nance of theme passes to the mastery. One meets there, in conjunction with appropriate applications, with progressions, logarithms, exponentials and probabilities, with geometry—plane, solid and analytic, with trigonometry, ballistics, etc. The inexperienced reader will find the going here slower. Upon occasion he will understand better the author's statement: "There was a time when mathematics was regarded as an intricate subject," than he will the assertion: "Fortunately, this day is long past." More experienced readers may learn less, but will enjoy more. There is much here wherewith the more sober presentations of ordinary textbooks can be supplemented and enlivened.

"To Discover Mathematics" is, for all its intentionally informal style, a didactic rather than an entertaining volume. Though chapters may be headed in such manner as: "The Fountain Head," "Magic of the Mind," "Declaration of Independence," etc., these superscriptions, in fact, refer to discussions of elementary algebraic and number theoretic matters, of geometric methods, synthetic or analytic, of logarithms and exponentials, or of trigonometry and the calculus. Professedly the book is designed to expose the utility and beauty of mathematics through the use of elementary but significant material, and to this profession it adheres with considerable success. This reviewer would recommend this book to many an advanced college student. Such will find it easy—perhaps in spots a trifle tedious—but may draw from it on the whole a rewarding synthesis of many disparate topics.

The proclaimed mission of "Mathematics and the Imagination" is "to extend the process of haute vulgarization to those outposts of mathematics which are mentioned, if at all, only in a whisper; which are referred to, if at all, only by name; to show by its very diversity something of the character of mathematics, of its bold, untrammeled spirit, of how—as both an art and a science—it has continued to lead the creative faculties beyond even imagination and intuition." The reader will find here clever discussions of the possibilities of largeness in numbers and of smallness, of the finite versus the transfinite, of the limiting process, of analytic geometry (to n dimensions), of Euclidian and non-Euclidian geometries, of mathematical pastimes and paradoxes, of probability, topology and the calculus (to space filling curves, and curves without tangents). It goes without saying that with a program so broad the discussion is far from exhaustive, nor was it the intention that it should be so. Lest the reader regard the subjects as too profound, the author gives incidental assurances to the effect that the "high and mighty mumbo jumbo" in terms of which they are usually couched, is wholly dispensable, since "High priests in every profession devise elaborate rituals and obscure language as much to conceal their own ineptness as to awe the uninitiate." Even in the face of such an exhortation, one might still hold that the mathematically sophisticate will glean more from this book than will the novice. For those already in possession of some outlook in mathematics and who wish either to broaden it, or at least to militate against its ossification, this book is wholly recommendable.

The authorship of books such as these is a laudable and withal no simple task. Of the beauties and essentials of mathematics a few, to be sure, are easily accessible. For a proper appreciation, however, even these frequently demand a deeper understanding. By and large, what lies near the surface of the subject belongs much more often among its trivia than among its profundities. The navigable literary channel between the Scylla of unintelligibility and the Charybdis of tediousness, is thus prevailingly narrow. Is it surprising, therefore, that the discovery of a royal road to mathematics is not yet to be signalized? That is, perhaps, after all, a hopelessly Utopian vision.

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SPECIAL ARTICLES

THE INORGANIC CONSTITUTION OF BONE

THROUGHOUT the last century there has been active discussion regarding the inorganic constitution of bone. Analyses show that the principal constituents are calcium, phosphate and carbonate with minor amounts of magnesium and sodium. Bone gives an x-ray diffraction pattern similar to that of the mineral apatite, the unit of structure of which contains $Ca_{10}(PO_4)_6F_2$. Various substitutions, such as $(OH)^-$ for F^- and Mg^{+2} for Ca^{+2}, are known to occur in the apatite lattice without producing significant changes in the diffraction pattern.

