OH)UO_2(H_2O)_3^{+3}$ and $(H_2O)_3UO_2$-$(OH)_2UO_2(H_2O)_3^{+2}$ respectively, and they correspond to Hietanen and Sillén's complexes $(UO_2)_2(OH)^{+3}$ and $(UO_2)_2(OH)_2^{+2}$. Structurally, these two complexes correspond in the way the coordination problem is solved to the two crystalline low-temperature forms of $UO_2(OH)_2$: the pentagonally coordinated, hydrated complex forms (Fig. 4) and the square coordinated β-form (Fig. 2). A simple extension of the pentagonal dimer is possible by adding a third uranyl pentagon which is condensed with both of the other two (Fig. 5*c*). This complex may be written $[(H_2O)_2UO_2(OH)]_3(OH)^{+2}$, and corresponds to Hietanen and Sillén's third complex, $(UO_2)_3(OH)_4^{+2}$. Extended double-bridged constructions are also possible utilizing square coordination, but for this discussion, pentagonal coordination has been preferred wherever possible.

Rush, Johnson, and Kraus (*20*), in an utracentrifuge study in sodium chloride medium, show that their results cannot be reconciled with the existence of the infinite series of complexes postulated by the core-links hypothesis, but did not conclude which complexes are involved, except that they must involve a threefold polymer, but perhaps not higher than that. They suggest that a mixture of UO_2OH^+, $(UO_2)_2(OH)_2^{+2}$, and $(UO_2)_3(OH)_5^+$ will account for their results, but indicate that other combinations of polyions may also give a satisfactory explanation.

Peterson (*21*) made electromotive titration studies of uranyl ion in sulfate medium, and obtained somewhat different results from those obtained by Hietanen and Sillén (*19*) in perchlorate medium. He found that the core-links hypothesis gave a fairly good explanation of the data, and gave formation constants for $(UO_2)_2(OH)_2^{+2}$, $(UO_2)_3(OH)_4^{+2}$, and $(UO_2)_4(OH)_6^{+2}$. Sillén has now reported (*22*) the results of much more extensive work done in his laboratory (which includes that of Hietanen and Peterson) in various media including perchlorate, sulfate, chloride, and nitrate. Unlike many other hydrolyzing systems the behavior of uranyl ion varies markedly in different ionic media. Sillén's coworkers have found complexes of the type $(UO_2)_q(OH)_p^{+(2q-p)}$ for which (p, q) is (1,2), (2,2), (4,3), (5,3), (6,4), (7,4), and (8,4), in order of generally decreasing constant of formation. Obviously, the system is too complicated to make any clear prediction of what the structures of these various complexes are. The fact that they are present in different proportions in different media indicates that the "inert" ions are probably also involved in the complexes, replacing coordinated H_2O in some cases in an unknown way. Also, while most of the complexes can be assigned structures which utilize all the associated $(OH)^-$ groups as bridges, the appearance of (5,3)- and (7,4)-complexes indicates that hydroxyl may also play a nonbridging role.

In any case, it is clear that these structures need not be, and, in fact, probably are not based on a puckered hexagonal-coordination principle. There are many possible ways to build models of the various complexes utilizing the three structural elements illustrated in Fig. 5. The best information now available departs decisively from the core-links principle of an infinite series of complexes and this is not surprising in view of the complications that can occur in structure-building with pentagonal elements and the unknown influence of the ionic medium. Prof. Sillén himself (*23*) has recently said that "cases with a considerable number of core-links complexes do not seem to be as frequent as I may once have thought on the basis of our earliest data" (*24*).

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24. I thank Prof. L. G. Sillén and Dr. G. Lundgren for stimulating discussions of uranyl-ion chemistry, and for informing me of their unpublished findings. I thank Prof. Sillén, the John Simon Guggenheim Foundation, and the U.S. Geological Survey for making possible a year in residence at the Royal Institute of Technology in Stockholm. Publication of this report has been authorized by the director, U.S. Geological Survey.
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16 May 1963

Corn Seeds Affected by Heavy Cosmic Ray Particles

Abstract. *Corn seeds of a special genetic stock were recovered from two satellite flights and the plants grown from them were examined for abnormalities. Some evidence for a slight increase in chromosomal deletions was observed, which was predicted from the flux of heavy cosmic ray primary particles. Nothing unexpected was observed.*

The ionizing radiations which exist at altitudes greater than 120 km, where the earth's atmosphere is very sparse or nonexistent, have been extensively studied in recent years with the aid of balloons and satellites. The biological effect of these radiations has been predicted from the physical measurements alone, but it seems desirable to test these predictions with appropriate live material.

