Contents

NOTICE TO AUTHORS

Manuscripts are to be submitted to associate editors of the appropriate section and *may* be submitted directly to the editor in chief. Clear manuscript, preferably typed, with wide margin to the left, with double spacing between lines, is desirable. Please try to follow the typographical style of the most recent issue of the BULLETIN. Line drawings should be submitted on Bristol board, or similar material, and done in India ink. Figure number should be written on this in pencil. Titles for drawings, with figure numbers, should be typed on a separate sheet. Please try to minimize footnotes. Appended references and bibliographies, clearly so marked, should be done in the style of the A.A.A.S. publication, *Science*.

Anthropology

THE SYNTHETIC THEORY OF EVOLUTION (*Continued*)

J. FRANKLIN EWING, S.J.

ANNOTATED BIBLIOGRAPHY (CHIEFLY OF BOOKS) ON EVOLUTION.

This bibligraphy mentions the more recent works of a general nature. The bibliographies of the works will in turn supply references to other current and past publications.

————, 1950. Origin and Evolution of Man. *Cold Spring Harbor, Symposia on Quantitative Biology*, vol. XV. The Biological Laboratory, Cold Spring Harbor, N. Y.

An important collection of papers contributed by geneticists and anthropologists. Not for the beginner, but very stimulating to one who has become somewhat familiar with the subject.

BOULE, Marcellin—VALLOIS, Henri V.—1946. Les Hommes Fossiles. Éléments de Paléontologie Humaine. Troisième éd. Paris, Masson.

Any textbook or general survey in this field is at least partially out of date by the time it is published. The new fluorine method of dating, for instance, has changed many problems since this book was issued. However, it remains an excellent source-book, with many illustrations. It adds to the pioneer work of Boule the careful and solid qualities of Vallois. It is, in fact, the best general but technical book on human paleontology I know, and includes correlated information on prehistoric cultures.

BOYD, William C.—1950. Genetics and the Races of Man. An Introduction to Modern Physical Anthropology. Boston, Little, Brown.

With minor flaws (such as a lack of appreciation of the contributions of morphological studies) a sound and stimulating book. In addition, it contains up to date and concise descriptions of genetics, population studies, etc.—precisely the factors that make all the difference in the understanding of evolution. Should be read by all.

BRODRICK, A. H.—1948. Early Man. A Survey of Human Origins. London, Hutchinson's Scientific and Technical Publications. A very sound semi-popular book, well documented paleontologically. This book goes into more detail about more fossil types than does the work of Fr. Murray. Its geographical division is useful. A glossary at the end.

DOBZHANSKY, Th.—1941. Genetics and the Origin of Species. 2nd ed. New York, Columbia University Press.

Still one of the most important books the student of evolution must read. More recent work has, of course, added details and minor modifications, but the main structure continues fundamental. Dobzhansky's publications since 1941 should also be read by the advanced student.

FLINT, R. F.—1947. Glacial Geology and the Pleistocene Epoch. New York, Wiley.

A review, fairly technical, of present knowledge and theory concerning glacial geology. Not the great work that Wright's was, but satisfactory. Since the glaciations were the great environmental rhythms of the Age of Early Man, an appreciation of their nature and function is imperative to a student of human evolution. For the student who has gone through the elementary books.

GREGORY, W. K.—1951. Evolution Emerging. A Survey of Changing Patterns from Primaeval Life to Man. 2 vols. New Pork, Macmillan.

A monumental work, in one volume of text and one of illustrations. In the text there is discussion of the various groups of animals, all of them. The part on Man is too short, for our interest. The illustrations are an invaluable collection. The result of a lifetime's study this work is top priority. One will prescind, in a kindly way, from the rather naive philosophical remarks, especially at the end of the text.

HOOTON, E. A.—1942. Man's Poor Relations. New York, Doubleday, Doran.

The only book of which I am aware, that collects all the known facts about Primates other than Man, not only anatomical but ecological (and even humorous).

HOOTON, E. A.—1946. Up from the Ape. Rev. ed. New York, Macmillan.

Although considerably outdated, especially in some portions, this book is still very useful for a number of purposes. There is an adequate discussion of the major fossils; for modern man, there is one of the best racial classifications ever made. A great deal of information on Primates other than Man, and much information on the life cycle and other subjects usually presumed, is included. Hooton is the most prominent of the older generation of anthropologists, but has kept alive to changes, too.

HOWELLS, W. W.—1945. Mankind So Far. New York, Doubleday, Doran.

A popular, very well written book, on the whole quite sound. More about modern races than is usual in such books may be

found in the second half. Very good for the beginner. Might well precede the reading of Fr. Murray's book.

HUXLEY, Julian (ed.)—1940. The New Systematics. London, Oxford University Press.

A "must" for the advancing student. Finally taxonomy catches up with evolution, or rather, every phase of evolutionary studies is integrated (at least inchoatively) by taxonomy. A large number of important papers, with a fine introduction by the editor. For the advancing student.

HUXLEY, Julian—1942. Evolution. The Modern Synthesis. London, Allen & Unwin.

Another "must" book, even if it is difficult reading. A phenomenal amount of documentation and broad coverage of the subject. For the advancing student.

JEPSEN, G. L., Mayr, E., and G. G. Simpson. (ed.)—1949. Genetics, Paleontology, and Evolution. Princeton, Princeton University Press.

A very important book, the individual papers of which are of varying values, especially for the general reader. For those somewhat familiar with the subject, even the short summary papers are useful. For me, personally, the most revealing article was that on comparative anatomy. All in all, a valuable sourcebook, and a milestone in the progress of the synthetic theory. For the student who has got beyond elementary books.

KEITH, Sir A.—1929. The Antiquity of Man. 2 vols. London, Williams and Norgate.

KEITH, Sir A.—1931. New Discoveries Relating to the Antiquity of Man. London, Williams and Norgate.

These are old books, now, but I include them because no serious student of human evolution should miss reading them, because of what in them remains true today, and because the descriptions of the sites and circumstances of discovery of the various finds make pleasureable reading, written as they are in Keith's urbane style.

LE GROS CLARK, W. E.—1950. History of the Primates. 2nd ed. London, British Museum (Natural History).

An eminently useful book, because it is a handbook, designed for the intelligent general reader, yet written by one of the foremost students of the paleontology of Man. For the beginner, but to be kept by one for later use as well. An outline of Le Groso Clark's view of the course of evolution is of continuous value.

LULL, R. S.—1951. Organic Evolution. 3rd ed. New York, Macmillan.

I have not yet seen the third edition, but I imagine it has brought this useful and very general work up to date. It has always been

[82]

a valuable source book. One of the few nuclear books for the student who has gone beyond the very first steps of the popular books.

MARCOZZI, V.—1948. Evoluzione o Creazione. Le Origini dell'-Uomo. Terza edizione riveduta e ampliata. Milano, Casa Editrice Ambrosiana.

A fairly complete, somewhat traditional review of the whole field of human evolution by a Professor at the Gregorian University (a Jesuit). Leans heavily on the morphological and paleontological aspects. Valuable to a Catholic for the discussions of philosophical and theological implications. Fr. Marcozzi is favorable to evolution, although at times he gives somewhat less weight of certitude to some of the evidence than I should.

MAYR, Ernst.—1942. Systematics and the Origin of Species. New York, Columbia University Press.

A masterly exposition of geographical speciation. A "must" book for all who would wish to go to a more professional knowledge of evolution. For the somewhat advanced student.

MURRAY, Raymond W.—1948. Man's Unknown Ancestors. The Story of Prehistoric Man. Milwaukee, Bruce.

A very readable survey of human evolution, from the paleontological and prehistorical viewpoints, by a Notre Dame priest (C.S.C.). A large section is concerned with the American Indians, who are interesting but not pertinent to the main problem. There is a final chapter on the relations of science and religion *re* evolution. A "must" book for the beginning student; certainly the best book to be recommended to the general and inquiring reader.

ROMER, A. S.—1945. Vertebrate Paleontology. 2nd ed. Chicago, University of Chicago Press.

An authoritative and complete text, which serves as a good background for the study of human evolution, since it gives the general picture of the whole vertebrate phylum. More easily readable, but less detailed, is Romer's "Man and the Vertebrates," 3rd ed., U. of Chicago Press, 1941.

SIMPSON, George Gaylord—1944. Tempo and Mode in Evolution. New York, Columbia University Press.

This book is extraordinarily provocative of thought, and must be read by every serious student of evolution. It discusses rates, determinants and sundry ways of evolution, always with much originality and point. The same subject is taken up much more briefly in Simpson's paper in "Genetics, Paleontology, and Evolution", (cf. supra). There is also a very condensed section on rates in "The Meaning of Evolution". (cf. infra).

SIMPSON, G. G.—1949. The Meaning of Evolution. A Study of the History of Life and of Its Significance for Man. New Haven, Yale University Press.

The first part of this book gives in rapid outline a general conspectus of the course of evolution. This is useful for Simpson is a premier paleontologist and one of the foremost figures in the synthetic school. The rest of the book is only to be read by specialists. Part II deals with the immediate interpretation of evolution (orthogenesis, progress, etc.), and contains much that Catholics would argue with, but that specialists should read because they should know varieties of opinion. Part III, entitled "Evolution, Humanity, and Ethics", is philosophically (and therefore theologically) vitiated. Young students should not be given this book to read.

SINNOTT, E. W., DUNN, L. C., and Th. Dobzhansky—1950. Principles of Genetics. New York, McGraw-Hill.

A good standard text in genetics, brought up to date. One should have gone through this or a similar text, before reading Dobzhansky's "Genetics and the Origin of Species", and other works dealing with evolution and genetics.

STERN, Curt.—1949. Principles of Human Genetics. San Francisco, Freeman.

An excellent introduction to the subject, very readably written. The first book to read or to consult, when starting a student on this field. A text on genetics in general is not presupposed in this book, but having read one first is no harm.

WEIDENREICH, Franz—1943. The Skull of Sinanthropus Pek.; a Comparative Study on a Primitive Hominid Skull. *Palaeontologia Sinica*, n. s. D, No. 10; whole ser., No. 127.

A complete study of the Sinanthropus skull, and a classic. Particularly valuable because of the comparative material, both in text and in illustrations. This is a sample of what Weidenreich produced; bibliographies will furnish references to his important works on the mandible, teeth, etc.

WEIDENREICH, Franz.—1946. Apes, Giants, and Man. Chicago, University of Chicago Press.

A small book, summarizing in quite readable form the recent finds of Gigantopithecus, Meganthropus and Pithecanthropus robustus. A more technical discussion of the fossils is in Weidenreich's "Giant Early Man from Java and South China," *Anthropological Papers, Amer. Mus. Nat. Hist.*, vol. 40, part 1, 1945. There certainly was a large dose of gigantism and robusticity in the Far Eastern early men, but I do not see my way clear to agreeing with Weidenreich on a giant ancestry for Man. This is especially true, since the evidence is based on skulls and teeth only. I do not plump for the hominid or hominoid status of Gigantopithecus solely on the basis of a few teeth.

WRIGHT, Sewall.—1949. Population structure in evolution. *Proc. Amer. Phil. Soc.*, vol. 6, pp. 471-478.

Since Wright has written only papers, I must depart from the rule of citing only more or less general books. However, this paper gives a non-mathematical summing up of his present thought, and references to past papers. There is also a contribution in "Genetics, Paleontology, and Evolution" (cf. supra). Wright's work has been in the important one of population studies, which he has attacked mathematically.

ZEUNER, Frederick E.—1946. Dating the Past. An Introduction to Geochronology. London, Methuen.

