

A. M. D. C.

BULLETIN

of the

**American Association of
Jesuit Scientists**

Eastern States Division

(Founded 1922)

(for private circulation)

Published at

WESTON COLLEGE
Weston, Massachusetts

VOL. XXVIII

MAY, 1951

NO. 4

SEVENTY-FIFTH BIRTHDAY
MAY THE EIGHTH
NINETEEN HUNDRED AND FIFTY-ONE

Reverend Henry M. Brock, S.J.

TO ONE OF THE FOUNDERS OF THE ASSOCIATION,
A FORMER PRESIDENT AND EDITOR,
THE MEMBERS OF THE ASSOCIATION
DEDICATE THIS ISSUE OF THE BULLETIN AS A TOKEN OF
THEIR ESTEEM AND APPRECIATION

AD MULTOS ANNOS

Bulletin of the American Association of Jesuit Scientists

EASTERN STATES DIVISION

VOL. XXVIII

MAY, 1951

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Biology

THE STRUCTURE OF PROTOPLASMA MACROSCOPIC, MICROSCOPIC AND SUBMICROSCOPIC

WILLIAM D. SULLIVAN, S.J.

In the last edition of the BULLETIN (March, 1951), "life" in protoplasm was shown to have many interpretations. No mention was made of the macroscopical and microscopical structure. The more important theories, therefore, of protoplasmic structure will be discussed in this chapter, and their chief exponents will be presented.

Though ordinarily described as a jelly-like mass within a living unit, it is indisputably a highly coordinated system of living activities. For this reason all explanations of its complex structure must conform to the scientific findings as well as to the philosophical principles of living matter.

1. GRANULAR THEORY

According to this theory, protoplasm is considered a compound of innumerable minute granules which alone are capable of life, and which are the essential active basis of living protoplasm exhibited in all cells. Altmann (1886), a prominent exponent of the Granular Theory, called these elementary living units within the cell, *bioblasts*, and the non-living liquid surrounding the bioblasts he called *byaloplasm*. The bioblasts were described by Altmann as "bacteria-like" granules.

The Granular Theory, therefore, interprets the cell not as a living unit of life, but as an aggregate of bioblasts which multiply by division: "omne granulum e granulo".

Of the physical and chemical constitution and the physiological significance of protoplasmic granules, very little is known. It has been noted by some of the authors that undue importance has been attached to these granules. Under the head of granules may be included such particles as plastids, secretory granules, mitochondria (rods, spheres and threads), globules of oil, crystals of salt and sugar, grains of starch and even some of the vacuoles. Many of these serve as food for the living organism; some others are waste products.

As a general theory of protoplasmic structure, the Granular Theory is least satisfactory and the least capable of explaining all the cellular behavior. It is of historical interest only.

2. EMULSION THEORY

There can be no doubt but that protoplasm, superficially viewed, is an emulsion of some kind. Confusion arises from the interpretation

of the function and the nature of protoplasm as an emulsion. Though it appears to be an homogeneous hyaline substance free from globules, protoplasm was revealed by Seifritz (1936; 1940) to be a very fine emulsion when viewed with the Spierier lens. He called the dispersed phase, i.e. the illuminated phase, *phaneroplasm*; the dispersion phase he called *cryptoplasm*. As long as protoplasm remains quiet the two phases present a mottled, mosaic picture. While under tension, as when straining, the emulsion assumes a striated appearance due to the parallel arrangement of the now elongated and illumined emulsion globules. Under stress the globules become distorted into rods, which are joined end to end forming one continuous thread.

Though it is not easy to differentiate vitally between the relative importance of the protoplasmic constituents, nevertheless, if we attempt to distinguish between phaneroplasm and cryptoplasm from the viewpoint of their vital significance, then the discontinuity of the former and the active streaming of the latter, suggested to Seifritz that the cryptoplasm is the more fundamental.

Because protoplasm is quite evidently an emulsion, and because of its frequent references to the colloidal structure of jelly-like substances, this theory of an emulsion held first place for quite some time.

The outer layer (ectoplasm) of protoplasm was noted to be a fine, ultra-microscopic emulsion close to the reversal point. When the emulsion swings to one side or the other, it becomes more or less permeable to water soluble substances. This phenomenon is more noticeable in an emulsion of oil in water than of water in oil. Such a theory adequately explains certain features of protoplasmic permeability. Very convincing was the discovery of proportionately equal amounts of *Na* and *Ca* in an emulsion as in sea water, blood and other physiological solutions maintaining these solutions at the reversal point. Among other points of interest and advantage presented by this theory, there is demonstrated a number of surfaces within the cell membrane sufficient to explain the numerous complicated activities of the living organism.

There are, however, many other characteristic properties of protoplasm which cannot be explained by the emulsion theory. (1) The coagulation of the protoplasmic proteins is not accounted for in this theory. Emulsions do not coagulate. (2) The elasticity of protoplasm has also been found wanting in emulsions. (3) Investigation to date has revealed no manifestation of phase reversal in protoplasm, yet all emulsions can be clearly seen to manifest this phenomenon. It is still possible that such a protoplasmic activity may be present in an ultra-microscopic process.

3. ALVEOLAR THEORY

Butchli (1892) observed a symmetrical or checker-board appearance, which he regarded as the fundamental structure of protoplasm. He considered protoplasm to consist of tightly compressed globules, which, due to pressure, become angular geometric-shaped

figures. In cross section, the globules present an hexagonal outline called aveoli. Though an emulsion, he regards it as a compound of two liquids, one of which is in droplet form, and the other in the form of lamellae (between the droplets).

The aveoli described by this theory would seem to be minute vacuoles which are found to be more abundant in protoplasm than is usually realized. Other investigators are convinced that most emulsions, aveoli and like structures of protoplasm are all modifications of vacuolar structures. Though microscopically the structure of protoplasm was regarded by Butchli to be aveolar, submicroscopically he considered it to be an extremely fine emulsion.

Further investigation has described this structure of protoplasm as an interlacing system of filaments which are not wholly discontinuous. It has often been compared to the external structure of a bath-sponge. The efficiency of such a structure of protoplasm finds its value in the numerous surfaces present, which surfaces are necessary to explain the complexity of activities in a single cell.

Though such a structure does appear in protoplasm, it is not to be found in all protoplasm and especially is this true in general of the protozoa.

4. FIBRILLAR THEORY

Velten (1873; 1879), from his study of *Tradescantia*, concluded that protoplasm is composed of finely branched fibrils which are not joined so as to form a continuous network of fibrils. The Reticular Theory is a variation of the Fibrillar Theory in which theory the protoplasmic filaments are said to aggregate so as to form a fine network of continuous threads. However, the conclusions of Velten were further developed by Flemming (1882) who called the fibrillar substance *mitome* and the fluid, bathing the mitome, *paramitome*. Some of the investigators assert that the fibrils are in reality minute canals filled with liquids, and the granules, observed by other scientists are merely the secretions from these canals.

Urna (1894) pointed out that Butchli's aveoli and Flemming's mitomes were not necessarily opposed to each other, but rather that at one time the structure may be aveolar and at another time it may be fibrillar. For the most part modern biologists maintain that protoplasm is non-particular and indefinite in its structure. The most accurate of the modern structural descriptions is that of Mast (1926). After the latter, Scarth (1942) demonstrates five different regions in the one cell: (1) cellulose wall (in plant cells only), (2) protoplasmic membrane (ectoplast in animal and plant tissue), plasmagel (cortical endoplasm), (4) plasmasol (liquid endoplast), (5) inner tonoplast (vacuolar membrane surrounding globules of food, waste products, etc.). The latter are found to be extremely complex in *Pelomyxa collustris*.

According to Seifritz (1936) the appearance of an emulsion in protoplasm is in no way a reflection of some kind of molecular

structure, but rather is the visible result of a nutritive process within the cell. Wilber claims that there are definite visible structures demonstrating evidence for microscopic changes in protoplasm. Pollister (1941) discovered that the general configuration of mitochondria gives some indication of a submicroscopic structure.