Suggested formulas for the phosphate compound of bone and their latest proponents are: $Ca_5H_2(PO_4)_4$, Berzelius (1845); $Ca_{10}(PO_4)_6CO_3$, Gassman (1937); $Ca_{10}(PO_4)_6(OH)_2$, Klement (1938); a neutral compound containing carbonate, Logan (1938); $(Ca,C)_{8-9}[(P,C)O_4]_6Ca(OH)_2$, Gruner, McConnell and Armstrong (1937).[1] In the last formula carbon is present not only in hypothetical $[CO_4]^{-4}$ groups but also as C^{+4} ions replacing Ca^{+2} ions.

[1] References are to be found in recent review articles; C. Huggins, *Physiol. Rev.*, 17: 119, 1937, and S. Eisenberger, L. Alexander and W. D. Turner, *Chem. Rev.*, 26: 257, 1940.

Possibility of carbonate substitution in the apatite lattice was summarily demonstrated by McConnell and his coworkers.[1] We now find that this substitution, unlike the one suggested by these authors, involves replacement of $3(PO_4)^{-3}$ groups by $4(CO_3)^{-2}$ groups with accompanying changes, such as Ca^{+2} replacement by Na^+, in the positive ions to maintain balance of charge. The manner in which this possibly takes place is shown in Fig. 1 (A) and (B).

Tricalcium phosphate prepared from solutions also has an apatite type structure giving a diffraction pattern closely similar to that of bone and thus must be considered. This compound, the existence of which is questioned in almost all the literature on the subject, can readily be prepared in crystalline form as shown by the electron microscope; a convenient method of preparation being hydrolysis of $CaHPO_4 \cdot 2H_2O$ in solutions more acid than pH 5.0 at 100° C. Its limiting formula appears to be $Ca_3(PO_4)_2 \cdot 2/3H_2O$ and the water is unusual in that much of it is held to 600° C. In this respect the compound resembles the silicate mineral apophyllite[2] in the lattice of which water probably is split into H^+ and $(OH)^-$ ions as required by Pauling's electrostatic valence principle. The apatite-like unit of structure of tricalcium phosphate hydrate contains $[Ca_9](PO_4)_6(H_2O)_2$ which perhaps is better written as $[Ca_9(H^+)_2](PO_4)_6(OH)^-{}_2$. A probable way in which these substitutions take place in the apatite lattice is shown in Fig. 1 (C) and (D). The phosphate of this compound can be partially replaced by carbonate as in other apatites.

The neutral or basic character of the inorganic compound is ascertainable by accurate analysis of properly prepared samples of bone. Unfortunately, most analyses have been carried out on bone from which organic matter was removed by methods which would result in hydrolysis of a neutral compound. Many other analyses of bone show an apparent excess of positive ions due to incomplete recovery of phosphate.[3,4]

Trustworthy analyses,[5,6,7] with the magnesium and sodium determinations of Klement,[8] indicate that the average composition of the unit of structure for the apatite compound of human bone is near

$$[Ca_{8.50}Mg_{0.25}Na_{0.19}][(PO_4)_{5.07}(CO_3)_{1.24}](H_2O)_{2.0}$$

[2] W. L. Bragg, "Atomic Structure of Minerals," Ithaca, pp. 226 *ff.*, 1937.
[3] C. M. Burns and N. Henderson, *Biochem. Jour.*, 29: 2385, 1935.
[4] A. E. Hoffman and P. Caldwell, *Jour. Assoc. Official Agr. Chem.*, 25: 206, 1942.
[5] M. A. Logan, *Jour. Biol. Chem.*, 110: 375, 1935.
[6] C. M. Burns and N. Henderson, *Biochem. Jour.*, 30: 1207, 1937.
[7] J. Marek, O. Wellmann and L. Urbanyi, *Zeit. f. Physiol. Chem.*, 226: 3, 1934.
[8] R. Klement, *Naturwiss.*, 26: 145, 1938.