Although the astronomical method of absolute dating for Pleistocene events is the central thesis of this book, the volume still contains much valuable information on other methods and on specific sites connected with early Man. The astronomical method is controverted by many, probably the majority, of other workers in the field. In my own opinion, it is to be rejected.

Science and Philosophy

PHILOSOPHICAL IMPLICATIONS OF PHYSICAL STATISTICS
(*Continued*)

4d. THE BOSE-EINSTEIN STATISTICS[57]

In the Bose statistics the momentum-space of the photons is to be divided into equal compartments, and various distributions of the particles among these are to be compared in order that one of them may be chosen as the most probable, and thus create a picture of the entropy of the assemblage. But the manner of defining a distribution in Bose statistics, the manner of counting the ways in which a distribution may be realized, and finally the procedure for computing its probability, is changed in a most complete and fundamental manner.

One starts with any distribution of the particles, defined by saying that there are N_0 of the particles in the compartment O, N_1 in the compartment 1, and in general N_i in the compartment i. Count the number of compartments that contain no particle; call it Z_0. Count the number of compartments containing one particle each; call it Z_1. In general, let Z_i represent the number of compartments each one of which contains i particles. Transcribe the values of all the numbers Z_i.

Now revise the terminology. Elect some neutral term, e.g., 'ar-

rangement', to denote what has heretofore been called 'distribution', and reserve 'distribution' for the following new sense: a 'distribution' is henceforth to be described by stating the values of the numbers: $Z_0, Z_1, Z_2 \ldots Z_i \ldots$, and the total energy of the assemblage. This means in effect that each distribution in the newer sense comprises a number of distinct distributions in the former signification. This is now to be regarded as the number of different ways in which the distribution (in the new sense) may be realized. One now identifies the probability W' of a distribution with the number of arrangements that are included within it. Previously one had identified the probability W of an arrangement with the number of permutations included within it. This policy is now abandoned. One proceeds as if the probability of each arrangement were the same.

In computing the value of W' note that one must count, not the total number of arrangements yielding the prescribed set of values of the quantities Z_i, but rather that portion of these which give the prescribed value to the total energy of the assemblage. Now superimpose upon the previous partition of the momentum-space into small compartments of equal volume, another partition into equal shells, each of which is sufficiently large to contain any of the compartments, yet sufficiently small so that the same value for the relation between energy and momentum may be assigned to all the compartments within it. The final outcome thus will be a smoothed-out formula.

Consider now any random shell s. Denote by Q_s or by Z the total number of compartments that it contains, by Z_{is} the number of those compartments each of which contains i particles, and by M_s the number of particles in the shell. Let the total number of ways of attaining the particular distribution characterized by the numbers Z_{is} be W'. As the energy values for all the compartments in the shell are by hypothesis approximately the same, the various ways of attaining the distribution Z_{is} all correspond approximately to the same total energy, as well as to the same total number of compartments and the same total number of particles.

Assume this process to be repeated for every one of the shells s. Then the total number of ways of achieving the actual distribution, compatible with the conditions of total energy, total number of compartments, and total number of particles, is the product of all the quantities W'_s. Call it simply W'. Now form the expression for log W' and then *identify* log W', multiplied by a constant k, with the entropy of the assemblage:

$$S = k \log W'.$$

By thus proposing a new conception of entropy the Bose-Einstein statistics leads to a new distribution for thermal equilibrium. This distribution is expressed by stating the number of compartments in each shell which contain each of the permissible quotas of particles.

[86]

4e. The Fermi-Dirac Statistics

The statistics invented by Fermi and later independently by Dirac, involves the same fundamental assumptions of Bose-Einstein. There reappears the same manner of counting the ways in which a distribution may be realized, of defining its probability, of picturing its entropy. But there is an additional assumption that functions in the theory after the fashion of a restriction. It is here postulated that a compartment may contain not more than some specified maximum number of particles. In particular, for a gas to which no external field is applied, it is postulated that each compartment must be empty or else contain at most one and only one particle.

It was the exclusion-principle of Pauli that supplied the suggestion which the Fermi-Dirac statistics developed. The reasoning of Fermi follows exactly the same Bose-Einstein course in the derivation of the distribution law, except that now all the summations over the variable i are summations of two terms only: $i = 0$ and $i = 1$. For each of the shells there are two and only two numbers Z_{is} required to describe the distribution, namely, Z_{os}, or the number of empty compartments, and Z_{1s}, or the number of compartments that contain at most one and only one particle each. At this point it is easy to calculate the distribution of maximum probability by comparing its formula with all of the others that satisfy the conditions of same total number of particles and same total energy. One can then derive the formula for the number of particles in a shell s.

It is thus obvious that the further development of atomic physics during the last decades has altered the character of physical statistics to such a degree that statistical mechanics has been obliged to extend its mathematical apparatus in order to include quantum phenomena. From the contemporary point of view one must regard quantized systems as a general type of which the classical systems become a limiting case. Quantum statistics however also presents some new mathematical problems. Thus the justification of the special principles of statistical calculations which are the basis of the Bose-Einstein and Fermi-Dirac statistics require mathematical arguments which are distinct in principle (and not only in their mathematical apparatus) from all those treated in the classical statistical mechanics. Nevertheless it seems in general that the transition from classical systems to quantum systems does not introduce any essentially new mathematical problems. For any method of justification in statistical mechanics seems to require only an extension of the analytical apparatus in order to be reapplied to quantized systems. This does of course introduce some minor difficulties of a technical nature, e.g., where one used before finite sums or series, one needs now to operate with integrals, and continuous distributions of probability are replaced by discrete ones. But in general quantum mechanics is shown to reduce to classical mechanics for systems of large mass and/or systems free to move without effective confinement. Ordinary bodies of daily experience conform to

these conditions. It is therefore proper to regard quantum mechanics as the more general discipline which takes the form of ordinary mechanics in all circumstances under which the latter is known to be valid.

5. PROBABILITY IN CLASSICAL AND QUANTUM STATISTICS[58]

But there are significant differences between the two and it is important to discern wherein they lie. In classical physics in general a situation is determined if the parameters $q_1 \ldots q_n$ and $p_1 \ldots p_n$ are given. Let q be written for $q_1 \ldots q_n$ and p for $p_1 \ldots p_n$. Let values at the time t_0 be indicated by the subscript $_0$. One may then summarily condense the derivative relations of classical physics as follows:

if one is given:
(1) the values of q_0 and p_0 at the time t_0, and
(2) the laws of classical physics,
then there are determined:
(3) the value u_0 of every other entity concerned at t_0,
(4) the values q_t and p_t of q and of p at a time t, and
(5) the value u_t of any other entity u at a time t.

The routine derivation of (3)—(5) is achieved by means of mathematical functions which depict the (deterministic) causal laws involved.

Now it so happens that there are certain areas of physical investigation where the values of q_0 and of p_0 cannot *in point of fact and in practice* successfully be measured exactly. This is the problem which makes classical statistical mechanics procedurally and methodologically necessary. For the systems of statistical mechanics, *leaving the (deterministic) casual laws of physics intact,* undertake to substitute for the practically immeasurable values of q_0 and p_0 the statement of their probability distributions. Classical statistical mechanics is therefore an adroit combination of statistical methods and of classical (deterministic) physical laws.

Let us write such probability distributions at the time t_0 in the form: $d_0(q)$, $d_0(p)$, and $d_0(q, p)$, the latter function giving the probability of combinations of values of q and p. Then the derivative relations of classical statistical mechanics may be written as follows:

If one is given
(1) the probability distribution $d_0(q, p)$ at the time t_0, and
(2) the laws of classical physics,
then there are determined:
(3) the probability distributions $d_0(q)$, $d_0(p)$, and the probability distribution $d_0(u)$ of every other entity concerned at the time t_0,
(4) the probability distribution $d_t(q, p)$ at the time t, and
(5) the probability distributions $d_t(q)$, $d_t(p)$, and the proba-

[88]

bility distribution $d_t(u)$ of every other entity concerned at the time t.

If we now compare both cases above, it is clear that the distinction between $d_0(q, p)$ and $d_0(q)$, $d_0(p)$, entails a further important distinction. The first distribution $d_0(q, p)$ appears within the statistical scheme in the category of what must be given, whereas the latter two distributions $d_0(q)$, $d_0(p)$, are included in the category of what is thereby determined. And it is important to realize that this determination cannot be reversed, i.e., the distribution $d_0(q, p)$ of the combinations is not determined merely by the individual distributions. Only in case it is known that q and p represent independent entities can it be written that:

$$d_0(q, p) = d_0(q) \times d_0(p).$$

But this application of the Special Product Theorem of the calculus of probability presupposes some definite physical knowledge about the independence of q and p. Without such additional knowledge the function $d_0(q, p)$ must be directly given; and in general it will not have the precise form of the Special Product Theorem. But if neither such surplus information nor a statement of the function $d_0(q, p)$ is at hand, knowledge of the individual distributions $d_0(q)$, $d_0(p)$ alone will not suffice to determine the corresponding functions $d_t(q)$ and $d_t(p)$ at a later time.

The function $d_0(q, p)$ therefore may be said to determine the probability state of the system, or its physical situation, so far as it can be stated in statistical terms. For if $d_0(q, p)$ is known, all the other probability distributions are determined. Hence, given $d_0(q, p)$, the probability of every combination of values of q and p is also known. Now the (deterministic) causal laws of physics coordinate to every combination of q and p a specific value u; the probability distribution therefore $d_0(u)$ is also determined. Similarly the causal laws coordinate to every combination of values of q and p a value of q or of p at a later time. Hence the probability distributions of these values are also determined.

So much then for classical physics and classical statistical mechanics. Before however passing on to quantum statistics, it is necessary to recall briefly the basic principles of quantum mechanical method:

(1) the characterization of physical entities in a given context by operators, eigen-functions, and eigen-values, determined by the first Schrödinger equation;

(2) the characterization of the physical situation by a function ψ which determines the probability distributions and is inversely determined by these distributions;

(3) the law of the time dependence of ψ, given in the second Schrödinger equation, and

(4) the quantum-mechanical definition of measurement as a physical operation relative to which the ψ function of the

[89]

physical system is represented by one of the eigen-functions of u, or by one of the practical eigen-functions of u.

The principle of indeterminacy and the disturbance of the object by the measurement process are not included as basic principles because they are derivable from (1)—(4) above.[59]

In quantum mechanics therefore the analogue of the probability distribution $d_0(q, p)$ of classical statistical mechanics is the complex function $\psi_0(q)$, if we write this expression for $\psi(q, t_0)$, i.e., the form of the ψ function at the time t_0. Like $d_0(q, p)$, the function $\psi_0(q)$ determines the probability state of the system, and also the physical situation of the system so far as this is possible in quantum physics. With these conventions one may express the derivative relations of quantum mechanics, as follows:

If one is given:

(1) the complex function $\psi_0(q)$ at the time t_0, and
(2) the laws of physics,[60]
then there are determined:
(3) the probability distributions $d_0(q)$, $d_0(p)$, and the probability distributions $d_0(u)$ of every other entity concerned at the time t_0;
(4) the complex function $\psi_t(q)$ at the time t, and
(5) the probability distributions $d_t(q)$, $d_t(p)$, and the probability distribution $d_t(u)$ of every other entity concerned at the time t.