In the past few years the most productive attack on the physical structure of protoplasm is through the chemical method. It was through such a method that the protein structure of protoplasm was discovered. Astbury (1943; 1944) first used the x-ray on wool, hair, etc., before attempting work on muscle protein. The success of the former experiments, prompted him to demonstrate new findings in the muscle proteins. He found that the protein is in a partially folded polychain and not in a straight line as was formerly believed. Dissociating the chain he discovered that it could undergo changes under different conditions. He also demonstrated two different folds of chains, which he called *alpha* and *beta* conditions of the protein polychain. Due to tension forced on the chains both conditions may be pulled out to a straight line. For example in the case of the hair polychain, he found the two types, alpha and beta chains. In general the alpha (keratin) polychain is found in hair, but under tension the hair elongates because of the straightening of the chains of proteins causing the beta condition of the polychain. A third type of chain demonstrated by Astbury's experiments is the *corpuscular* chain which is so completely folded that it is in the form of a molecular corpuscle.

The environment, therefore, may be changed by such conditions as heat, water vapor and tension and the molecular configuration of the polychain will likewise change.

Birefringence (Sullivan, 1949) on the other hand has shown evidence of a micelle structure, a minute crystal far below the size of microscopic visibility. The swelling of protoplasm has also demonstrated the presence of micelles. Because the micelle is said to swell in one direction more than in the other, protoplasm is shown to be a linear structure submicroscopically.

Gengrosse (1936) has produced evidence for the fact that micelles are not separate individual crystals but are rather the *points* of crossing of several chain molecules. According to him the gel is composed of a liquid and a solid, the solid being the micelle. What the substance is, filling in between the fibrils, Gengrosse does not mention.

Frey and Wyssling (1938) attempted to measure the spaces between the micelles by impregnating various cells with gold. They found that the spaces now filled with gold form a continuous network measuring 50^{A} to 60^{A} in width and 500^{A} to 600^{A} in length. The cellulose of plant cells has been found to manifest the same structure of micellular formation.

Herzog (1932) demonstrated that in any biological system there are two types of molecular formation. The one is a linear structure,

or a fibrous structure in which the long axis of every micelle is parallel to every other micelle. It is composed of true polypeptide chains of molecules, which are joined in a crystalline form. The other is a laminar structure composed of an association of fibrillae in the same plane in sheathes and not necessarily parallel to each other. According to Picken (1940) this latter type of arrangement is found in three different forms of animal tissue and to which he attributed three classifications. The first class is subcellular or parts of individual cells such as membranes, spindles and cilia. The second is extracellular, as in those parts outside the cell itself such as cellulose (in plant cells) and chitin. The third class is supracellular, macroscopic in structure, and in which class are hair, feathers, bone and muscle.

Fundamentally these structures are composed of proteins, long chains of amino acids and peptide linkages. The structure of the fibrillar protoplasm is composed of many of these long chains and peptide linkages running parallel to each other and many besides are bound by side chain linkages. In some (keratinoid fibers) of these the side chain linkage is strong and the peptide linkages themselves hold the protein chain closely taut. Bangor and Szent Gyorgi (1940) discovered that the protein molecule in tissue of mechanical function, such as keratin (hair), myosin (muscle) and elastin (feathers) are of such a structure. Tissues of solid structure or of a supporting nature (collagenous fibers) such as tendon and other connective tissue are found to have weaker side chain linkages and weaker peptide linkages between the parallel peptide chains. As a result of such differences more or less water is allowed to enter the greater or less space between the different protein molecules of these fibers. This difference in amount of water depends, therefore, on the type of linkage in the side chain, as well as on the strength of the peptide linkage, which, in turn, influences the physiological activities of these mechanical and supporting tissues.

Until quite recently, proteins were thought to be globular in structure. However, Bangor and Szent-Gyorgi demonstrated that this need not be necessarily true. Globules of kidney tissue were extracted from the kidneys so that all that remained of the kidney was the supporting structure. This supporting structure clearly demonstrated birefringence, while the globules themselves were negative to birefringence.

Seifritz demonstrated certain structural units as linear molecules so arranged as to form a net-work of chains. They may be either globular or linear and these chains may change from the one to the other. He compares them to a brush-heap and if one is pulled the others will also give with the pull. Some theorists claim that the chains are nothing more than a mass of threads. Astbury claims they are in the form of a bridge. According to Seifritz these chains may show an overlapping and as a result the small chains demonstrate a very good x-ray picture. Wringer claims that protoplasm is a cyclol

molecule hooked together. However, this theory cannot explain viscosity or elasticity, since it has to do with spherical molecules.

The Hydrogen Bond Theory proposed that protoplasm is composed of linear units since the continuity of structure is evident, i.e., a liquid which flows even in the gel state. Just how the chain theory explains the phenomenon of viscosity is hard to see; the Hydrogen Bond Theory is quite plausible. Since hydrogen has a valence of one, let us assume that it has a very low energy value of five calories. We would then have one strong bond and one weak bond. This weak bond (an ionic bond) could have various strengths. Pauling says that an hydrogen bond is found in water, and its strength varies with the electro negative atom. This can explain viscosity, flow, elasticity, etc. ("Nature of the Chemical Bond" by Pauling).

According to Wrinch, the chromosomes are bundles of polypeptide chains with one of the nucleic acids binding the links together. Schmidt and Singer (1938), however, made a study of chromosomal birefringence and their discoveries show that such a structure is impossible because in order that such a theory be valid, the nucleic acid must also be parallel which is not at all the case with the nucleic acids.

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Chemistry

THE LIMITS OF ERROR IN VOLUMETRIC ANALYSIS. III. DOUBLE INDICATOR TITRATIONS^{1,2}

REV. BERNARD A. FIEKERS, S.J.

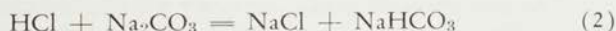
It is often stated that double indicator titrations for alkalis and alkali carbonates are apt to be unreliable from the point of view of the relative error in the results. This investigation is based on critical principles developed in an earlier paper.² It aims at stressing the necessity for a design of procedure in these determinations such as to enhance their precision. And it shows that certain techniques and procedures are far more conducive to accurate results from precision design than are others.

Given the following components: NaOH, Na₂CO₃ and NaHCO₃, or other alkali metal equivalents, conceivably: (1) all of them could be present in a dry sample; or any of the three pairs, namely: (2) NaOH, Na₂CO₃, (3) Na₂CO₃, NaHCO₃ or (4) NaOH, NaHCO₃. But on dissolving these samples (wet), cases 2 and 3 would remain, while cases 1 and 4 would, by virtue of the reaction,



be equivalent to cases 2 or 3, with the product Na₂CO₃ in common and either NaOH or NaHCO₃ left over because of its presence in excess.

Titration then with acid to a phenolphthalein (pp) endpoint, would measure all of the NaOH if present, and by the following reaction,



half of the Na₂CO₃. Continued titration to the methyl orange (mo) endpoint would measure none of the NaOH, half of the Na₂CO₃ by reaction with the NaHCO₃, the product of equation (2).



and any NaHCO₃ originally present.

These volume relations are summarized in Table I.

In Table I, V_{pp} signifies the volume of standard acid required to establish the phenolphthalein endpoint. But V_{mo} is defined by

$$V_{\text{total}} = V_{pp} + V_{mo} \quad (4)$$

¹THIS BULLETIN, 12, 96 (1934).

²Ibid., 22, 71 (1945).

as the *added* volume of acid required to establish the methyl orange endpoint. These definitions are convenient. Since the *mo* endpoint follows the *pp* endpoint it includes the error of the *pp* endpoint and is therefore less precise.

TABLE I.

Components:	NaOH	Na ₂ CO ₃	NaHCO ₃
Mixtures			
NaOH, Na ₂ CO ₃	$V_{pp} - V_{mo}$	$2 V_{mo}$	—
Na ₂ CO ₃ , NaHCO ₃ *	—	$2 V_{pp}$	$V_{mo} - V_{pp}$

In each of the four determinations in Table I, the relative error due to volume measure is comprised of the sum of the absolute volume errors in the different volume readings, divided by the volume that actually measures the substances to be determined. This is summarized in Table II.

TABLE II.

Components:	NaOH	Na ₂ CO ₃	NaHCO ₃
Mixtures			
NaOH, Na ₂ CO ₃	$\frac{2 dV}{V_{pp} - V_{mo}}$	$\frac{2 dV}{V_{mo}}$	—
Na ₂ CO ₃ , NaHCO ₃	—	$\frac{dV}{V_{pp}}$	$\frac{2 dV}{V_{mo} - V_{pp}}$

Throughout Table II it will be noticed that at least two factors contribute to the relative error value, (1) the absolute error term dV , and, (2) the volume, or difference of observed volumes, used to measure the components that are present.