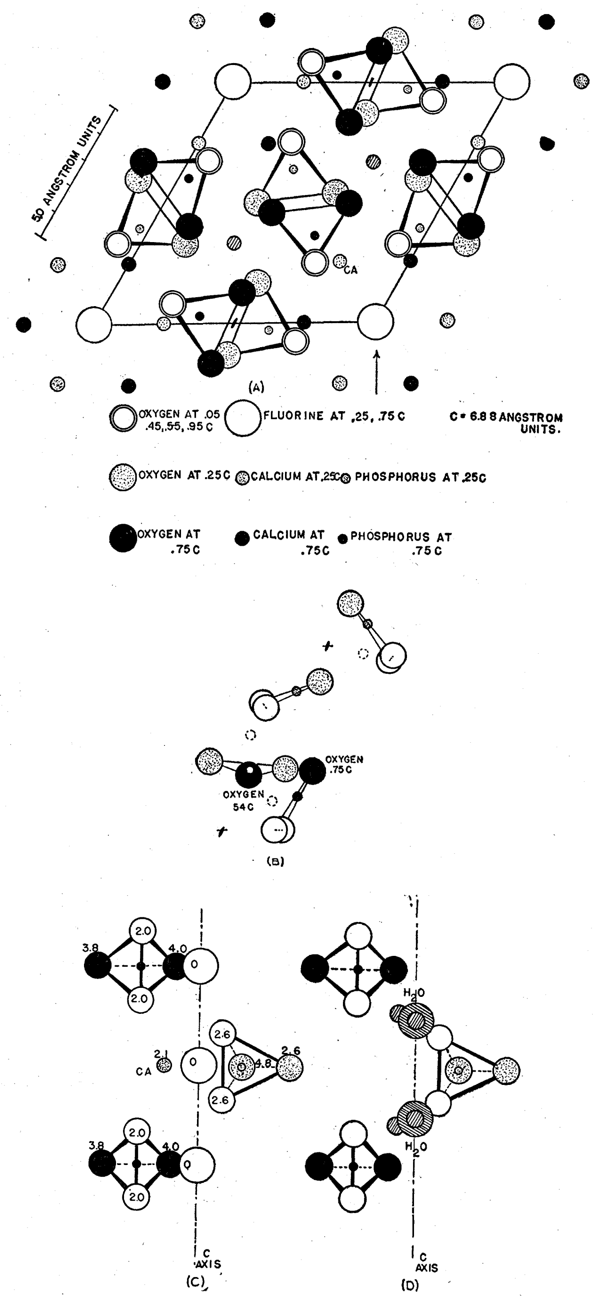

FIG. 1: (A) Projection of the apatite structure on the basal plane. Since each PO_4 group has one edge parallel to the c axis two oxygen atoms of a group are superimposed and the group thus appears as a triangle. (B) Projection parallel to the c axis showing a way in which $4CO_3^{--}$ groups can replace $3PO_4^{---}$ groups. Relationship of this projection to (A) can be seen by superimposing the plus marks. (C), (D) Projection of a portion of the apatite structure on (10.0) [along the arrow in (A)] showing the manner in which Ca^{+2} and $2F^-$ are replaced by $2H_2O$ or $2(OH)^-$ and $2H^+$ ions. Distances in angstrom units from the projection plane are indicated.

Sodium, of course, may replace Ca^{+2} ions on account of similarity in ionic radius and to an extent that depends upon the Na^+ concentration in plasma. Limited analytical results from the literature indicate that dentine, while still a hydrated tricalcium phosphate, differs significantly from bone in having a possibly higher Mg^{+2} and lower $(CO_3)^{-2}$ content. Its average formula approaches

$$[Ca_{8.36}Mg_{0.45}Na_{0.16}][(PO_4)_{5.34}(CO_3)_{0.88}](H_2O)_{2.0}$$

Enamel on the other hand is a more basic compound and a representative sample of human enamel has the formula

$$[Ca_{9.48}Mg_{0.18}Na_{0.11}][(PO_4)_{5.67}(CO_3)_{0.45}](OH)_{1.54}(H_2O)_{0.46}$$

which approaches that of a carbonate hydroxyapatite.