Comparisons here are instructive and enlightening. For as in the classical statistical case, the two probability distributions $d_0(q)$ and $d_0(p)$ are not sufficient to determine the probability state, since the latter distributions do not determine the function $\psi_0(q)$. The function $\psi_0(q)$ thus resembles the function $d_0(q, p)$ so far as it states more than the individual distributions. There is however a remarkable difference. The complex function $\psi_0(q)$ is determined by a pair of two other probability distributions, for example, by the pair of two consecutive functions $d_0(q)$ and $d_1(q)$. Whereas therefore the complex function $\psi_0(q)$ represents a pair of two probability distributions in one variable, the function $d_0(q, p)$ is in general superior to such a pair. For, apart from special cases of mutual and exclusive independence, it is impossible to determine a function of two variables in terms of two functions of one variable. And this holds true when we replace q and p by the sets $q_1 \ldots q_n$ and $p_1 \ldots p_n$. For the function $d_0(q_1 \ldots q_n, p_1 \ldots p_n)$ which has 2n variables is in general superior to a pair of two functions of n variables each. It is clear then that the probability state which is termed a quantum mechanical situation, or a pure case, is of a special kind. Hence, if the number of parameters of the classical problem is 2n, the probability state of the quantum mechanical problem is expressible in terms of two probability distributions of n variables each. It is this fundamental fact which is expressed by the use of a complex function ψ for the

characterization of a quantum mechanical situation. Only for a mixed case, where an assemblage cannot be described in terms of a single ψ-function, is a function of 2n arguments needed, comparable to $d_0(q_1 \ldots q_n, p_1 \ldots p_n)$.

The physical situations of quantum mechanics thus represent statistical cases of a special type, which may be compared with the classical statistical cases of the independence type, i.e., cases in which the function $d_0(q, p)$ bifurcates into two functions $d_0(q)$ and $d_0(p)$. But this is merely an analogy. For the quantum mechanical situation cannot be conceived as a situation in which the parameters q and p are independent because $d_0(q)$ and $d_0(p)$ do not determine $\psi_0(q)$. There is no way of deriving any statement that speaks about a distribution $d_0(q, p)$ in a quantum mechanical situation. Hence no statement with respect to a Special Product Theorem form of this distribution is valid or legitimate. Quantum mechanics therefore does not include any statements about simultaneous values of q and p.

The intervention of the function $d_0(q, p)$ in classical statistical mechanics derives from the fact that these methods employ (deterministic) causal laws that correlate with a combination q, p the later values of these entities, or values of an entity u, in the sense of a mathematical function. If such laws are necessary for the determination of these values, then a knowledge of the probability of the combination q, p is necessary. The fact that the quantum-mechanical method does not use a function $d_0(q, p)$ shows that this method does not include the assumption of any such (deterministic) laws.

This difference may be explained as follows: a (deterministic) causal law is interpretable as the limit of probability relations, resulting when both distributions $d(q)$ and $d(p)$, or the distribution $d(q, p)$, approach concentrated distributions. The probability distributions then degenerate to the values at the center of the concentrated distributions, and operators degenerate into functions. But the relation of indeterminacy discloses that it is not possible to find physical situations in which both distributions $d(q)$ and $d(p)$ are concentrated. It is not possible therefore to verify (deterministic) causal laws of the classical type to any desired degree of approximation. There is a limit to this approximation, set by the relation of indeterminacy. This is why quantum-mechanical statistics does not employ such laws.

6. Philosophical Implications of 1 — 5[61]

I conclude (1) that the classical statistical mechanics of Maxwell-Boltzmann, of Gibbs and of Darwin and Fowler, is an apt *methodology* the *probability* predictions of which are a constructed technical device, not prescribed *in principle* by any known or presumed properties of the elements in its *Kollektiv*, but solely by their otherwise unmanageable multitude. It follows that the success of these methods

leaves intact, wherever established, a philosophical world-view that ascribes a universal and inescapable determinism *of conventional type* to each and every unit entity in the material universe of physical science.[62]

I conclude (2) that the quantum-mechnical statistics of Bose-Einstein and Fermi-Dirac is an apt *method* the *probability* predictions of which are not merely a constructed technical device but prescribed *in principle* by the known or presumed properties of the elements in its *Kollektiv* and altogether independently of their otherwise un-manageable multiplicity. It follows that the success of hese methods does not leave intact, wherever established, a philosophical world-view that ascribes a universal and inescapable determinism *of the conventional type* to each and every unit entity in the material universe of physical science.[63]

It happens that this contemporary abolition of *conventional* determinism in physical science may be interpreted in two ways: (1) one gives an exclusively *epistemological* significance to Heisenberg's indeterminacy relation and maintains that, although physical science cannot now know with equal accuracy both the position and the velocity of a fundamental 'particle', for example, yet physical unit entities must necessarily possess simultaneously a determinate pair of such values.[64] Or (2) one accepts the *ontological* implications of the indeterminacy relation, and acknowledges that it makes no sense to claim to know that 'particles' possess simultaneously 'unknowable' space and time coordinates.

If one selects the first and epistemological interpretation, then the core of conventional determinism remains intact, but it loses its glamour and aura of omniscience and is stripped of its trappings as a reasoned, analytical conviction of philosophy and is in fact reduced to the status of an ineffable insight, as impervious to criticism as it is devoid of all logical grounds.[65] If one chooses the second and, I think, preferable interpretation, then some reputable sort of de-terminism may remain in good philosophical standing, but it can *not* be of the conventional type.

To survive in the contemporary context of physical research, a responsible philosophical determinism that espouses on good grounds an authentic order of nature, must undergo revision at some crucial points. This redaction of a philosophical tradition is a delicate and a difficult affair. But the attempt must be made.[66]

At the risk of welcome correction I submit a central area within which revision may successfully be engineered. I focus the issue on what has been called in quantum phenomena "the loss of individuality of the 'particle' ".[67] And I contend that upon careful reexamination and reinterpretation the very same physical evidence, adduced by some for the loss of individuality of the 'particle', are grounds and proof and expression of the precise and inalienable individuality of the 'particle'.

The nub of this suggestion is found in two declarations: (1) 'quantum' physics is paradoxically 'quale' physics insofar as it re-admits into physics analogues of the metaphysical category of quality, namely a diversity of modes or ways in which an identical quanti-tative entity may 'have itself'; (2) indeterminacy is the quantum analogue of individual personality.

These statements are at least provocative, if not profound, and I may be permitted to explain them further. I rest my case upon the forgotten distinction between the *nature* of an individual unit entity and the irreducibly different and incommunicable *individuality* [*suppositum*] of it. And *individuality is a surd,* inevitably and irre-mediably associated with a certain variable amount of 'degrees-of-freedom', utterly irreducible to formulation in laws. In areas of investigation of the same order of dimensions as the individuality of the object the determinations of nature wobble within the range of the irreducible 'degrees-of-freedom' of the unit object. This in-determinacy is not a disappearance of the individuality of the object. It is the precise expression of it.

On the level of observable human activity the conspicuous free-dom of rational nature obscures for us the irreducible idiosyncracies of the individual who exercises it. If all men are free, it is no less true that no two single persons have ever made the same category of objective choice in precisely identical and indistinguishable ways. And no single individual ever repeats a choice in exactly the same way. But these individual idiosyncracies of choice are negligible in the large view of social statistics and do not, for example, appreciably affect the standard *J*-curve of institutionalized behavior. For the con-spicuous freedom of rational nature obscures the uniquely individual reactions of the single person. I have called 'indeterminacy' the quan-tum analogue of personality. But personality has other analogues in the individuality of single specimens of animal and plant life. And it does seem possible to work out a hierarchical scale of analogues, descending from human personality to quantum indeterminacy. Such an analogical scale has excellent philosophical precedents. And the results of this analysis would disclose (1) that whereas there is no indeterminacy of *nature* in the universe of physics, as there is in the world of man, (2) nevertheless there is an irreducible and irremedi-able indeterminacy of the *individual* subject of a determined nature, which the large masses and unrestricted motions of macroscopic ex-perience tend to mask and obscure.

If this proposal makes good sense and its development succeeds, then one might correlate physical statistics and 'laws of nature' (in a strictly philosophical sense) in the following way: (1) classical statistical mechanics are in fact irrelevant to laws of nature; (2) quantum statistical mechanics are indeed relevant to laws of nature but leave them intact as laws of *nature*, which however are perfectly compatible with idiosyncratic indeterminacy of individuals.

References

[1]For a conveniently integrated and systematic presentation see Robert B. Lindsay, *Introduction to Physical Statistics* (New York: John Wiley and Sons, Inc., 1941), pp. 50-69.

[2]Josiah Willard Gibbs, *Elementary Principles in Statistical Mechanics* (New York: Charles Scribner's Sons, 1902).

[3]C. G. Darwin and R. H. Fowler, "On the Partition of Energy", *The Philosophical Magazine and Journal of Science* 44 (1922) 450-479; iidem, "On the Partition of Energy: Part Two", *ibidem* 823-842; iidem, "Partition Functions for Temperature Radiation and the Internal Energy of a Crystalline Solid", *Proceedings of the Cambridge Philosophical Society* 21 (1922-1923) 262-273; iidem, "Fluctuations in An Assembly in Statistical Equilibrium", *ibidem* 391-404; R. H. Fowler (with the aid of C. G. Darwin), "Dissociation-equilibria by the Method of Partitions", *The Philosophical Magazine and Journal of Science* 45 (1923) 1-33; C. G. Darwin and R. H. Fowler, "Some Refinements of the Theory of Dissociation Equilibria" *Proceedings of the Cambridge Philosophical Society* 21 (1922-1923) 730-745; R. H. Fowler, "Thermodynamics and Statistical Mechanics", *The Philosophical Magazine and Journal of Science* 45 (1923) 497-516; R. H. Fowler, *Statistical Mechanics* (Cambridge: Cambridge University Press, 1929).

[4]Bose, "Plancks Gesetz und Lichtquantenhypothese", *Zeitschrift für Physik* 26 (1924) 178-181. The article is translated for the journal by A. Einstein who appends these remarks: "Boses Ableitung der Planckschen Formel bedeutet nach meiner Meinung einen wichtigen Fortschritt. Die hier benutzte Methode liefert auch die Quantentheorie des idealen Gases, wie ich an anderer Stelle ausführen will". See thus A. Einstein, "Quantentheorie des einatomigen idealen Gases", *Sitzungsberichte der Preussischen Akademie der Wissenschaften, physikalisch-mathematische Klasse* (1924) 261-267; (1925) 3-14.

[5]E. Fermi, "Zur Quantelung des idealen einatomigen Gases", *Zeitschrift für Physik* 36 (1926) 902-912; *idem*, "Eine statistiche Methode zur Bestimmung einiger Eigenschaften des Atoms und ihre Anwendung auf die Theorie des periodischen Systems der Elemente", *ibidem* 48 (1928) 73-79; *idem*, "Statistische Berechnung der Rydbergkorrektionen der S-Terme", *ibidem* 49 (1928) 550-554; *idem*, *Quantentheorie und Chemie* (Leipzig: S. Hirzel, 1928), pp. 95-111. See also P. A. M. Dirac, "On the Theory of Quantum Mechanics", *Proceedings of the Royal Society of London* A 112 (1926) 661-677; *idem*, "The Quantum Theory of the mission and Absorption of Radiation", *ibidem* A 114 (1927) 243-265, and compare V. Fock, "Verallgemeinrung und Lösung der Diracschen statistischen Gleichung", *Zeitschrift für Physik* 49 (1928) 339-357.

[6]The statistical theory of errors is now a very large subject. The above abbreviated survey is restricted exclusively to the normal law and has disregarded other known types of error distributions found in practice. An excellent review of the entire field in terms of the latest information is found in W. Edwards Deming and Raymond T. Birge, "On the Statistical Theory of Errors", *Reviews of Modern Physics* 6 (1934) 119-161. The preceding account follows in large meas-

ure the neat exposition by R. B. Lindsay, *Introduction to Physical Statistics* (New York: John Wiley and Sons, Inc., 1941), pp. 33-39. For a standard reference work on statistics in general consult G. Udny Yule and M. G. Kendall, *An Introduction to the Theory of Statistics*[14] (New York: Hafner Publishing Co., 1950).