The absolute error term is definitely fixed by the choice of burette. It generally has the value of 0.005 ml. for a 5 ml. microburette; 0.05 ml. for a 50 ml. burette; and 0.1 ml. for a 100 ml. burette. These values correspond to tolerance value 0.001 throughout; 0.005/5, 0.05/50 and 0.1/100 respectively. In Table II this absolute error value is doubled in all cases, except in that of the determination of carbonate in the presence of bicarbonate. Accordingly this exception can be just as precise as any determination of direct analysis that involves comparable volumes.

The volume terms in the denominators of Table II on the other hand can contribute far more to the relative error value in a given determination than the absolute error term discussed above: the smaller the denominator, the greater the relative error. The determination of sodium carbonate can easily be designed so that large volumes will be used and precision enhanced. The determinations of the sodium hydroxide and the bicarbonate do not have this advantage.

EXERCISE I. Determine from the following volume relationships the substances possibly present: V_{pp} greater than V_{mo} , V_{pp} less than V_{mo} , $V_{pp} = V_{mo}$, $V_{pp} = 0$, $V_{mo} = 0$.

EXERCISE II. A 4 gm. sample of dilute caustic was dissolved and diluted to 500 ml. 50 ml. of this required 69.36 ml. of a 0.1322 N HCl solution for the *pp* endpoint and 0.89 ml. more for the *mo* endpoint. What substances are present? Calculate their percentages as sodium compounds.

V_{pp} greater than V_{mo} . Therefore OH^- and $\text{CO}_3^{=}$ present. By Table I, sodium carbonate is measured by $2 V_{mo}$; and NaOH, by $V_{pp} - V_{mo}$. In general:

$$\% = \frac{(V)(N)(\text{MEW})(100)(V_m)}{(W_s)(V_p)} \quad (5)$$

and

$$\% \text{Na}_2\text{CO}_3 = \frac{(2)(0.89)(0.1322)(0.053)(100)(500)}{(4)(50)} = 3.11\%$$

$$\% \text{NaOH} = \frac{(69.36 - 0.89)(0.1322)(0.04)(100)(500)}{(4)(50)} = 90.6\%$$

EXERCISE III. In the data of exercise II, calculate the contribution of volume error to the error in the results, assuming that a 100 ml. burette was used with dV value 0.1 ml.

Consulting Table II, error for sodium carbonate = $2 dV/V_{mo} = 0.2/0.89 = 0.224$ or about 224 parts per thousand or about 75 parts per 311. This means that the true answer might be anywhere between 2.73 and 3.49% sodium carbonate. The error for sodium hydroxide = $2 dV/(V_{pp} - V_{mo}) = 0.2/68.47 = 0.003$ or about 3 parts per thousand for the volume contribution to the error.

A case of compromise in precision is had when, as a first approximation, equimolecular amounts of two components are found in a given mixture. Using a 50 ml. burette, and disallowing burette refills, approximately 16 to 17 ml. of acid are required to measure each of the components present:

$$V_{\text{total}} = 50 = V_{pp} + V_{mo} = 33_{pp} + 17_{mo}$$

This volume sets the limit to the maximum precision obtainable under these conditions. The relative error is 0.006 for both components, namely sodium hydroxide and sodium carbonate. Similar reasoning and results apply to the analysis of the other pair.

Allowing burette refills, however, will not contribute substantially to the precision of the determinations, except to some extent in the following isolated case. Some precision can be gained for the

sodium hydroxide determination if the first 50 ml. are used to establish the *pp* endpoint:

$$V_{\text{total}} = 75 \text{ ml.} = V_{\text{pp}} + V_{\text{mo}} = 50_{\text{pp}} + 25_{\text{mo}}$$

Here the relative error values are: $0.1/25 = 0.004$ for the sodium hydroxide and $0.15/25 = 0.006$ for the sodium carbonate. The added 0.05 ml. in the numerator of the latter is due to the refilling and extra reading involved.

As the molar ratio of sodium hydroxide to sodium carbonate increases, the precision of the sodium hydroxide determination increases to the detriment of the carbonate. The same can be said for the reciprocal ratio with reference to the carbonate.

In the sodium carbonate, sodium bicarbonate determination, on the other hand, as high as 50 ml. can be used to establish the *pp* endpoint for a precise carbonate determination. But two refills are required for the *mo* endpoint:

$$V_{\text{total}} = (100 \text{ to}) 150 \text{ ml.} = V_{\text{pp}} + V_{\text{mo}} = 50_{\text{pp}} + (50 \text{ to}) 100_{\text{mo}}$$

Relative error for sodium carbonate is $0.05/50 = 0.001$; for bicarbonate, $0.15/50 =$ (about) 0.003 best value.

Again precision under these conditions varies directly as the value of the molar ratio of the components. Further the relative error in the determinations of the two components are equal when there are twice as many mols of sodium bicarbonate as carbonate present.

It seems that a change in technique might enhance precision. Carbonate can be precipitated, separated and determined gravimetrically. The other component can then be determined in the filtrate by titration. But this is no longer indirect analysis.

A useful "dodge" is suggested in the use of a 5 ml. microburette. For this, there is only one sound application. It is the case of the determination of relatively small quantities of sodium carbonate in the presence of relatively large quantities of sodium bicarbonate. Titration to the *pp* endpoint with the microburette measures the carbonate precisely. Continued titration to the *mo* endpoint with a suitable macroburette measures the bicarbonate with twice the precision ordinarily had under otherwise comparable conditions. For the absolute error of the microburette is so small that it does not enter into the second titration to any great extent.

This suggests other devices, such as adjustment of concentration, weight of sample, etc., in establishing the various endpoints. Investigation will show that these are good substitutes for the microburette, but only in the case that was cited. Frequently the technique and calculations are badly complicated when such alternatives are recruited. For it is our purpose to stress the design of such experiments; not to evaluate the precision and to justify experimental conditions that are established in a random way.

In practice it is well to make preliminary titrations to both endpoints in order to make an estimate of the relative magnitudes in-

volved. Then in many cases the choice of the technique to be followed can be made in accordance with the principles here laid down. In any event, the weights of sample should be chosen large enough to give precision efficiency to the determinations.

A NOTE ON BALANCING EQUATIONS IN CHEMISTRY

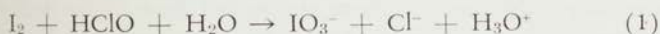
REV. BERNARD A. FIEKERS, S.J.

A criterion for balanced ionic redox equations, over and above the usual balancing of coefficients and subscripts, is the equality of the algebraic sum of the ionic charges on each side of the equation. For, if this condition is not satisfied, the absurd implication is had that a given reaction can produce one or more charged particles which are not accompanied by others of equal and opposite sign. If, on the other hand, the algebraic sum of charges is equal (positive, negative or zero), the inference is made that the neutralizing particles would have appeared on both sides of the equation, but that explicit reference to them was omitted in order to emphasize only the essentials of the reaction. In other words they cancelled out.

This reason is not always mentioned in texts which include the topic. In many, the topic is not even mentioned. Both in the texts and in the literature itself, this principle has at times been violated.

But this device of balancing charges on both sides of an ionic equation is no mere critical tool. It has positive value in determining some numerical coefficients for equations which are otherwise difficult to balance.

Consider, for example, an equation which contains hydronium ion, as follows:



By the usual electron loss and gain or the valence change methods, one determines the initial ratio to be one iodine to five hypochlorous acid molecules, 1 : 5. That immediately determines two iodate and five chloride ions to the right of the equation, which incidentally adds up to seven negative charges to the right. One can then take the chance that the sixth oxygen in the two iodates came from one molecule of water, and thus balance the equation. But the balancing becomes complicated. Using, however, the device here suggested, the argument follows: since the algebraic sum of the charges to the left is zero, the sum to the right should also be zero. Hence seven hydronium ions are needed to the right of the equation. The balancing can then be finished in the usual way. It follows;



A less elegant dodge in this example is first to substitute proton for hydronium ion:



and to balance the equation. Then seven hydronium ions can be had by adding seven molecules of water to the right, to be balanced with the addition of seven to the left and equation (2) results. But such a dodge might not be quite so fruitful as a general method.