Possible variation in the basicity and composition of the inorganic compound of bone with type, species, age and pathological condition, although the subject of many studies in the past, can only be ascertained by further extensive analyses in which the errors of past work are avoided and in which the minor but not unimportant sodium and magnesium are determined. In general, evidence now available would seem to indicate that bone contains a hydrated tricalcium phosphate type of compound instead of hydroxyapatite as widely accepted and that sodium and carbonate are essential constituents of this compound.

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OCCURRENCE OF AVIDIN IN THE OVIDUCT AND SECRETIONS OF THE GENITAL TRACT OF SEVERAL SPECIES

AVIDIN, the anti-biotin factor which produces egg-white injury, has hitherto been known to exist only in the white of the hen's egg.[1] The site of origin and physiological significance of this potent biological substance have remained obscure. The white of the hen's egg represents a secretion from the mucosal lining of the oviduct.[2] Since the translucent jelly-like secretion found adherent to frogs' eggs is the direct homologue of the white of the bird's egg, it was deemed advisable to determine whether avidin might be present in this secretory product of the frog oviduct as well as in the oviduct itself. In addition, the oviduct of the hen and the eggs of several other species of birds were also assayed for avidin.

The materials to be tested were obtained in the fresh state, spread on glass plates and dried in a current of warm air at 37° C. The dried preparations were then pulverized and assayed for avidin by the yeast-growth method of Eakin *et al.*[3]

It was found that avidin exists in readily demonstrable quantities in the oviduct of both the hen and wood frog (Table I). It is noteworthy that the egg-jelly from two different species of frogs also contains very considerable anti-biotin potency. The presence of avidin in the egg-white of all the species of fowl tested should also be noted.

TABLE I

AVIDIN CONTENT OF BIRD AND AMPHIBIAN TISSUES AND SECRETIONS

Species	Material assayed	Units* of avidin per gm. dried weight
Hen (New Hampshire)	Egg white	11.5
	Oviduct	2.3
	Intestine	0.0
Wood frog (R. sylvatica)	Egg jelly	1.7
	Oviduct	0.75
	Intestine	0.0
Pickerel frog (R. palustris)	Egg jelly	1.5
Turkey	Egg white	16.2
Duck	" "	7.1
Goose	" "	8.0

* A unit of avidin is that amount required to completely neutralize the yeast growth supported by one microgram of free crystalline biotin.

Dried intestine of the hen and of the frog was employed as a control tissue and was found to contain no demonstrable activity.

The relatively low titres found in the oviduct of the hen and of the frog may be accounted for by the fact that the muscularis and stroma of these organs contribute a considerable proportion of inert material to the assay.

These data suggest that avidin is a secretory product of the oviduct of birds and amphibia and therefore may play an important role in embryonic development and in the physiology of the genital tract.

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1 P. Gyorgy, *Annual Review of Biochemistry*, xi: 337, 1942.

2 B. Patten, "Embryology of the Chick." P. Blakiston's Son and Co., Inc., Philadelphia. 1929.

3 R. E. Eakin, E. E. Snell and R. J. Williams, *Jour. Biol. Chem.*, 140: 535, 1941.

HEREDITARY TRANSMISSION OF INDUCED TETRAPLOIDY AND COMPATIBILITY IN FERTILIZATION

THE writers have reported[1] that the change to a tetraploid condition (4n = 28 chromosomes) induced by colchicine in the branches of self-incompatible diploid (2n = 14 chromosomes) plants of *Petunia axillaris* (Lam.) B. S. P. was accompanied by a change to self-compatibility in fertilization and seed formation. It may now be reported that further investigations show that the condition of self-com-

1 A. B. Stout and Clyde Chandler, SCIENCE, 94: 118, 1941.