[7]The literature is immense. A competent introduction to both the subject and its bibliography is given by Ernest Nagel, "Principles of the Theory of Probability", *International Encyclopedia of Unified Science* 1. 6 (Chicago: University of Chicago Press, 1947).

[8]Henri Poincaré, *Calcul des probabilités* (Paris: Gauthier-Villars, 1912).

[9]Jean Ville, *Étude critique de la notion de collectif* (Paris: Gauthier-Villars 1939).

[10]John Maynard Keynes, *A Treatise on Probability* (London: Macmillan and Co., Ltd., 1929).

[11]Jacobi Bernoulli . . . *Ars Conjecturandi* . . . . (Basileae: Impensis Thurnisiorum Fratrum, 1713), pp. 211, 214, 218-219, and *passim*. Another classic is that of Laplace, *Théorie analytique des probabilités*[2] (Paris: Courcier, 1814).

[12]J. von Kries, *Die Principien der Wahrscheinlichkeitsrechnung: eine logische Untersuchung* (Freiburg in Breisgau: J. C. B. Mohr, 1886).

[13]Emanuel Czuber, *Wahrscheinlichkeitsrechnung und ihre Anwendung auf Fehlerausgleichung, Statistik und Lebensversicherung*[2] (Leipzig: B. G. Teubner, 1908).

[14]See note 11.

[15]Corrado Gini, "Gedanken zum Theorem von Bernoulli", *Schweizerische Zeitschrift für Volkswirtschaft und Statistik* 82 (1946) Heft 5; *idem*, "Concept et Mesure de la probabilité", *Dialectica* 3 (1949) 36-54.

[16]See note 8.

[17]Émile Borel, *Éléments de la théorie des probabilités* (Paris: A. Herman et fils, 1909); *idem, Principes et formules classiques du calcul des probabilités* (Paris: Gauthier-Villars, 1925).

[18]Paul Lévy, *Calcul des probabilités* (Paris: Gauthier-Villars, 1925).

[19]Emanuel Czuber, *Die philosophischen Grundlagen der Wahrscheinlichkeitsrechnung* (Leipzig: B. G. Teubner, 1923).

[20]Paul Finsler, "Über die mathematische Wahrscheinlichkeit", *Elemente der Mathematik* (Leipzig: S. Hirzel, 1947), Volume 2, Section 6.

[21]See note 15.

[22]Guido Castelnuovo, *La probabilité dans les différentes branches de la science* (Paris: Herman et Cie., 1937).

[23]Corrado Gini, "Über statistische Beziehungen und deren Inversion", *Schweizerische Zeitschrift für Volkswirtschaft und Statistik* 83 (1947) Heft 6.

[24]Antoine A. Cournot, *Exposition de la théorie des chances et des probabilités* (Paris: L. Hachette, 1843).

[25]L. Ellis, "On the Foundation of the Theory of Probabilities", *Transactions of the Cambridge Philosophical Society* 8 (1843) 1-6.

[26]John Stuart Mill, *A System of Logic*[8] (London: Longmans, Green, Reader and Dyer, 1872) Book 3 in Volume 2.

[27]John Venn, *The Logic of Chance: An Essay on the Foundations and Province of the Theory of Probability* (London: Macmillan, 1866).

[28]See note 12.

[29]H. Bruns, *Wahrscheinlichkeitsrechnung und Kollektivmasslehre* (Leipzig: B. G. Teubner, 1906).

[30]K. Marbe, *Die Gleichförmigkeit in der Welt: Untersuchungen zur Philosophie und positiven Wissenschaft* (München: C. H. Beck'sche Verlagsbuchcandlung, 1916).

[31]R. A. Fisher, "On the Mathematical Foundations of Theoretical Statistics", *Philosophical Transactions of the Royal Society of London* A (1922) 309-368.

[32]R. von Mises, "Grundlagen der Wahrscheinlichkeitsrechnung", *Mathematische Zeitschrift* 5 (1919) 52-99; *idem*, *Wahrscheinlichkeit, Statistik und Wahrheit* (Wien: Julius Springer, 1928); *idem*, *Wahrscheinlichkeitsrechnung und ihre Anwendung in der Statistik und theoretischen Physik* (Leipzig: Franz Deuticke, 1931); *idem*, *Mathematical Theory of Probability and Statistics* (Cambridge, Mass.: Harvard University Graduate School of Engineering, 1946). There is an English translation of item 1, *Probability, Statistics, and Truth* (New York: Macmillan and Co., 1939). And see W. Feller, "The Fundamental Limit Theorems in Probability", *Bulletin of the American Mathematical Society* 51 (1945) 800-832. And compare the important piece by E. C. Kemble, "Is the Frequency Theory of Probability Adequate for All Scientific Purposes?", *American Journal of Physics* 10 (1942) 6-16.

[33]J. L. Coolidge, *An Introduction to Mathematical Probability* (Oxford: Oxford University Press, 1925).

[34]J. H. Baptist, *Analyse des probabilités* (Louvain: Librairie Universitaire, 1947).

[35]Johann Frederick Steffensen, *An Introduction to the Theory of Probability* (London: published for the Institute of Actuaries, 1948).

[36]Karl Popper, *Logik der Forschung: zur Erkenntnistheorie der modernen Naturwissenschaft* (Wien: Julius Springer, 1935).

[37]See note 9.

[38]L. Vietoris, "Über den Begriff der Wahrscheinlichkeit", *Monatshefte für Mathematik* 52 (1948) 55-85.

[39]A. H. Copeland, "Admissible Numbers in the Theory of Probability", *American Journal of Mathematics* 50 (1900) 535-552; *idem*, "The Theory of Probability from the Point of View of Admissible Numbers", *Annals of Mathematical Statistics* 3 (1932) 143-156; *idem*, "Consistency of the Conditions Determining Kolektivs", *Transactions of the American Mathematical Society* 42 (1937) 333-357.

[40]Erich Kamke, *Einführung in die Wahrscheinlichkeitstheorie* (Leipzig: S. Hirzel, 1932).

[41]K. Dörge, "Zu der von R. von Mises gegebenen Bergründung der Wahrscheinlichkeitsrechnung", *Mathematische Zeitschrift* 32 (1930) 232-258; *idem*, *Wahrscheinlichkeitsrechnung für Nichtmathematiker* (Berlin: B. G. Teubner, 1939). And in this connection see too Artur Pavelka, "Die Wahrscheinlichkeit als Grenzwert der relativen Haüfigkeiten: Kritik des Grundbegriffes der Statistik", *Divus Thomas* (Freiburg) 25 (1947) 409-436; 26 (1948) 26-46.

[42]E. Tornier, *Wahrscheinlichkeitsrechnung und allgemeine Integrationstheorie* (Leipzig: S. Hirzel, 1936).

[43]Hans Reichenbach, "Axiomatik der Wahrscheinlichkeitsrechnung", *Mathematische Zeitschrift* 34 (1931-1932) 568-619; *idem*, *Wahrscheinlichkeitslehre* (Leiden: A. W. Sijthoff, 1935); *idem*, *Experience and Prediction* (Chicago: University of Chicago Press, 1938). A revision and translation of *Wahrscheinlichkeitslehre* has appeared as *The Theory of Probability* (Berkeley of California Press, 1949).

[44]Abraham Wald, "Die Widerspruchsfreiheit des Kollektivbegriffes der Wahrscheinlichkeitsrechnung", *Ergebnisse eines mathematischen Kolloquiums*, Heft 8 (1935-1936) [Leipzig: Franz Deuticke, 1937] 38-72. See too Alonzo Church, "On the Concept of a Random Sequence", *Bulletin of the American Mathematical Society* 46 (1940) 130-135.

[45]See note 36.

[46]Oskar Anderson, *Einführung in die mathematische Statistik* Wien: Julius Springer, 1935).

[47]M. Fréchet, *Recherches théoriques modernes sur la théorie des probabilités* (Paris: Gauthier-Villars, 1937).

[48]J. Dubourdieu, *Les principes fondamentaux du calcul des probabilités et la théorie de l' assurance maladie* (Paris: Herman et Cie., 1939).

[49]A. Kolmogoroff, "Grundbegriffe der Wahrscheinlichkeitsrechnung", *Ergebnisse der Mathematik und ihrer Grenzgebiete* (Berlin: Julius Springer, 1933) Band 2, Heft 3.

[50]Andrei A. Markoff, *Wahrscheinlichkeitsrechnung* (Leipzig: B. G. Teubner, 1912).

[51]F. M. Urban, *Grundlagen der Wahrscheinlichkeitsrechnung und der Theorie der Beobachtungsfehler* (Leipzig: B. G. Teubner, 1923).

[52]See note 20.

[53]Harald Cramér, *Mathematical Methods of Statistics* (Princeton: Princeton University Press, 1946); *idem*, "Problems in Probability Theory", *Annals of Mathematical Statistics* 18 (1947) 165-193.

[54]On this whole matter see H. Jecklin, "Historisches zur Wahrscheinlichkeitsdefinition", *Dialectica* 3 (1949) 5-15. See also I. Todhunter, *A History of the Mathematical Theory of Probability from the Time of Pascal to that of Laplace* (London: Macmillan and Co., 1865). For the contemporary American picture see "A Symposium on Probability", *Philosophy and Phenomenological Research* 5 (1945) 449-532 [D. C. Williams, E. Nagel, H. Reichenbach, R. Carnap]; 6 (1945) 11-86 [H. Margenau, G. Bergmann, R. von Mises, F. Kaufmann, D. Williams]; 6 (1946) 590-622 [R. Carnap, F. Kaufmann, R. von Mises, E. Nagel, D. C. Williams], and also *Proceedings of the Berkeley Symposium on Mathematical Statistics and Probability* (Berkeley: University of California Press, 1949).

[55]The ensuing account follows in large part the succinct exposition of Henry Margenau, *The Nature of Physical Reality* (New York: McGraw-Hill Book Co., Inc., 1950), pp. 273-277.

[56]The account which follows is indebted in large part to the able presentation of Henry Margenau, *The Nature of Physical Reality* (New York: McGraw-Hill Book Co., Inc., 1950), pp. 277-280.

[57]Here and in the following section the account follows closely the exposition of Karl K. Darrow, "Statistical Theories of Matter, Radiation, and Electricity",

The Physical Review Supplement, Reviews of Modern Physics 1 (1929) 90-155, pp. 109-114, 114-123. E. T. Whittaker, *From Euclid to Eddington* (Cambridge: at the University Press, 1949), pp. 180-181, thus picturesquely relates the various types of statistics:

. . . there are three kinds of statistics that are commonly found in assemblages of particles: the Maxwellian [of which Gibbsian and Darwin-Fowler methods are an extension], the Fermi-Dirac statistics, and a third kind called *Bose-Einstein* statistics. The differences between them may be explained roughly in this way. Suppose an empty railway train is standing at a platform and passengers are getting into it. If we make the assumption that every passenger chooses his compartment blind-folded, so to speak, without noticing whether other passengers are getting into it or not, then it would be possible to calculate the probability of any particular allocation of passengers among the compartments. This set of probabilities would constitute a statistics, and we may compare it to the Maxwellian statistics. If, however, we make the assumption that passengers like to have compartments to themselves, or at any rate like to have corner seats, then the probabilities of the different distributions of passengers among compartments would be altered. The probability would be raised for those distributions in which every compartment has at least one occupant and no compartment is crowded. This set of probabilities may be compared to the Fermi statistics. If, lastly, we make the contrary assumption that the passengers are very friendly and gregarious people, who don't like to be alone and who choose by preference compartments into which a lot of other people are going, then the probabilities of the different distributions would again be modified, this time in favour of those distributions in which some compartments are crowded and others quite empty. This set of probabilities may be regarded as analogous to the Bose statistics. The Maxwellian statistics is a kind of limiting case between the Fermi statistics and the Bose statistics, just as the parabola is the limiting case between the ellipse and the hyperbola. Fermi statistics and Bose statistics deviate from Maxwellian statistics in opposite directions, and tend to Maxwellian statistics when temperature increases indefinitely.