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News Items

BAGHDAD COLLEGE

(The editor asked Fr. Guay to write an article on the new science building of which he was the architect and contractor. Fr. Guay's reply is printed below with only minor editing.—Ed.)

DEAR FATHER IN CHRIST, P.C.

Many thanks for your kind comments on the Bishop Rice Memorial Science Building and your kind invitation to write an article about it and my experiences. I am writing a letter to you rather than prepare a formal article and you may edit it as you see fit.

The plans use European notation and metric measurements. Therefore, the Ground Floor corresponds to the first floor in the U.S. and the First Floor corresponds to the second floor in the U.S. The Rice Memorial Science Building is a two story building, 168'×61'. There is no basement, but there is a long tunnel the length of the building for cooling air for our gravity air conditioning. The biology department is on the ground floor and it comprises a lecture room (34'×19.8'), technique room (22'×19.8'), laboratory (54'×25') and a museum (27'×19.8'). The laboratory has 4 large windows (6½'×7') with good north light. Also on the ground floor are three other lecture rooms, a science library, a small research laboratory, a work shop, and two teacher's rooms, one for Jesuit teachers and one for lay teachers. The research lab. was deliberately placed on the first floor, so that one cool place could be available to the chemistry and physics professors during the hot summer months when the floor above would be too hot. The first floor (i.e., second floor in U.S. notation) houses the chemistry department, the physics department, and a large lecture room (54'×25'). The two laboratories are each 54'×30'. The chemistry department also has a balance room (11'×20'), a preparation and store room (32'×20'), and a lecture room (34'×20'). The physics department has an optics room, an apparatus room and a lecture room with corresponding measurements.

The hot summer sun rides high and so glances the south side of the building at a very oblique angle, but all forenoon it pours its heat into the east wall and all afternoon into the west wall. Therefore, the east and west walls have been planned as small as possible. That is why I have avoided an L or H or U shaped building. Also, by avoiding such structures, I have also avoided large spaces which are difficult to light and ventilate.

THE CHEMISTRY LAB. There are five island tables, $16' \times 4\frac{1}{2}'$, each with 40 good sized drawers and 10 lockers; a trough runs down the middle, with water and gas above the trough and under a shelf; electrical outlets are below the lip of the table. Made in Baghdad of teak wood according to my own specifications, completed they will cost about \$500 each. There is a platform and chalkboard (green) at one end of the lab. and a wall table at the other. The north wall has shelves for scales and chemicals; the south wall has three large open fume hoods and an emergency shower, with space for a key cabinet. (Capacity—50 students.)

THE PHYSICS LAB. There are four island tables, $12' \times 4'$, with electricity and water. There are wall tables all around the west, north and east sides, and gas at the west wall. South wall has cabinets for equipment in current use. (Capacity—60 students.)

THE VISUAL EDUCATION ROOM or large lecture room can hold more than 200, but is planned for five classes of 30 each. It has a stepped floor (steps 5 in.) with platform for a projector at the rear, a 20' green chalk board and 12' demonstration table up front.

THE BIOLOGY LAB. has a $2\frac{1}{2}'$ wall table along north wall and six tables, $18' \times 2\frac{1}{4}'$, arranged longitudinally for the best lighting for microscopes.

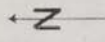
THE SCIENCE LIBRARY has book shelves 10' high along the west and east walls with lower shelves along the south wall. Each library table sits six students. At present we have 1400 volumes, including many excellent reference works. We also have quite a set of journals in chemistry, most of them donated by Weston College. Little used journals are kept on top shelves, while books and other journals are on the lower shelves.

LECTURE ROOMS. All lecture rooms save one are large enough to accommodate 60 if necessary, but it is planned to have 30 in a class, and all save one have sloping or stepped floors (risers 6 in.). One lecture was left flat so that it might be used for the science library, when it outgrows its present quarters. Chemistry and physics lecture rooms have large demonstration tables 12' long. All chalk boards are green carborundum surfaced boards.

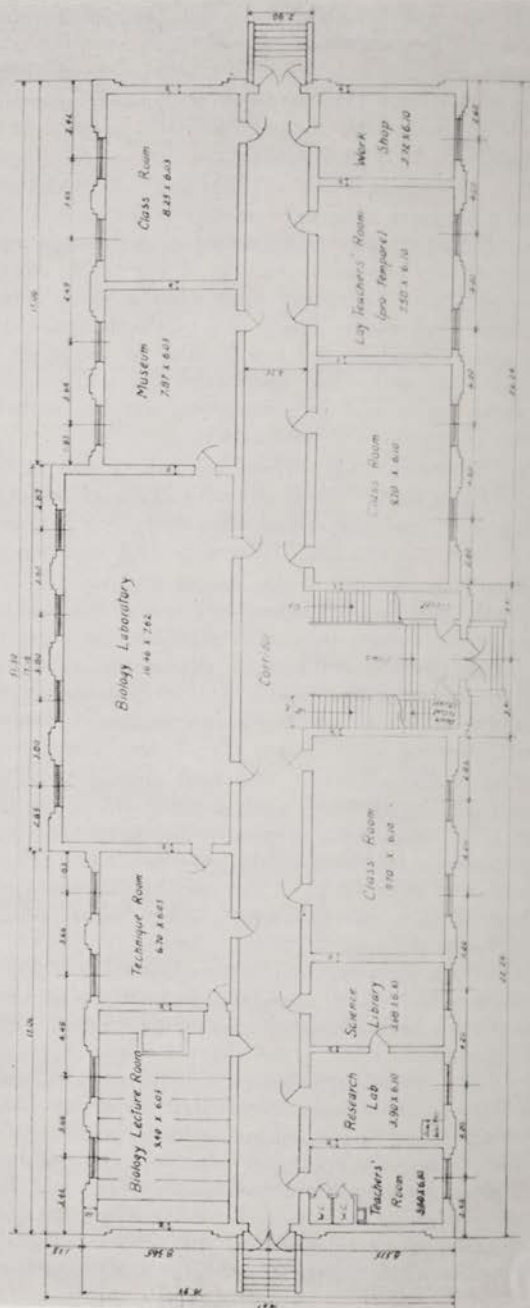
PLUMBING. Plumbing is mostly out in the open so that necessary repairs may be made conveniently. The main distribution systems for gas and water and main waste lines are all under the ceiling of the ground floor corridor. They will be painted in the standard colors used by chemical industries. There is no plumbing inside the big

Drawing ①

BISHOP RICE MEMORIAL SCIENCE BUILDING BAGHDAD COLLEGE



Scale 1/100 June 5, 1949



GROUND FLOOR PLAN

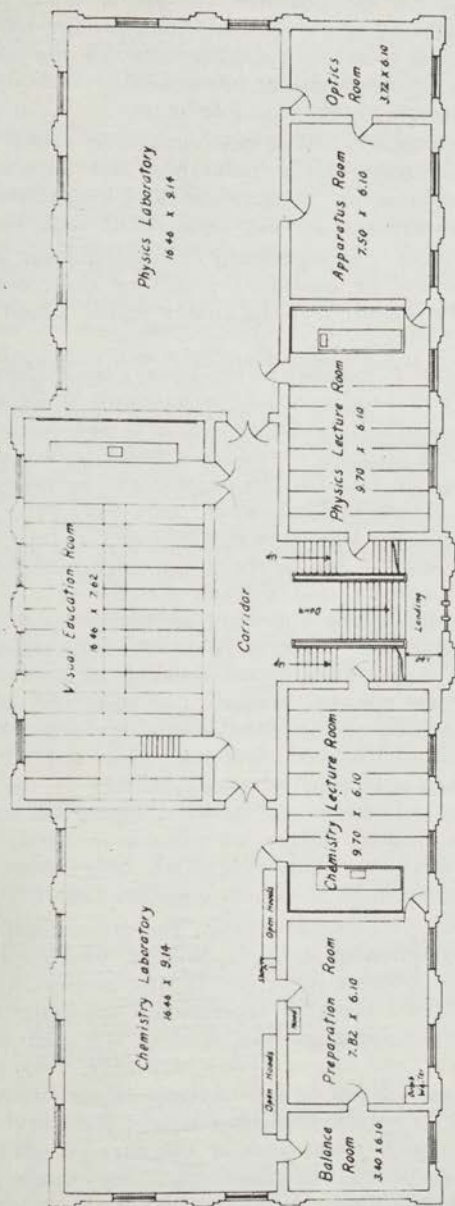
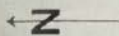
1-11-49, S.S.
Engineer, June 16, 1949

BISHOP RICE MEMORIAL

SCIENCE BUILDING

BAGHDAD COLLEGE

Scale 1/100 June 6 1949



FIRST FLOOR PLAN

L. J. Eury, S.A.
Baghdad, June 6, 1949.

chemistry tables, so the tables need not be taken apart for plumbing difficulties. Galvanized iron pipes were used for water, black iron pipes for gas and cast iron for waste. Acid proof waste pipes are not available. Gas will be made from gasoline by means of an Aerogen Gas Machine situated in the tower, which also houses a two ton water tank for equalizing water pressure. The capacity of the gas machine is 40 burners.