The present experiments employed corn seeds as the test material. The seeds were flown in satellites and returned to the laboratory, where they were germinated and grown. Certain of the early leaves were examined for abnormalities which would indicate radiation damage to the embryo. If radiation causes genetic damage in one or more individual cells of a leaf primordium of the seed embryo, then for each mutated cell a change can be observed at a corresponding point in the leaf of the plant.

The radiations can be divided into three categories, as follows. (i) Electromagnetic radiations such as x- or gamma rays which would be expected to have a negligible effect on the seeds at the radiation levels encountered. (ii) Electron and proton radiations which comprise by far the most abundant type of radiation and would be expected to cause genetic damage in individual scattered cells of the seed embryos. Readings from ionization chambers in the satellites, together with experience gained from previous exposures to known radiation sources, permit an accurate estimate to be made of the frequency of leaf sectors to be expected from this source. (iii) Heavy cosmic ray particles, consisting of stripped atomic nuclei having masses as high as iron and traveling at very high speeds, may produce a very broad path of dense ionization as they enter matter. As the particle slows down the track increases in ionization density, and just before its end it becomes very broad and dense. This section, known as a thindown, may be as much as 25 μ in diameter in tissue and several millimeters long. Since the particles are traveling very fast in outer space, almost none of them would be expected to be slowed down in a small object, like a package of seeds, sufficiently to form a thindown. However, behind rather thick shielding or when the particles have penetrated the atmosphere some distance, thindowns should be encountered rather frequently. Schaefer (*1*) has shown the maximum number to occur at an altitude of about 40 km and to decrease sharply at higher altitudes, reaching zero in an unshielded situation in outer space beyond about 80 km.

These high-energy heavy particles cannot be produced in the laboratory, so there has been no direct biological experience with them. Thus the chief interest in this experiment was with this type of radiation, and corn seeds were chosen as the test object because they would be expected to respond to it in an observable way.

In general, the biological damage produced is proportional to the ionization produced, and for the heavy particles this ionization is concentrated in very small volumes, except for the thindown portion of the track. The diameter of this part of the track may be wide enough to hit several cells of the corn embryo, and within its core the ionization would be very dense. If such a track went through an embryo, one would expect damage to the primordia of all leaves through which it passed. The plant grown from such a seed might show damaged areas in several leaves, and from the positions of these one should be able to estimate the course and extent of original damage to the embryo as it was traversed by the particle. The very-high-speed heavy particles encountered would be expected to cause occasional damaged cells in the seeds which would show as mutant streaks in mature leaves. It was this speculation that the experiment was designed to verify.

The corn seeds used in these experiments have embryos in which six leaves or leaf primordia are present in various stages of development. Observations on leaves 3 and 4 were used in these experiments to obtain quantitative data on genetic damage. These leaves are most easily scored because of the size and frequency of mutant sectors produced, which, in turn, are due to the particular combination of numbers of target cells in the embryonic initials and the amount of cell division and expansion that occurs in subsequent growth. The seeds employed were of a genotype that is heterozygous for alleles controlling green (Yg_2-dominant) versus yellow-green (yg_2-recessive) color of the leaf. The larger the dose of radiation delivered to one of the cells of an embryonic leaf, the greater is the probability that the cell will undergo chromosome breakage, and the higher is the frequency of loss of the allele (Yg_2) responsible for green color. As a consequence of such a loss, this altered cell and all its progeny will fail to form the fully green chlorophyll of normal leaf cells. Thus, a single "mutation" in an embryonic leaf cell in this stock will show up in the growing plant as a yellow-green streak or sector in the mature leaf (*2*). A microbeam of deuterons from the Brookhaven cyclotron has been developed as a tool for simulating the biological effects of the thindown particles (*3*) and the effects of these beams on this genetic stock of corn have been described (*4*) and these results have been used to predict the appearance of a thindown hit in this material.

Seeds were flown and successfully retrieved from two satellites: Discoverer 32 launched on 13 September 1961, and a satellite launched in midsummer 1962 (*5*). These satellites were in polar