[56]The ensuing account follows in large measure the exposition of Hans Reichenbach, *Philosophic Foundations of Quantum Mechanics* (Berkeley: University of California Press, 1948), pp. 111-117. And see also H. Jeffreys, "Probability and Quantum Theory", *The Philosophical Magazine and Journal of Science* 33 (1942) 815-831.

[59]While accurate in the main, the above exposition is no substitute for a full description of quantum mechanics. See for example P. A. M. Dirac, *Quantum Mechanics*[8] (Oxford: Oxford University Press, 1947).

[60]*Including* the rules for the construction of operators *and* of the first Schrödinger equation, the rules for determining the probability distributions, *and* the second Schrödinger equation.

[61]This phase of the subject is not altogether new to the *Association* files. See for example Joseph P. Kelly, S. J., "Statistical Laws and Causality", *Bulletin of American Association of Jesuit Scientists: Eastern Section* 11 (1934) 198-202; *idem*, "Statistical Laws and Causality", *ibidem* 13 (1935) 29-30; *idem*, "The

Principle of Causality and Statistical Laws", *ibidem* 13 (1936) 106-113. Compare John J. Murphy, S. J., "The Logic of Statistics", *Proceedings of the Jesuit Philosophical Association* 13 (1936) 53-63. See also Alois Gatterer, S. J., "Das Problem des statistischen Naturgesetzes", *Philosophie und Grenzwissenschaften* 1 (1924) 1-69; *idem*, "Zufall und Gesetz im Naturgeschenen" *Stimmen der Zeit* 119 (1930) 428-443; José M. Ibero, S. J., "Abuso de la ley estadística en las teorías modernas", *Estudios Ecclesiásticos* 10 (1931) 524-537; 11 (1932) 228-240.

[62]And here see D. J. Struik, "The Foundations of the Theory of Probabilities", *Philosophy of Science* 1 (1934) 50-70, especially pp. 65-69. Consult also for some interesting remarks P. W. Bridgman, "Statistical Mechanics and the Second Law of Thermodynamics", *Reflections of a Physicist* (New York: Philosophical Library, 1950) 150-182.

[63]For a succinct survey of the evidence on which this conclusion is based see Heinz Koppe, *Die Grundlagen der statistischen Mechanik* (Leipzig: S. Hirzel, 1949), pp. 5-21. For a competent if unacceptable treatment of the evidence and its philosophical implications see (1) Ernst Cassirer, *Determinismus und Indeterminismus in der modernen Physik* (Göteborg: Elanders Boktryckeri Actiebolag, 1937, and (2) Max Born, *Natural Philosophy of Cause and Chance* (Oxford: at the Clarendon Press, 1949).

[64]This is what Einstein equivalently does. See excerpts from his letters on this point, quoted by Max Born, *Natural Philosophy of Cause and Chance* (Oxford: at the Clarendon Press, 1949), pp. 122, 123. See also Max Born, "Einstein's Statistical Theories", in *Albert Einstein: Philosopher, Scientist* [Edited by P. A. Schlipp] (Evanston, Illinois: The Library of Living Philosophers, 1949) 163-177, p. 166:

. . . [Einstein's] conviction seems always to have been, and still is today, that the ultimate laws of nature are causal and deterministic, that probability is used to cover our ignorance if we have to do with numerous particles, and that only the vastness of this ignorance pushes statistics into the forefront.

[65]Compare Einstein's admissions in letter quoted by Max Born, *Natural Philosophy of Cause and Chance* (Oxford: at the Clarendon Press, 1949), p. 123:

. . . I cannot substantiate my attitude to physics in such a manner that you would find it in any way rational. . . . I cannot provide logical arguments for my conviction, but can only call on my little finger as a witness, which cannot claim any authority to be respected outside my own skin.

[66]*And* under whatever guidance tradition may provide in this matter. See Aristotle, *Analytica Priora* 2. 27. 70^{a}3-5; *Physica* 2. 5. 196^{b}10-16; *Rhetorica* 1. 2. 1357^{a}33-38. Note that Aristotle's recurrent phrase: ἐπὶ τὸ πολύ, seems to endorse some sort of frequency interpretation of probability. See also Aquinas, *In Metaphysica* 6. 3; *Summa Theologica* 1. 115. 6; *Summa contra Gentes* 3. 2; *Summa Theologica* 1. 80. 1; 2. 1. 1. 2; *De Veritate* 24. 2, and *Summa contra Gentes* 2. 47-48 in that order. Note (1) that Thomas renders Aristotle's recurrent probability phrase by *'frequenter'* which also seems to favor even semantically a frequency interpretation, (2) and explains irregularity in terms of *materia*, which also functions as the root of *individuation*. It may be that the solution proposed in the text above is concordant with these inherited insights.

[67]See Louis de Broglie, "L' espace et le temps dans la physique quantique", *Revue de métaphysique et de morale* 54 (1949) 113-125, where further references are given to Destouches and others who phrase the issue as above.

Biology

PROTEINS

WILLIAM D. SULLIVAN, S.J.

Of all the components within the cell, the proteins are certainly the most indispensible for the maintaining of the many vital processes going on within the cell membrane. Many of the mysterious vital phenomena of living organisms have been revealed by investigations performed on proteins in the past few years. They are extremely complex substances, synthesized by the living cells and found in all protoplasm, constituting the chief constituents of all solid material of animal tissues. It is practically impossible to define precisely the term protein. Since it is of such a complex structure, no chemist has been able to determine exactly its chemical constitution. The instability and non-crystalline nature of the protein have added to its indefinable nature. For this reason, then, one can only describe the nature of proteins with what is known at present as a result of modern discoveries.

According to Hartley (1951), the word 'protein' owes its origin to a Dutch chemist, Berzelius, who suggested to another Dutch chemist, Mulder, in a letter written to the latter on July 10, 1838. In this letter Berzelius explains his reason for suggesting the word as follows:

"Le nom proteine que je vous propose pour l'oxyde organique de la fibrine et de l'albumine, je voulais le deriver de parce qu'il parait etre la substance primitive ou principale de la nutrition animale que les plantes preparent pour les herbivores et que ceux-ci fournissent ensuite aux carnassiers."

Proteins have been classified as follows, *simple,* which on hydrolysis yield nothing but amino acids, *conjugated,* which is a protein hooked-up to a non-protein group called a prosthetic group, and *derived* proteins, which are derived from a partial hyprolyzation of a complete protein. Among the simple proteins are the *albumins,* which are soluble in water, coagulable by heat and lacking in glycine, e.g., egg serum; *globulins,* which are insoluble in water, soluble in dilute solutions of NaCl, coagulable by heating, e.g., serum and vegetative globulins; *prolamines,* (gliadins), which are insoluble in water,

soluble in 70% to 80% alcohol, lacking in lycine, e.g., zein and gliadin from wheat (mostly found in the plant kingdom); *glutilins,* which are insoluble in neutral solutions, insoluble in dilute NaCl solution, soluble in dilute acids, e.g., oryzenin from rice, seeds of cereals; *albuminoids* or *sclerol,* which are insoluble in strong solutions of acids or alkalines, NaCl has no effect on the albuminoids, e.g., supporting or protecting tissue in animals such as keratin and spongin from sponges; *histones,* which are soluble in water, insoluble in dilute ammonia, contain histidine and argenine, rich in quantities of histons, and in combination with nucleic acids some form nucleohistines which are found in the thymus and pancreas cells; *protamines,* which are soluble in water and incoagulable by heat, simple in structure, and because of their simplicity they are known as the restricted or simple type of protein, e.g., ripe fish sperm. These latter proteins precipitate out if an aquaeous solution of them is treated with alcohol. Salmine and sturine are given off when the protamines are hydrolyzed.

Among the conjugated proteins we have the *nucleoproteins* which are found chiefly in the nucleus joined to a nucleic acid (the prosthetic group). According to some of the authors it has not been proved conclusively that the nucleic acids are actually joined to the proteins within the cell. The prevailing opinion, however, is that they are joined. The nucleic acids are extremely complex compounds, each one being composed of a tetranucleotide, which, on hydrolysis, yields 4 nucleotides. Each nucleotide, on being hydrolyzed with an alkaline solution, will give off the phosphoric acid and the remaining compound after the phosphoric acid is split off is called a nucleoside, which is composed of a carbohydrate and either the purine or the pyrimidine base. In the case of nucleoproteins, hydrolysis will yield amino acids, the carbohydrate, phosphoric acid, the purine base (guanine or adenine) and the pyrimidine base (thymine or cystine). Besides the nucleoproteins, the *glycoproteins* are also classified under the class of conjugated proteins. These may be constituted by one or more proteins plus a carbohydrate, e.g., mucin in saliva; the *phosphoproteins,* which are compounds of the protein molecule joined to a substance, as yet undefined, of phosphorous characteristics other then a nucleic acid or lecithin, e.g., casein in milk, vitellin in egg-yolk; *chromoproteins,* which are compounds of the protein molecule with hematin or some similar substance, e.g., hemoglobin in which the globin is combined with iron (0.335%) porphyrin compound, heme, and hemocyanin in which copper takes the place of iron in hemoglobin. Hemocyanin is found in the blood of many of the invertebrates. The *lecithoproteins* are conjugated proteins and are compounds of the protein molecule with lecithin, e.g., fibrinogen of the blood. The *lipoproteins* are a combination of a basic protein and cephalin, a slightly acidic lipid substance. This combination is said by some of the authors not to be due to the acid-base reaction. The lipid cephalin is less acidic than lecithin.

The derived proteins have been divided into the *primary* protein derivatives and the *secondary* protein derivatives. The primary protein derivatives are apparently derived from the hydrolytic change which involves only slight alterations of the protein molecule. They are the *proteans*, which are insoluble in water, and are the first products which result from the action of acids, enzymes or water on the protein, e.g., estadan from estadin. The *metaproteins* are also included in this group. They are the products resulting from prolonged action of the acids and alkalies, by which the protein molecule is so far altered as to form products which are soluble in very weak acids and alkalies; they are insoluble in neutral fluids, e.g. acid and alkali albuminate. A third type of primary protein is the *coagulated protein*, which is the insoluble product resulting from the action of heat or strong alcohol on the protein. The secondary protein derivatives are the products of further hydrolytic changes and cleavages of the protein molecule. Among this group are the *proteoses*, which are soluble in water, incoagulable by heat and are precipitated by saturating their solutions with ammonium sulfate. *Peptides* are clearly characterized by a combination of two or more amino acids, the carboxyl group of one being united with the amino group of the other, with the elimination of a molecule of water. Dipeptides are composed of two amino acids, polypeptides are composed of several amino acid residues. According to Spanster and Bath (1942) the distance between two peptide links in a polypeptide chain of amino acids is 3.5 Å.