ELECTRICITY. Counting outlets on tables there are about 360 electrical outlets in the building. Table lines and appliance circuits are all high current wires. Electricity is distributed through 4 panels. The chemistry and physics departments each have their own panels.

TOWER. Our eight inch reflector and our Boston College 4 inch refractor will be used on the roof of the tower. Tower beams are planned strong enough to hold a dome, which we hope to acquire later.

COST. Not counting equipment, the building cost \$50,000. Dr. Neil Weber, formerly of Swarthmore College, now Professor of Geology at the Iraq College of Arts and Sciences, who had experience in the planning of a science building, declared that the building is the best in Iraq for the purpose and he estimated roughly that in the U.S.A. the building would cost \$400,000. I think his estimate is too high, but I am sure it would cost at least \$200,000 in the U.S. The low cost is due to the lower wage scale here, to lower cost of materials (bricks, steel, cement, plaster and sand are all cheaper here, only certain metals and wood are higher) and also to the labor and ability of Fathers Madaras, Williams, Shea and myself. Fr. Madaras, who has had a hand in the building of every building at Baghdad College and who has planned and built two buildings himself, was the constructor and bore on his able shoulders the chief responsibilities. Fr. Williams was procurator and buyer and with Fr. Shea, Minister, made sure that supplies were available at the right times. I was architect and supervisor. Actual construction started in March 1950 and was finished, though not painted, in eleven months. The science library, teachers' rooms, biology lab., five lecture rooms and the visual education room have been in use since Feb. 1951.

PERSONAL EXPERIENCES. The greatest experience was the thrill and satisfaction of seeing a building which I had planned in every detail go up brick by brick. It was, perhaps, an experience accorded to very few. For that experience I am grateful to Fr. Rector who has always encouraged me in every way and who gave me his full confidence, and also to Bishop McEleney, who, as provincial, told me to plan on a big scale and to think of the future.

We had eight good masons who were paid day by day. In fact all our workers were paid by the day, except the electrician. These masons knew no English except a few words like "foot" which to them meant a tape measure, and I knew practically no Arabic. However, I learned a few words myself, like "baab" for door, "shabach"

for window, "shalman" for steel beam, etc., and managed to make myself understood. When Yusef, our factotum, was around he would be my interpreter, but often he was not present and I had to depend entirely on my meager Arabic. Then you could hear me say, "Baab hina, metertain wa nus" (a door here, two meters and a half). It is surprising how well they understood. Very, very little had to be taken apart and done over again. In fact, a few times when they misunderstood me, they had done the thing I wanted a better way. These Moslem masons were very industrious and proud of their work. At night when I would meet them going home, they would turn around, look back at the building and say, "Helu" (it is beautiful). They even wanted to take down the handball courts nearby because they detracted from the looks of the building. Our head carpenter knows English, and so did our plumber and electrician so I had no difficulties with them. God gave us very good workmen. Our carpenter was good not only with wood, but also with steel. He cut and fitted the steel beams for the stairs. We were fortunate to get one of the very few plumbers who knows anything about gas piping. The masons especially seemed to enjoy working for us. This was their second building on which they had worked at Baghdad College, and now they are asking when we will start the third building, our chapel. These masons laid about a thousand bricks a day and got about \$3 a day, but we gave them tea two or three times a day and we always greeted them as friends rather than as workmen.

The plans for the science building grew in part from dreams. Baghdad College, a secondary school specializing in science according to the Iraq Government program, had outgrown its old lab. where physics, chemistry and biology shared its facilities. Fortunately, Fr. Sheehan and Fr. Gerry and I got along very well and had no difficulties, but it was hard to have to take down every apparatus almost immediately after setting it up. So, from the beginning I began to dream of a new building—a modest one story building. But when Fr. Provincial told me to plan big and think of the future, I dreamed bigger dreams. At night before falling asleep I would think out the sizes of tables I wanted, and go over all details in my mind. When the Easter vacation came I put them all down on paper and my preliminary floor plans were done. After consideration by the other science professors, the final floor plans were drawn. The engineering plans, i.e., the steel beam plans, foundations, etc., were all done at Ksara, the French Jesuit Science Observatory in Lebanon, where I usually spend my summers.

In the beginning I did all my own blue prints. (I also blue-printed Mr. Madaras' plans for our excellent faculty and senior boarders' residence.) Then Fr. Collins, our mission procurator, sent me a roll of Ozalid paper. I had no directions for developing this paper, but worked out a way of developing them with ammonia gas in a large wooden packing box. These are much better than the old

blue prints, for they give blue lines on white. Now, however, the embassy staff does my printing for me on their Ozalid machine. At present I am working on the preliminary plans for the chapel. Please keep this new building in your masses and prayers and ask God to help us make this home for Him better than the home we have made for science.

An added item, if you wish to use it. As director of our incipient observatory, I have become interested in astronomy. I am only an amateur and our telescopes are only amateur telescopes, an eight inch reflector and a four inch refractor, the latter an excellent telescope donated by Boston College. I have had as many as ninety people in a week visit the school in order to view the heavens through our instruments. And one of my boys of the scientific society has made a fairly good three inch telescope. At about one o'clock on the afternoon of Feb. 25, 1952, there will be a total eclipse of the sun in Iraq. The path of totality is near the Gulf and so may be cloudy. Fr. Heyden of the Georgetown University Observatory kindly sent me some data published by the U.S. Naval Observatory. Using that data I drew a large map of Iraq showing the path of totality and lines indicating how much of the sun's disc will be hidden by the moon in other parts of Iraq. The map and an article in Arabic is appearing in our Baghdad College Annual, the *El Iraqi*. They will be published in the Baghdad newspapers later. In the meantime the Air Attache here has obtained permission, provided world conditions permit, for a flying trip over the clouds on that day. I hope to have Fr. James Larkin and Fr. Robert Sullivan with me to photograph the eclipse, for both are very good photographers.

We have very little opportunity to do any direct apostolic work here, but we do a lot of indirect apostolic work through science. Three weeks ago I gave a lecture on science and religion to an audience who would not dare to ask for a lecture on religion. And because of our science we are well received in Baghdad. All of us are very busy, but, thank God, we like our work and we think God's blessing has been with us. He has favored our school in so many ways—especially with the best community I have ever seen—and we are proud of Baghdad College. Please keep its continued success in your masses and prayers. Au revoir and God bless you.

YOURS IN CHRISTO

LEO GUAY, S.J.

COLLEGE OF THE HOLY CROSS

DEPARTMENT OF CHEMISTRY. On April 20, 1951, word came through that the College of the Holy Cross was selected for an R.O.T.C. Air Force Unit commencing in September 1951. Further details were not available. The Naval R.O.T.C. Unit will continue at Holy Cross. The Mathematics and Science Division of the New England Regional Unit, College and University Division of the

National Catholic Educational Association met on the campus on April 28, 1951. One hundred and twenty-seven out of the one hundred and eighty-eight mathematics and natural science instructors in the region attended this meeting. On May 8, 1951, Fr. J. A. Martus of this department gave a demonstration lecture on Chemiluminescence to the Science Club of Leicester, Mass., High School. Father Fiekers and Dr. VanHook represented the College at the Eighth Meeting of the New Eng'and Conference of Graduate Schools, held at the University of Maine in Orono, on May 5, 1951. Father Fiekers was appointed to the nominating committee by President of the Conference, the Reverend George A. O'Donnell, S.J., of Boston College and of THIS ASSOCIATION. For the first time in years, a systematic course in anion analysis has been put into the curriculum of Freshman Chemistry and seems to be working out exceptionally well. A recent improvement in qualitative analysis, hailed especially by non-chemists, and with which many of our chemists are undoubtedly familiar, is the introduction of a new hydrogen sulfide reagent into the course, thioacetamide, an Eastman product. Sulfide precipitates are produced with as little as eight drops of the aqueous solution added to a sample and boiled for four minutes. The traditional "qualitative" odor has all but disappeared from our laboratories.

Mathematics

INTEGRALS WITH INFINITE UPPER LIMITS

REV. THOMAS D. BARRY, S.J.

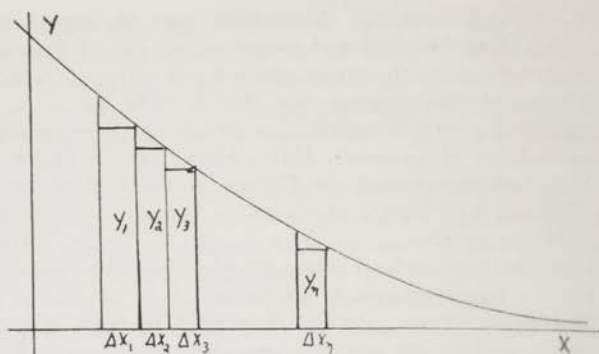
The two functions $y=x^{-2}$ and $y=x^{-1}$ do not look very different. Both are asymptotic to the x-axis. Yet when they are integrated with lower limit greater than zero and infinite upper limit they yield vastly

different results. E.g.: $\int_1^{\infty} dx/x^2 = [-1/x]_1^{\infty} = -0 + 1 = 1$, and

$\int_1^{\infty} dx/x = [\log x]_1^{\infty}$ does not exist. Why does one integral give a finite result, the other infinite? One way to attack the problem is to consider the changes in the ordinate as x increases without limit.

The figure shows a curve asymptotic to the x-axis. The distance from $x = a$ to $x = b$ is divided into intervals $\Delta x_1, \Delta x_2, \dots, \Delta x_n$, giving ordinates y_1, y_2, \dots, y_n , and horizontal lines are drawn completing a series of rectangles. An approximate value of the area between the curve, the x-axis, $x = a$ and $x = b$ can be found by adding the areas of these rectangles:

$$y_1 \Delta x_1 + y_2 \Delta x_2 + \dots + y_n \Delta x_n.$$



If the Δx 's are taken equal this becomes:

$$(y_1 + y_2 + \dots + y_n) \Delta x.$$

If now, without changing the value of Δx , b becomes infinite, thus adding an unlimited number of rectangles to this sum,

$$y_1 + y_2 + \dots + y_n$$

becomes an infinite series. If this series is convergent, the product $(y_1 + y_2 + \dots + y_n) \Delta x$ will have a finite value, its limit as Δx approaches zero (which gives the exact area under the curve) will be finite, and the corresponding integral will be finite. But if the series is divergent, the product, and hence the limit and the integral, will be infinite.

In applying this principle to the examples given at the beginning of this article, let $a = 1$ and $\Delta x = 1$. Then for $y = x^{-2}$, the series $y_1 + y_2 + \dots + y_n$ is $1/2^2 + 1/3^2 + 1/4^2 + \dots + 1/n^2$. This is a p -series, with $p = 2$. For $p > 1$, the p -series is convergent. Therefore the integral is finite. For $y = 1/x$, the series is

$$1/2 + 1/3 + 1/4 + \dots + 1/n.$$

This is the harmonic series, which is divergent. Hence no limit to the integral.

By interchanging x and y , the same principle may be applied to the integrals of functions which become infinite at either of the limits of integration.

Physics

WAVE FUNCTIONS AND IONIZATION POTENTIALS FOR THE GROUND STATE OF CARBON DIOXIDE*

JOSEPH F. MULLIGAN, S.J.

In quantum-mechanical calculations on atoms the Bohr orbits of the old quantum theory are replaced by one-electron wave functions or atomic orbitals, which are mathematical expressions related to the probability distribution of the electrons in the atom. In molecular quantum mechanics two different approaches are possible. One of these is the so-called "valence-bond method", which is useful in considerations of chemical binding. The other is the method of molecular orbitals, which is more useful in calculating ionization potentials and energy levels of molecules. In this method an attempt is made to obtain one-electron wave functions for the molecule as a whole, and the electrons are considered as belonging not to individual atoms, but to the whole molecule. In this sense it may be thought of as an extension of the Bohr theory of electron configurations from atoms to molecules.

As the method of molecular orbitals is usually applied, the molecular orbitals are made up as linear combinations of atomic orbitals, that is, it is assumed that the molecular wave functions can be expressed mathematically as linear combinations of the atomic wave functions of the individual atoms making up the molecule. This is the so-called LCAO MO (linear combination of atomic orbitals molecular orbital) method.

A further refinement in the theory is the introduction of self-consistency. This means essentially the following. The desired molecular orbitals are obtained by a variational calculation, which minimizes the energy of the desired electronic state of the molecule. Now this energy includes both the kinetic energy of the electrons, and their potential energy in the field of the nuclei and the other electrons. It is obviously impossible to solve exactly the many-body problem which results, and so an approximation is introduced according to which each electron is conceived as moving in the field of the nuclei, and the "smeared-out" average field of the other electrons. The field due to the other electrons is obtained by replacing them by their mathematical equivalents, i.e., by the molecular orbitals to which they belong. This seems to be a vicious circle. The molecular orbitals are needed to obtain an expression for the potential energy which

*This is an abstract of an article by the same author published in *The Journal of Chemical Physics*, Vol. 19, no. 3, pp. 347-362 (March, 1951).

will be used in the variational procedure, which will in turn lead to the molecular orbitals as solutions. The method of the self-consistent-field points the way out of this dilemma. In this method a guess is made at a starting set of molecular orbitals, and the calculations are carried through which result in the obtaining of a new set of molecular orbitals. These are compared with the original assumed values, and if they do not agree, new values are assumed and the method is repeated. Finally molecular orbitals are obtained which agree with those originally assumed. The molecular orbitals are then said to be self-consistent, and the method is called the method of the self-consistent field (SCF).

In the work reported here molecular orbitals have been calculated for the ground electronic state of carbon dioxide, using the LCAO SCF method. In the calculations no experimental data were used, except the known internuclear distances and linear form of the molecule. The atomic orbitals were assumed to take the form derived from calculations on the separated atoms, and the coefficients with which they enter the molecular orbitals were determined by the self-consistent-field procedure. Since the energies of the individual electrons in the molecule were obtained along with the molecular orbitals, it was possible to obtain the ionization potentials for the two most loosely bound electrons in carbon dioxide. These calculated ionization energies were 11.5 and 17.9 electron volts, compared with the experimental values of 13.8 and 18.0 eV, respectively, obtained from Rydberg series in the vacuum ultraviolet.

These results are considered good for a completely theoretical calculation of this type, which involved no arbitrary assumptions or empirical data, as applied to as complicated a problem as carbon dioxide presents from a quantum-mechanical point of view. The method used is as fundamental an approach to molecular quantum mechanics as is possible at present, and the results again indicate the agreement with experimental data that quantum mechanics can give, if only the tedious calculations involved can be carried through.

A point that may be of interest to Ours in connection with the work reported here, is that the general method used was recently developed by Dr. Clemens C. J. Roothaan, formerly of the physics faculty at the Catholic University of America in Washington, and now at the University of Chicago. Dr. Roothaan is the great-grandnephew of Father John Philip Roothaan, S.J., "the General who rebuilt the Jesuits."

A HORSE POWER EXPERIMENT

REV. HENRY M. BROCK, S.J.

In *Popular Science* for October 1950 there appeared an article entitled "What you should know about Horse Power" by Kenneth N. Swezey. The author gives a brief account of the origin of the term and describes methods for measuring it on a small scale. Refer-

ring to human effort he states that a man may develop 0.1 Horse Power by turning a meat grinder tightened to require a pull of about twenty pounds. He then adds "In a spurt of running up stairs a man might develop over one Horse Power but he could not keep it up for long." Though not at all new, it may be of interest to describe an experiment affording some evidence of the truth of the latter statement. It was first tried at Weston in November 1945 by eight members of the First Year Physics Class. The procedure was simple. It consisted simply in running up stairs from the first to the fourth floor of the Philosophers' wing. The vertical height was 36.6 feet though the actual distance traversed was greater. The work done by each man against gravity was this height multiplied by his weight. This of course was independent of the way he ascended whether walking, running or even crawling. The power exerted, or the rate of work, was the product divided by the time in seconds and this quotient divided by 550 gave the horse power.