It is known that proteins contain carbon (50-55%), hydrogen (6.5-7.3%), nitrogen (15-18%), oxygen (20-24%), sulfur (0.4-2.5%), and phosphorous (0.1-1.0%). Nitrogen has been the determining factor for analysts in estimating the amount of protein present in any given sample. By the Kjeldahl method of determining the amount of nitrogen present in the sample, the percentage of protein present may be determined. Multiply the amount of nitrogen found by this method by 6.25 and the resulting figure is the amount of protein present. The excess acid resulting from a heating of nitrogen and sulfuric acid (giving ammonium sulfate) may be titrated with any standard alkali and the amount of ammonia present may be determined and thus the percentage of nitrogen is found. The nitrogen given off must be given off as ammonia for the resulting ammonium sulfate. This is the Kjeldahl method.

Other elements have been found in proteins, and one in particular is iron. Since the hydrolysis of proteins yields from 5 to 25 amino acids, they may be described in general as chemical compounds whose essential constituents are the amino acids. Since proteins differ so widely from each other it is impossible to do any more than describe each protein as it is known.

The hydrolysis of proteins may be performed either by enzymes or by boiling the proteins in strong acids or bases. The results of hydrolysis are either amino acids or compounds which are composed

of amino acids. In this process of hydrolysis the molecules of proteins are continually being broken down into simpler substances. It is possible, therefore, for a certain salt to break down a protein to a certain extent, the reaction ending after the activity of this salt has ceased. Another salt or another method of hydrolysis must be used to break this protein down still further. Likewise a protein may be coagulable by heat to a certain temperature. More heat is then needed to coagulate the protein in a greater degree. On complete hydrolysis a simple protein may be broken down to 23 different amino acids. The number and kind of amino acids resulting from hydrolysis of proteins is different and relative to the type of protein. There is no protein known which will give only one amino acid on hydrolysis. There are some proteins which lack certain of the amino acids and there are other proteins which contain a great number of the amino acids.

In general the amino acids are said to be colorless crystalline compounds, water soluble, with the exception of cystine and tyrosine. They are not soluble in organic solvents or or strong absolute alcohol, while they are soluble in dilute alcohol. When heated to high temperatures (200-350° C) they are known to decompose, though they have not real melting points. They are said to be acid, basic or neutral in as much as they contain either a carboxyl group ($-$ COOH), or an amino group ($-$ NH$_2$), or an equality of both of these groups in the same amino acid. Except for glycine, all the amino acids are optically active, having either the dextero- or the levo- form. They never have both of these forms in the same amino acid.

They are derived from the aliphatic acids, with the amino group, $-$ NH$_2$, replacing in the a-position the a-hydrogen. Due to what is known as the *peptide linkage*, they have, as one of their most outstanding characteristic, the ability to combine with each other. In the peptide linkage a nitrogen atom intervenes between 2 carbon atoms and is demonstrated in the following formula.

$$R - NH_2CH - COOH + R\text{-}NH_2CH - COOH \rightarrow R - NH_2CH - CO + NH - RCH - COOH$$

(peptide linkage)
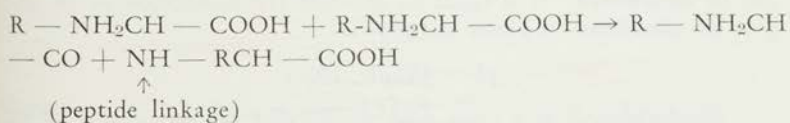
The letter R is a symbol indicating the specific note of individuality of the amino acid. It is usually composed of a hydrocarbon chain with an acid or basic group attached. This R group is free and unattached in all cases and the sum total of the R groups will determine the physical and chemical properties of proteins. This group may have an acid or base attached to it. If most of the attached groups are acid then the protein will be acid, if most of them are alkaline, then the protein will be basic.

This property of ready combination is due to the presence of the carboxyl group and the basic group, and for this reason the amino

[103]

acids are called *amphoteric* substances. The acid group of one molecule will combine with the basic group of another and in the combining of these groups one molecule of water is lost.

It is in acordance with the *Zwitterion hypothesis* that the amino acids are said to be amphoteric, i.e., they can act either as acids by virtue of the carboxyl group, or as bases by virtue of the amino group. In solution the molecules may have either (or both) positive and negative charges due to the chemical behavior of these opposed groups. Such a type ion is known as a zwitterion. Confer Heilbrumm (1943) or Wertheim (1945) for a more complete explanation of the zwitterion, both of whom use glycine as an example.

At some definite pH the acid and the basic ionization would be of equal extent, and this point is known as the *isoelectric point*. In acid solutions, the positively charged amino acid will migrate to the cathode on electrolysis, and in alkaline solutions, the negatively charged amino acids will migrate to the anode. When the number of amino acids at the cathode and the anode are equal, the isoelectric point of that particular protein has been reached. The amino acids which can be electrically charged have been divided into two groups, the acidic and the basic groups. The acidic groups lose a proton and in that way become negatively charged. The basic group may gain a proton and become positively charged.

The acidic and the alkalinic association constants can be determined by the following formulas:

Acidic Association: $K_a = \dfrac{(H^+)(ROH^-)}{(HROH)}$

Alkalinic Association: $K_b = \dfrac{(OH^-)(HR^+)}{(HROH)}$

Knowing these two association constants the isoelectric points can be determined. It is equal to one-half the association as an acid plus the association as a base as follows:

$$pI = \tfrac{1}{2}(pK_a \; pK_b)$$

Electrophoresis is a term used to describe the movement of the proteins to the cathode in an electrical field when the pH is low, or to the anode when the pH is high, or when they do not migrate to either of the poles.

The action of the ions in the different pH electrical fields may be pictured as follows:

Amino ion as an acid: $H\text{-}R\text{-}OH \rightleftharpoons H^+ + ROH^-$
Amino ion as a base: $H\text{-}R\text{-}OH \rightleftharpoons OH^- + HR^+$
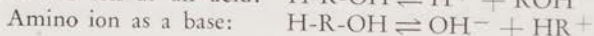
All the amino acids do not have the same isoelectric point. For example,
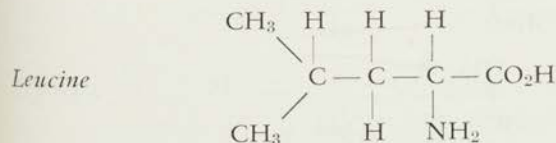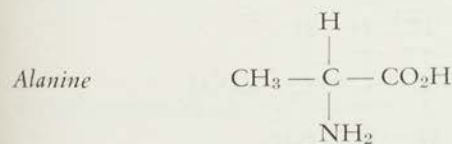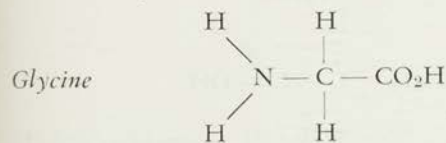
Alanine   6.1
Aspatic acid   3.0
Cystine   5.6
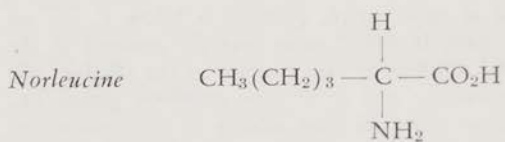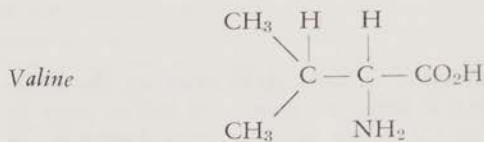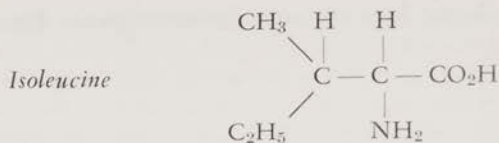Lysine   9.7
Histidine   7.6
   etc.

Should an aqueous solution of amino acids be made up, the amino acids are not at their respective isoelectric points and buffers must be used. The more complicated the amino acid the more diverse is the isoelectric point.

The isoelectric point of most native proteins is below 7, i.e., on the acid side of the pH scale. It would seem that the proteins in the human body act as anions. Ordinarily the proteins in the alkaline side of the scale are joined to nucleic acid or to some prothetic group, i.e., conjugated proteins. Amino acids are least soluble at their isoelectric points. To separate two amino acids, therefore, the medium must be adjusted to the isoelectric point of one of them and the other may then be filtered off. Osmotic pressure is also at a minimum at the isoelectric point. The swelling of the protoplasm is least and the viscosity is at its lowest at this point. The percent of dissociation will be different at different pH.
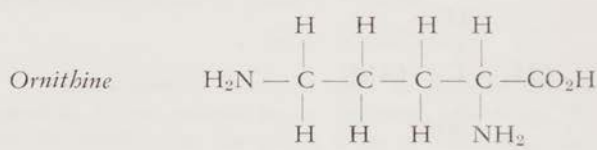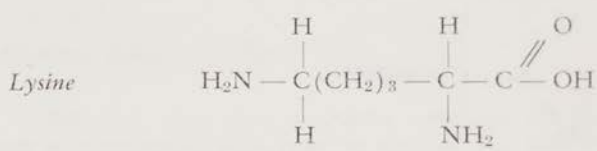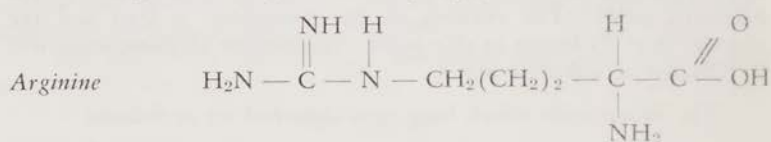
The amino acids which have been identified are as follows:

Monocarboxylic Acids (one amino-group)

Glycine

$$H_2N - CH_2 - CO_2H$$

Alanine

$$CH_3 - CH(NH_2) - CO_2H$$

Leucine

$$(CH_3)_2CH - CH_2 - CH(NH_2) - CO_2H$$

Isoleucine

$$\underset{\displaystyle C_2H_5}{\overset{\displaystyle CH_3}{\diagdown}} \underset{|}{\overset{|}{C}} - \underset{\underset{\displaystyle NH_2}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - CO_2H$$

Valine

$$\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\diagdown}} \underset{|}{\overset{|}{C}} - \underset{\underset{\displaystyle NH_2}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - CO_2H$$

Norleucine

$$CH_3(CH_2)_3 - \underset{\underset{\displaystyle NH_2}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - CO_2H$$

Monocarboxylic Acids (two amino groups)

Arginine

$$H_2N - \overset{\overset{\displaystyle NH}{\|}}{C} - \overset{\overset{\displaystyle H}{|}}{N} - CH_2(CH_2)_2 - \underset{\underset{\displaystyle NH_2}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - \overset{\overset{\displaystyle O}{\diagup\!\!\diagup}}{C} - OH$$

Lysine

$$H_2N - \underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}}(CH_2)_3 - \underset{\underset{\displaystyle NH_2}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - \overset{\overset{\displaystyle O}{\diagup\!\!\diagup}}{C} - OH$$

Ornithine

$$H_2N - \underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - \underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - \underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - \underset{\underset{\displaystyle NH_2}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - CO_2H$$

Hydroxy Monamino Acids

Serine

$$HC \underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle OH}{|}}{}} - \underset{\underset{\displaystyle NH_2}{|}}{\overset{\overset{\displaystyle H}{|}}{C}} - CO_2H$$

[106]

Threonine

```
            H   H   H
            |   |   |
      H  —  C — C — C — CO₂H
            |   |   |
            H   OH  NH₂
```
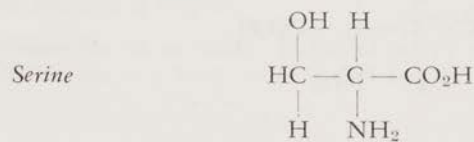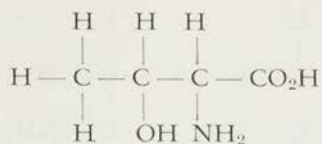
Dicarboxylic Acids with one amino group