In the actual experiment each man first weighed himself on a good scales. A timer was stationed on the fourth floor with a stop watch. The starter on the first floor was provided with a bell. At the sound of the bell, the timer started the watch and the contestant started running as fast as he could. When he reached the top floor the watch was stopped. All entered the contest in a competitive spirit and each man ran only once as the effort required was considerable. The results are given below.

Name	Weight	Seconds	Work (ft. lbs.)	Horse Power	Watts
L. J. McDonough	189	11	6917	1.14	853
P. V. Sullivan	195.2	12.4	7144	1.05	782
N. J. Carroll	171.2	11.2	6266	1.02	759
R. F. Healey	186.2	12.4	6815	1.00	745
R. M. Brackett	147	11	5380	0.889	663
G. W. Nolan	160.8	12.4	5885	0.863	644
W. M. Pashby	135	13	4941	0.691	516
A. M. Graham	126.2	12.4	4619	0.677	505

It will be observed that three of the group developed more than one Horse Power, the maximum being 1.14. Two of the men made the ascent in the minimum time—11 seconds—although one had to lift 42 pounds more than the other. The heavier of these two made it a point to cling closely to the balustrade and propel himself with his arms as well as with his legs. Larger values might have been obtained if there had been some preliminary training or if the height had been less and consequently the time shorter. An experiment of this kind may seem to be a sort of "stunt". It gives only the results of a maximum effort and no indication of the power used when work is done steadily over a period of time. However it can be easily per-

formed and requires no special preparation or equipment. It brings out the significance of the time element especially for the contestants.

One may ask if there are any data on hand with which the above results may be compared, to see whether they are greater or less than might be expected. Furthermore, what is the maximum human horse power that has been developed under different conditions? This second question was suggested by the "Question and Answer column" of the *Boston Traveler* for Dec. 21st, 1950. Some one had asked: "Can the power produced by human effort ever go as high as 13 horse power?" The answer given was: "Human power may for a period of seconds reach 13 horse power as for instance at the highest effort in running." This value seemed excessive and I was at first inclined to think that it was a misprint. I therefore wrote to the Information Bureau and they replied that it was correct and that it had been taken from *Physiology of Work and Play* by S. R. Riedman, published by the Dryden Press, New York, 1950. In chapter VII of this work there is a section entitled "Power and Limits of Human Work". After citing some examples up to 1.5 horse power, the author states on p. 115, "Higher figures than these have been reached, but only for a few seconds, in sprint running—up to 3 horse power and up to 13 horse power during the maximum speed of the run." No details are given but the reader is referred to an article by Wallace Fenn, "Mechanical Energy Expenditure in Sprint Running as Measured by Moving Pictures" in the *American Journal of Physiology*, 90:343, 1929. On p. 128 the author discusses resistance opposing the muscles. Thus, comparing running and swimming, the statement is made, "For example, swimming at the rate of 5 ft. per sec., one swimmer expended almost 150 Cal. per minute or 14 horse power, a rate which is matched only at the highest speed in the 100-yd. dash." At that energy rate, a runner could cover six times this distance in the same time. The reference given is "Energy expenditure in swimming," by Karpovich, P. V., and Millman, N., *American Journal of Physiology*, 142:140, 1944.

As for stair climbing, the author says on p. 115: "The work of subjects running upstairs to the top of a high office building has been calculated as the weight of the body multiplied by the height of the ascent. The average was 0.7 to 1.2 horse power during 14 seconds. This is an exceedingly high rate and could not be achieved in protracted work. It was possible only because the effort lasted less than a fourth of a minute—i.e., 14 sec. only." The results obtained by our competitors agree fairly closely with the above values though their mean time was a little less.

Apart from Horse Power it is interesting to note the amount of mechanical work done in climbing stairs in a scholasticate. It will of course vary with the floor an individual lives on, his weight, the order of the day, etc. At Weston the first floor is 17.4 feet above the basement. The other floors are 12.2 feet apart. I have made some inquiries and have taken 390 feet as a rough average for the total

height climbed by a man living on the fourth floor on a day of regular order. This is 169 feet higher than the Bunker Hill Monument. If he weighs 170 pounds he does 66,300 foot pounds of work against gravity. It only takes fifteen similar days to reach a million. The total in the course of a scholastic year including all days becomes quite formidable. These figures are large but they become less impressive when expressed in heat units. Dividing 66,300 by 778, the mechanical equivalent of heat, we obtain 85.2 B.T.U. Multiplying the latter by 0.252 gives 21.47 large calories. The body utilizes its food intake in doing mechanical work. According to Stearns (*Elementary Medical Physics*, p. 115), its over-all efficiency, considered as a machine is about 20%. Hence 107.4 large calories are required. Stearns also states that the heat of combustion of white bread is 2.66 large calories per gram. Our student can then do his daily climb on 40 grams or about one and a third slices of bread, a rather small fraction of the calorie ration per day.

Some may say that all this provides a good reason for using the elevator while others may claim that stair climbing is a useful form of exercise quite beneficial to a normal heart provided the horse power is kept moderate.

CHANGES IN THE BOSTON COLLEGE PHYSICS DEPARTMENT FROM 1860 TO 1950

REV. JOHN A. TOBIN, S.J.

Physics was taught at Boston College three years before the college received its charter. The building at Boston College on Harrison Avenue was completed in 1860 but it was used to train Jesuit personnel. Fr. Sestini, S.J. was the first teacher of physics and was followed by Fr. Varsi, S.J. in 1862. The Boston Scholasticate was closed in 1863 and that same year Boston College received its charter. But it is a fact worth noting that the Jesuits taught college grade physics in 1860 in Boston. This was before M.I.T. opened in 1865 and before B.U. was chartered in 1869. Fr. Varsi had studied physics in Paris and used "costly demonstration apparatus" in his lectures. He gave the first public demonstration of the electric lamp in Boston in the Immaculate Conception Church in 1863. He used one hundred Bunsen cells and the carbon-arc lamp. At Weston College there is an old carbon arc that was made in France and may have been the lamp used by Fr. Varsi.

The next report we have of the Physics Department is in 1876. The college charter was received in 1863 and the first classes started in September 1864. There were twenty-two students to begin Latin First Rudiments, or First Year High as it is called today. During the next twelve years courses were added so that it was in 1876 that the first Senior Class started in which a year of philosophy and physics was given. It is well to note that Jesuit colleges started as

high schools and took some years to reach the courses as we have them today in college.

In 1876 Mr. Thomas Stack, S.J. was the professor of physics. He was followed by Rev. John Ryan, S.J. in 1878 and by Mr. Joseph Ziegler, S.J. in 1880. Father Stack came back to physics in 1882 and became the President of the college in August 1887, but died seventeen days later. Rev. Michael P. Costin, S.J. and Rev. Patrick Mulry, S.J. taught physics after Father Stack. Mr. Albert Ulrich, S.J. then taught the physics course until Rev. Francis DeS. Fullerton, S.J. came in 1891. The text book used at this time was Ganot's "Physics".

At the Commencement in June 1877, there was an exhibition in science by the students of the graduation class culminating in a demonstration of the transmission of speech and music by Bell's Telephone. Cardinal O'Connell graduated in 1881 and received the silver medal in physics. The great interest of his Eminence in physics was manifest in his visits to the Physics Department in the Tower Building, and after 1924 in the Science Building. It may be noted that the programs for Commencement in 1878, 1880, 1881 and 1883 as printed in the Journal of the Boston College Physics Society in 1950 prove how the members of the graduating classes in those years were interested in physics.

In 1894 Father Fullerton was succeeded by Rev. George Fargis, S.J. who also taught chemistry which was the custom in those days. Father Fargis had been at Georgetown University where he developed the photochronograph for recording star transits photographically. It did not come into general use. However the photographic method in which Father Fargis was a pioneer is now in use with improvements at the Naval Observatory in determining the corrections of standard clocks. The text book used in those days was "Principles of Physics" by Gage, and there was no regular laboratory work required at that time. M.I.T. was one of the first schools to require laboratory work in physics.