Aspatic acid

```
            H           O
            |           ‖
      H  —  C  —  C  —  OH
            |           O
            |           ‖
      H  —  C  —  C  —  OH
            |
            NH₂
```

Glutamic acid

```
            H           O
            |           ‖
      H  —  C  —  C  —  OH
           /
      H —  C  — H        O
           \            ‖
      H  —  C  —  C  —  OH
            |
            NH₂
```
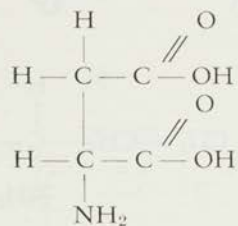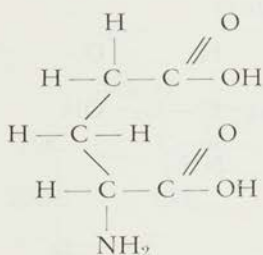
Hydroxyglutamic acid

```
                     H    H    H
                     |    |    |
      HO₂ — C  —  C — C — C — CO₂H
                     |    |    |
                     H    OH   NH₂
```
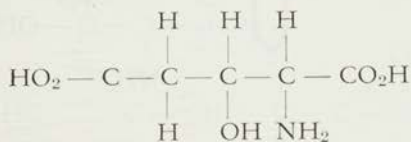
Sulfur-containing Acids

Cysteine

```
            H
            |
            S     H          O
            |     |          ‖
      H  —  C  —  C  —  C  —  OH
            |     |
            H     NH₂
```

Cystine

$$H-\overset{\displaystyle H}{\underset{\displaystyle |}{C}}-S-S-\overset{\displaystyle H}{\underset{\displaystyle |}{C}}-H$$

$$H-\overset{|}{\underset{|}{C}}-NH_2 \quad H-\overset{|}{\underset{|}{C}}-NH_2$$

$$\overset{|}{C}-OH \qquad \overset{|}{C}-OH$$

$$\overset{\diagdown}{O} \qquad\qquad \overset{\diagdown}{O}$$

Methionine

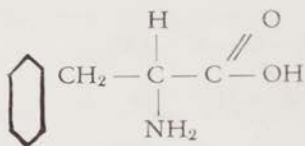$$CH_3-S-CH_2-CH_2-\overset{\displaystyle H}{\underset{\displaystyle NH_2}{C}}-CO_2H$$
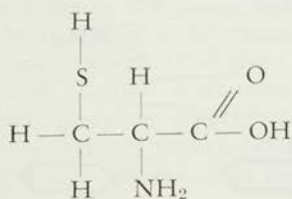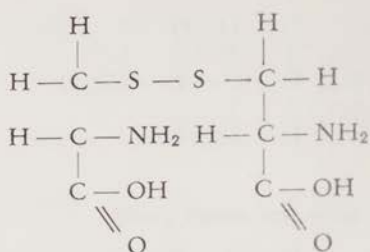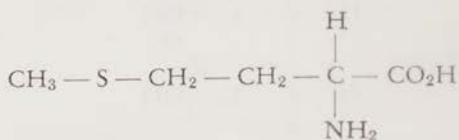
Aromatic homocyclic derivatives

Phenylalanine

$$CH_2-\overset{\displaystyle H}{\underset{\displaystyle NH_2}{C}}-\overset{\displaystyle O}{C}-OH$$

Tyrosine

$$HO-\quad CH_2-\overset{\displaystyle H}{\underset{\displaystyle NH_2}{C}}-\overset{\displaystyle O}{C}-OH$$

Iodogorgoic acid

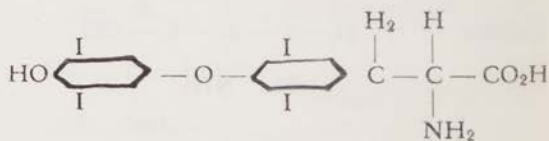$$HO-\overset{I}{\underset{I}{}}-\overset{\displaystyle H_2}{C}-\overset{\displaystyle H}{\underset{\displaystyle NH_2}{C}}-CO_2H$$

Thryroxine

$$HO-\overset{I}{\underset{I}{}}-O-\overset{I}{\underset{I}{}}-\overset{\displaystyle H_2}{C}-\overset{\displaystyle H}{\underset{\displaystyle NH_2}{C}}-CO_2H$$
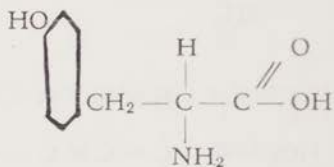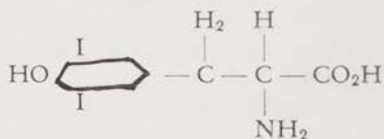
Heterocyclic derivatives

Tryptophan

$$
\begin{array}{c}
H \\
| \\
N \\
\end{array}
$$

— CH$_2$ — $\overset{\displaystyle H}{\underset{\displaystyle NH_2}{C}}$ — C $\overset{\displaystyle O}{\underset{}{\diagup\!\diagup}}$ — OH

Proline

H$_2$C, N—H, C — C — OH, H$_2$C — CH$_2$

Hydroxyproline

H$_2$C, N—H, C — C — OH, HOC — CH$_2$, H

Histidine

HC, N, C — CH$_2$ — C — C — OH, N — CH, NH$_2$
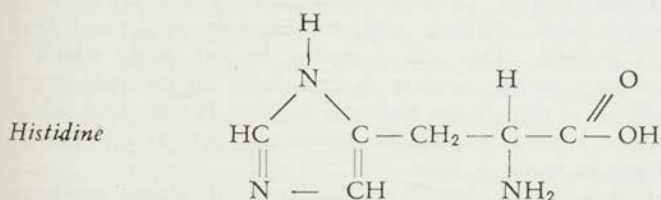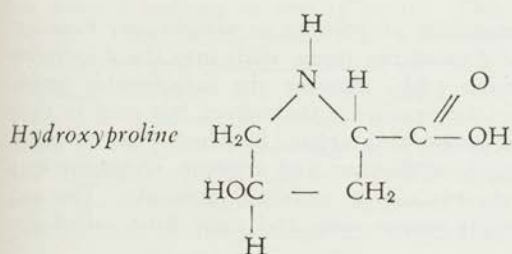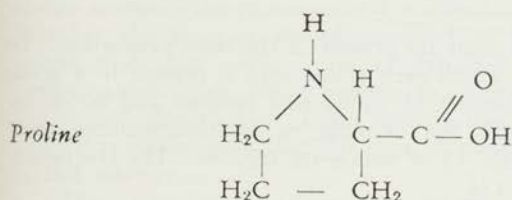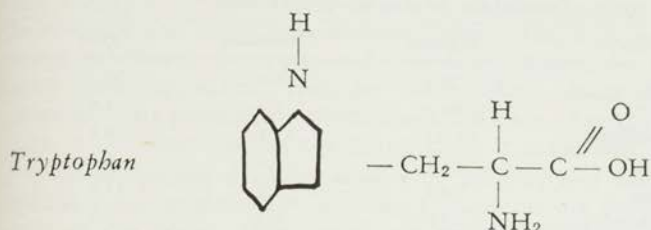
There is no protein which is composed of all the amino acids. Hetathaemoglobin contains 576 amino acid residues. This means that there are 576 building blocks in hetathaemoglobin. They are all different building blocks, though 12 of them may be arginine, 36 lysine, histidine, aspatic acid, glutamic acid; there is no glycine (the simplest of the amino acids), glycoline, tryptaphan; though there is tyrosine, proleine and cystine. Gelatin, though lacking tryptaphan, valine, and hydroxyproleine, has 25% glysine. Zein contains no glysine and casein contains 20% glysine.

From the following table one may see the amount of three amino acids which are present in different proteins:

[109]

TABLE I
PERCENTAGE OF AMINO ACID PRESENT

PROTEIN	*Argenine*	*Histidine*	*Lysine*
Casein	8.3	5.6	10.3
Gelatin	15.1	1.1	4.9
Haemoglobin	7.2	13.5	9.8
Insulin	6.3	8.5	3.0
Myosin	14.2	3.9	13.6
Egg Albumin	5.6	1.5	5.1
Salmine	87.4	——	——

Not all these amino acids are present in the same proportion. To find the frequency with which each amino acid is present in a given protein, take the total number of amino acid residues and divide by any individual amino acid. For example, in hetathaemoglobin there are 576 amino acid residues, 12 of which are arginine. The frequency, therefore, of arginine is $\dfrac{576}{12}$.

On treating the metabolism of proteins in vertebrates, Rose experimented with rats and divided the amino acids into the dispensible and the indispensible amino acids. Among the indispensible amino acids, which the rats could not synthesize themselves, but need in their daily diet, he enumerated lysine, tryptaphan, histidine, phenylalanine, leucine, isoleucine, threonine, methionine, and arginine. Arginine may be synthesized by the rats but not in sufficient amounts. The rats can synthesize the remaining amino acids and these Rose called dispensible.

The vertebrate body has a protective agency for the breaking down of amino acids. Hipuric acid, for example, is derived from fruits and vegetables. This acid contains benzoic acid, which is poison. However, benzoic acid is carried down to the kidney and attaches itself on to the glycine molecule to form hipuric acid, which is inert and not a poison. Here the amino acid acts as a protective agency and not so much as food.

Though it is not known how the leaves of plants synthesize proteins from nitrates and nitrites, it is certainly true that man and animal can obtain the required amount of proteins only from plants.

Ammonium salts are excreted in quantities in less than a gram per day. Proteins contain sulfur and phosphorous and as a result ammonium sulfate and ammonium phosphate are excreted through the urine.

In the course of digestion proteins are broken down into the individual amino acids and are absorbed in the blood until they arrive at specified tissues where they recombine to form the particular food which is needed by that tissue with no relation to the original food taken in. The amino acids can be fed as such and they can be ingested.

[110]

What do the ingested proteins serve in the body? They construct new tissue; a certain number of amino acids are selected by the cells to combine and mend broken-down tissues. The body is continually using substances (enzymes and hormones) which the amino acids must build up again. They are the building blocks of the body. Some say that proteins are stored up in the body. Though this may be true in the foetus and in the young child, it is doubted in the adult.

Some specific dynamic actions of proteins may be enumerated. Should a rat be given 100 calories, 130 calories are produced by the heat of the body. Thirty more are produced than originally given to the animal. The proteins exert a stimulating activity in the body. Whether the proteins are administered as food or ingested in the animal there does result a specific dynamic reaction. The most important amino acids which produce this dynamic activity are glycine, alanine and phenylalaine. From investigations performed on the lower animals it would seem that the liver of these animals play a large role in this activity.

Most proteins are amorphous, colorless compounds which have no definite melting or boiling points. They are insoluble in organic liquids. Those which dissolve in water give off a colloidal solution. Proteins are precipitated or salted out from their solution by the addition of inorganic salts, Na_2SO, and $NaCl$. If the salts are removed from the solution the protein immediately goes back into solution. Some of the acids which yield insoluble precipitates with protein are the following: picric, tannic, phosphomolybdic, ferrocyanic, phosphotungstic, metaphosphoric and chromic. Some of the bases which cause precipitation of the proteins are strychnine, quinine and other alkaloids, as well as the ions of copper, mercury, platinum, gold, lead, etc. All the proteins except the peptones are precipitated by a saturation of ammonium sulfate, and an acid solution of sodium chloride.

On the sizes and shapes of proteins, a great deal has been done in the past few years. Investigators have classed the proteins according to their shapes into two types, the corpuscular (globular) proteins and the fibrous proteins. Some fibrous proteins are actin, myosin, keratin and collagen; while corpuscular proteins include the crystalline proteins, some crystalline enzymes, egg albumin, hemoglobin, hemocyanin, pepsin and trypsin (all of which are crystalline). The corpuscular types of protein are spherical in shape while the fibrous are elongated chains. Some of the authors claim that these chains are similar to the polypeptide chains of many folds which were described in an earlier paper of this BULLETIN, (Sullivan, 1950), when referring to the polypeptide linkages of myosin. Those postulating the folded chain structure of proteins postulate various degrees of foldings, i.e., the alpha, beta, gamma folds as well as the supercontracted fold of Astbury. Wrinch, on the other hand, postulates a cyclol structure for the fibrous protein.

The *denatured* protein is one which has become less soluble in

water due to acids, alkalies, heat, high pressure and alcohol. The process of denaturation may be defined as any non-proteolytic modification of the unique structure of a *native* protein, which is a protein from living protoplasm, giving rise to definite changes of chemical, physical and biological properties. Their change in solubility is due to the molecular change in structure and in the non-polar group. There is more of the R-group in the hydrophylic proteins. The loss of the biological activity in the denatured protein is, perhaps, the greatest loss in this protein. It apparently cannot crystallize and seems to change from the corpuscular to the fibrous structure. There is an increase in the various activities of the various constituent groups within the molecule. The more condensed native proteins can change their shape according to most of the investigators. The denatured proteins are more readily attacked by hydrolytic compounds and enzymes. The nature of the protein definitely determines the acid or the alkaline to be used in hydrolyzation. The rate of hydrolysis may be determined by the following formula, where K equals the rate and x equals the percent of protein hydrolyzed in time t.

$$K = \frac{1}{t} \cdot \frac{1}{100 - x} \cdot \frac{1}{100}$$

With increase in temperature the hydrolysis is faster. Pressure also speeds up hydrolysis.

The physical denaturizing agents are heat, pressure, freezing, irradiation, sound waves and surface forces. The chemical agents are hydrogen, hydroxyl ions, solvents such as alcohol, organic solutes such as urea, and enzymes such as trysin, and pepsine.

The *coagulation* of a protein is the result of denaturation which eventually precipitates the protein out of solution. In coagulation of the proteins, the proteins themselves may precipitate or the entire solution may form a gel.

Due to the size of molecular proteins, they are often unable to pass through membranes which substances of smaller molecular size will pass through. For this reason, investigators have been able to prepare pure proteins through a process known as *dialysis*. Placing proteins in a colloidal sac with salt and then resting the sac in water, the salt will diffuse through the membrane leaving the protein, freed of foreign matter in the sac.

BIBLIOGRAPHY

Hartley, Nature *168*, 244 (1951).

Heilbrunn, An Outline of General Physiology, W. B. Saunders Company. Phila. and London. pp. 24-25 (1943).

Sponsler and Bath, Molecular structure in protoplasm. In "The Structure of Protoplasm" (Ed. Seifriz). Iowa State College Press, Ames, Iowa. (1942).

Sullivan, JESUIT SCIENCE BULLETIN *27*, 44 (1950).

Wertheim, Textbook of Organic Chemistry, The Blackiston Company. Phila. and Toronto. pp. 714-715 (1945).

Chemistry

LETHAL EFFECTS OF CARBON MONOXIDE
QUANTITATIVELY DEMONSTRATED

J. E. RANSFORD, S.J.
Department of Chemistry
University of Santa Clara, California

Carbon monoxide for this demonstration may be prepared by dropping concentrated sulfuric acid from a separatory funnel into slightly heated formic acid in a generating flask. The CO generated is collected in gas bottles inverted in a pneumatic trough. The gas bottles will need to be calibrated with 50 ml markings, if percentage of CO used is to be estimated afterwards.

A bell jar whose volume (about 6 or 7 liters) has been measured, and edges waxed, is inverted on a vacuum platform for bell jars (often available in the Physics Department) covered, except for inlet, with several thicknesses of newspaper. Connect rubber tubing about one foot in length to the platform stopcock.

Have several two-hole rubber stoppers which fit the gas bottles rigged up with elbows of glass tubing. One of the elbows in each stopper should be long enough to reach nearly to the bottom of the gas bottle. One empty gas bottle should have a U-shaped tube through its stopper whose length inside as well as outside is about the same height as that of the bottle. This bottle will serve as a gravity flow displacement reservoir. The other hole in this same stopper is fitted with a right angle elbow almost flush with the stopper's inner surface. Attach about eight inches of rubber tubing, equipped with a screw clamp, to this shorter elbow. Fill the reservoir bottle completely with water and insert its stopper *tightly*. Arrange a rigstand so that this reservoir bottle may be suspended upside down from it. Place the water reservoir in position several inches above the height of the gas bottle on the table level.

Attach the shorter elbow of a gas bottle (filled with CO) to the tube from the vacuum platform. Connect the suspended reservoir bottle to the longer, inlet elbow of this gas bottle.

Place a small animal, (white rats are best and may usually be obtained at a reasonable price from biochemical or medical school laboratories) by means of crucible tongs with rubber tips applied to the scruff of the animal's neck, under the bell jar. Adjust the screw clamp so that water from the reservoir bottle flows very slowly into the gas bottle. Start a stopwatch. Usually one bottle of CO

gas will be sufficient, but if another is needed, close the platform stop-cock, refill the reservoir, replace the gas bottle, and start over. The stopwatch is allowed to run until the animal collapses.

At intervals, e.g. every minute, measure the quantity of CO used, and from this the percentage of CO gas mixed with the air in the bell jar may be estimated and plotted against time. Stop the watch when the animal collapses completely. The folded newspaper will facilitate the disposal of the animal.

This demonstration makes a profound impression upon a class or any audience and vividly demonstrates the insidious (no sight, no sound, no odor), comparatively swift, and definitely lethal effects of small percentage mixtures of carbon monoxide with air.
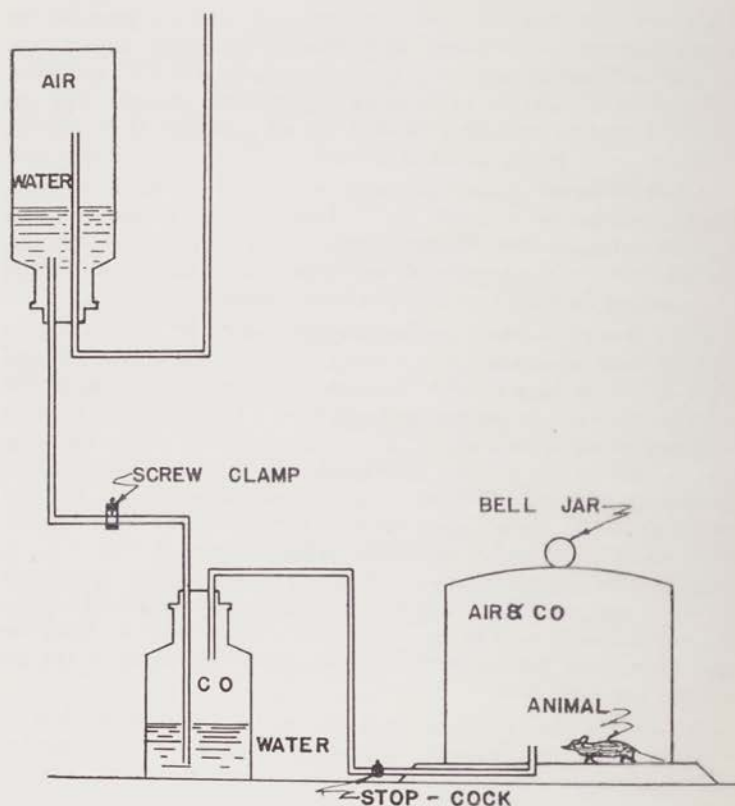

FIG. 1. CO GAS CHAMBER

SOLUBILITY OF HYDRATES

JOSEPH J. SULLIVAN, S.J.

The solubility of Inorganic hydrates is reported in various ways: (1) as grams of anhydrous substance per 100 grams of water, (e.g. Findlay, Phase Rule), (2) as grams anhydrous per 1000 grams of water (Smithsonian Physical Tables), (3) as grams anhydrous per 100 grams of solution (Chemiker Kalender, II, p. 321, (1929), (4) as mol fraction (International Critical Tables, 4, 2), (5) as formula weight per 1000 grams of water (International Critical Tables, ibid.) etc.

The problem of interpreting solubilities is indicated in the following quotation from Industrial Stoichiometry, 1st edition, by Lewis and Radasch, pp. 149, 150:

"Solvent of crystallization introduces certain confusion in expressing solubility. Although the saturated solution of a definite substance at a given temperature has a fixed composition, this may be quoted in different ways. Thus the solubility of Glauber's salt ($Na_2SO_4 . 10H_2O$) might be stated as the weight of this salt, which when dissolved in 100 parts by weight of water, will give a saturated solution. In this solution however, it is impossible to distinguish between water of crystallization and what might be called "dissolving water". Hence the composition of this same solution might be reported as parts of anhydrous salt per 100 of total water. Furthermore, this solution might have been made up by dissolving $Na_2SO_4 . 7H_2O$ in water; hence it might be convenient to have the solubility of the Glauber's salt, i.e. the composition of this same solution, expressed as parts of $Na_2SO_4 . 7H_2O$ per 100 of water. Finally, since the anhydrous salt and that with seven waters of crystallization, as well as Glauber's salt have their own specific solubilities, each of which, except at transition points, will differ from that of the other two salts, and since each can be expressed in terms of the other two, it is possible to have at a given temperature nine numerically different solubility figures for the system sodium sulfate and water. However, in three groups, each containing three of these solubilities, the figures are quantitatively equivalent. The following table giving seven of these nine possible solubilities at 20° C., is taken from a standard book of chemical tables.

Anhydrous Salt		Crystals, Decahydrate		Crystals, Heptahydrate		
Na$_2$SO$_4$	Na$_2$SO$_4$ · 10H$_2$O	Na$_2$SO$_4$	Na$_2$SO$_4$ · 10H$_2$O	Na$_2$SO$_4$	Na$_2$SO$_4$ · 7H$_2$O	Na$_2$SO$_4$ · 10H$_2$O
52.76	361.5	19.40	58.35	44.73	140.0	243.4

Computation shows that in the last number, two of the digits are transposed."

I corrected this last number and calculated the missing quantities as follows:

Anhydrous Salt			Crystals, Decahydrate			Crystals, Heptahydrate		
Na$_2$SO$_4$	Na$_2$SO$_4$ · 7H$_2$O	Na$_2$SO$_4$ · 10H$_2$O	Na$_2$SO$_4$	Na$_2$SO$_4$ · 7H$_2$O	Na$_2$SO$_4$ · 10H$_2$O	Na$_2$SO$_4$	Na$_2$SO$_4$ · 7H$_2$O	Na$_2$SO$_4$ · 10H$_2$O
52.76	186.3	361.5	19.4	44.4	58.35	44.73	140.0	234.4

These solubilities were checked in the works cited above. Appended is a list of other tables available. No incompatibility was found in the data as reported, but the conclusions the unwary may draw are evidently manifold.

Seidell, *Solubility of Inorganic and Organic Compounds*, 2nd edition
Storer, *Dictionary of Chemical Solubilities*
Lange, *Handbook*
Chemical Rubber Company, *Handbook*
Landolt-Börnstein, Band I, p. 675
Latimer and Hildebrand, *Reference Book of Inorganic Chemistry.*