The turn of the century brought many changes in the department. Fathers James Dawson, Thomas Freeman, and John Coyle taught physics for a year after Father Fargis, and in 1900 Rev. Dennis T. O'Sullivan, S.J. became head of the department. Some of the other Jesuits who taught physics here were Mr. Thomas Miley in 1907, Mr. Edward Phillips in 1909, Mr. Gregory Kiehne in 1910, and Father Patrick Rafferty in 1912.

In September 1913, the first complete collegiate year began in the new Tower Building. It may be noted that for the fiftieth year of the college, the Class of 1913 came out in March of that year, and in June, the first Commencement was held at Chestnut Hill. Rev. Henry M. Brock, S.J. started the Physics Department that year using the equipment that had been sent out from the old college. The laboratory and lecture room were located on the third floor overlooking the reservoir. The laboratory at the north eastern end was well

equipped for those days, and Father Brock was fortunate in obtaining excellent instruments from Max Kohl in Germany. The lecture room was on the south eastern side and the Fulton Debating Room was between the laboratory and lecture room. The results of Father Brock's labor is still seen in some of the excellent demonstration apparatus available for the lectures and in the equipment installed in the lecture room. Father Brock left in 1914 and was followed by Rev. Thomas Miley, S.J. In 1916 Mr. William Logue, S.J. and Mr. John P. Smith, S.J. carried on the work.

In August 1918 Mr. John A. Tobin, S.J. and Mr. John Delaney, S.J. arrived at Chestnut Hill to find a college geared to wartime needs with four barracks and mess hall on the campus and a new curriculum of studies requested by the War Department.

The Student Army Training Corps (SATC) started here in August 1918 and there was no need of the regular classes in physics except for a small group who were free from military service. Col. John Parke gave plenty of work in physics to the soldier students. After Armistice Day it was necessary to give courses to the students on mechanics and physics as so many in the SATC were not trained to take the regular A.B. course. Later on this course was called the PhB course. Rev. Daniel J. Lynch, S.J. returned from the war in 1919 and was made Head of the Physics Department and the Radio Club. The station WIPR was in the corridor of the third floor of the Tower Building. In May 1921 the "Two Million Dollar Drive" was successful in obtaining over one million dollars in cash and the new Science Building was started in 1922.

In this period mechanics was taught in Sophomore, heat, light, sound and electricity in Junior, and the laboratory work was performed in Senior. Assisting Father Lynch were Mr. Tobin, S.J., Mr. Joseph Kelly, S.J., and Mr. Thomas McLaughlin, S.J.

In 1926 Rev. William Crawford, S.J. was the Head of the Department, assisted by Rev. Thomas Fay, S.J. In 1929 Father Tobin was made Head of the Department.

The first B.S. in Physics class graduated in 1933 and the first M.S. class graduated in 1934. In September 1941, the first class in B.S. in Electrical Engineering was started, but after their Junior year all the students were called to the Armed Forces. The Senior year in Engineering was never started. From October 1929 to 1942, Civilian Pilot Training (CPT) program was given at B.C. and the Norwood Airport. In July 1941, Engineering Science Management Defense Training (ESMDT) was started and the laboratories were used day and night in these courses. On August 9, 1943, the Army Student Training Program was started and 300 students took the physics courses for basic engineering. This was seven hours of physics a week. In 1945 we were back to the regular classes again. A large number who had a training in physics in the Armed Forces wanted to continue their scientific studies, and entered the B.S. in Physics course. As a result, Boston College was fifth on the list in the United

States of undergraduate students majoring in physics. A comparison of the first catalogues of the college with those of the present time shows how the department has advanced.

The Bulletins of the Graduate School and the College of Arts and Sciences in 1950 show the great increase in faculty and courses. The large number in the Graduate School are able to specialize in spectroscopy, electronics, and acoustics. The required courses in theoretical physics, quantum mechanics, and mathematical physics are in great contrast to the courses found in the early catalogues. Another great change not noticed in the catalogues, is the large library in the department and the stock list of instruments required for the advanced courses. Instead of the one course in General Physics with the laboratory for this one course, today there are laboratories for spectroscopy, electronics, acoustics, and thermodynamics, and the large graduate laboratory for thesis work. Yet all this advance would have been impossible without the work of 1860 and the first year in 1876, and all the work and interest of the teachers who made possible the department of today.

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A SURVEY OF PUBLICATION IN THE CHEMISTRY DEPARTMENT OF THE COLLEGE OF THE HOLY CROSS. II.

REV. BERNARD A. FIEKERS, S.J.

The Department of Chemistry submits the following list of its publications for the period 1945-1950. Items 1-43, published prior to 1945, have already appeared in the *JESUIT SCIENCE BULLETIN*, 22, 77-80 (1945).

44. Fiekers, B. A. and Gibson, G. S., "Illustration of the gas laws, a dynamic model for statistical phenomena," *Journal of Chemical Education*, 22, 305-308 (1945).
45. Fiekers, B. A., "An electrical heater for funnels," *Chemist Analyst (J. T. Baker, Co.)* 35, 93-94 (1946).
46. VanHook, A., "Some chemical problems and prospects of the sugar industry," *Journal of Chemical Education*, 25, 49-51 (1948).
47. Fiekers, B. A., "Pipetting with a rubber bulb," (Laboratory suggestions), *Chemist Analyst (J. T. Baker, Co.)*, 37, 18 (1948).
48. Fiekers, B. A., "Improved lamp rheostat board," (Laboratory suggestions), *Chemist Analyst (J. T. Baker, Co.)*, 37, 41 (1948).

49. Fiekers, B. A. and Di Geronimo, E. M., "Para bromobenzyl bromide in the identification of some aromatic carboxylic acids," *Journal of the American Chemical Society*, 70, 1654-1655 (1948).
50. VanHook, A., Whelan, Jr., W. P. and Galkowski, T. T., "Kinetics of sucrose crystallization, VII. Real massecurites," *Proceedings of the American Association of Sugar Technicians*, 5, 552-556 (1948).
51. BOOK. "Sugar—its production, technology and uses," by A. VanHook. Ronald Printing Co., N. Y., 1949. "Humanizing of Science Series".
52. VanHook, A. and Bruno, A. J., "Nucleation and growth in sucrose solutions," *Discussions of the Faraday Society*, 5, 112-117 (1949).
53. VanHook, A., Baril, O. L. and Moroney, T. (S.), "Effect of manganese sulfate on sucrose solutions," *Sugar*, 44, (12), 44, 45 and 48, Dec. 1949.
54. Turner, C. F. and VanHook, A., "The effect of ultrasonic irradiation on the formation of colloidal sulfur and ice," *Journal of Colloid Science*, 5, 315-316 (1950).
55. Brennan, R. O., Canavan, F. L., Fiekers, B. A. and Mulligan, J. F., "Index of subjects, 1922-1948, Vols. 1-25," *JESUIT SCIENCE BULLETIN*, 25 (no. 5), October, 1949.
56. VanHook, A., "Atypical solid-liquid transitions and their possible biological significance," *Biodynamica*, 6, 81-92 (1947).

Most of the above items have been abstracted by *Chemical Abstracts*. Item no. 55, The twenty-five volume index of the *JESUIT SCIENCE BULLETIN* was a joint effort of Father Fiekers of the College with the three scholastics named then at Carroll House of the Catholic University, now at Woodstock College. In addition to this publication activity, the *JESUIT SCIENCE BULLETIN* was edited here by Father Fiekers from 1948-1950 and one issue of the student publication the *Hormone* appeared in November 1949; its next issue is to appear shortly. Publications by staff and accredited to other institutions include:

57. Guay, L. J., "The Sandmeyer reaction and the cathodic reduction of benzene diazonium chloride," *Clark University Bulletin (Dissertation and theses abstracts)*, 16, 6-10 (1944).
58. VanHook, A., "Kinetics of Sucrose crystallization. Mechanism of the reaction of real massecurites," *Proceedings of the American Association of Sugar Technicians*, 4, 558-564 (1946). Wyoming Univ.
59. Roboz, E. and VanHook, A., "Chemical study of beet pectin," *Proceedings of the American Society of Sugar Technicians*, 4, 574-583 (1946).
60. VanHook, A., "The liquid state. Position of the problem in various countries, 1936-1945," *Pontificia Academia Scientiarum (relationes tempore belli)*, no. 6, 1946. Wyoming Univ.

61. VanHook, A., "Kinetics of sucrose crystallization. Real messecuites," *Industrial and Engineering Chemistry*, 40, 85-89 (1948). Wyoming Univ.

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