THE ATOMIC PROBLEM

A CHALLENGE TO PHYSICISTS AND MATHEMATICIANS

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LONDON

George Allen and Unwin Ltd

Ruskin House Museum Street

First published in 1961

PRINTED IN GREAT BRITAIN
in 11pt Times Roman type

BY UNWIN BROTHERS LTD

WOKING AND LONDON

PREFACE

FUNDAMENTAL physical theory confronts difficult problems which may require fresh ideas for their solution. For example, the need for a far-reaching revision of basic principles is suggested by the fact that the key problem of the fine-structure constant was formulated by Einstein in 1909. [A. Einstein, *Phys. Zeit*., 10, 192-3, 1909, considered the dimensionless group e^2/hc, seven years before Sommerfeld introduced the 'fine-structure constant'.] Yet in fifty years no solution has been found. Though the Quantum Mechanics of 1925-30 was an immense and unprecedented achievement it threw no fresh light on this and similar problems, perhaps because-it retained too many Newtonian features. Clearly the solution of these problems must lie deep. The same may also be true of the new problems of high-energy physics arising from the experimental discoveries of the last thirty years. The conclusion is inescapable that an exceptional opportunity awaits minds with imagination and daring, ready to explore new methods potentially powerful enough to carry forward the great tradition of theoretical physics.

I have felt this opportunity for long * and have had no doubt regarding the kind of theory which should lead towards solutions of certain basic problems. Thirty years have passed since I first occupied myself with these matters and I have not found the appropriate mathematical expressions. But that does not, in my view, lessen the potential fertility of the method, particularly as a prediction made in 1931 has been fulfilled, as we shall see. [*A list of the author's relevant papers (W 1, etc.) and books WA, etc.) is given at the end of the Notes.]

There is now greater appreciation of the limitations of Quantum Mechanics and of the need for a new orientation. The logical consistency, epistemological strength, and empirical scope of Quantum Mechanics are so great that those not actively concerned with the unsolved problems may still regard this theory final. But some have always been aware of its limitations * and a new generation is now growing up whose judgment is less prejudiced by the success of a theory created by their predecessors. Moreover, new experimental facts are leading thought into fresh regions. [*As early as 1930 Heisenberg wrote: 'In addition to the modifications of our ordinary space-time world required by the theory of relativity and characterized by the constant c, and to the inexactitude relations of the quantum theory symbolized by Planck's constant h, still other limitations will appear connected with the universal constants e, m, M. It is not yet possible to see what form they will take.' Physical Principles of the Quantum Theory, 1930, p. 104. (Translated from the German edition.)]

I have therefore decided to summarize in a concise essay the physical principles which have guided my own inquiries, as an invitation to others to give them their appropriate mathematical expression: My aim has been to express these general principles with convenient brevity, and with a few exceptions necessary to make the ideas concrete to avoid those special problems where mistakes would be inevitable at this stage. More detailed analyses of some aspects of these ideas will be found elsewhere. * [*Nearly all the author's papers (W 1, etc.) treat special aspects of the relation of the ideas of this essay to current physical theories. The most relevant will be referred to on particular points. The books (WA, etc.) are all concerned with related ideas, but WB and WC are relatively precise and analytical.]

I am not concerned with questions of originality. Some of these ideas go back two hundred years, others have been vaguely in the air for several decades, and a few references are given to similar conceptions. But their present constellation may be fresh. Moreover, I am convinced that they have not yet been given sufficient attention by theoretical, mathematical, and experimental physicists, and that the time is ripe for a concise re-statement of this self-consistent set of principles awaiting mathematical expression and observational justification. Can any physicist of imagination with an understanding of the history of physics question that the time has come for a serious effort to be made, using appropriately novel methods, to solve a problem that Einstein recognized as crucial half a century ago? Does not this long delay mean that we have been more conservative than was necessary, that greater daring is justified and will bear fruit?

The decisive advances of this century in theoretical physics have been made in a period of a few years within a single mind. A new idea led to new algebra and so to new predictions in the thought processes of one person, from Planck and Einstein to Dirac and Pauli. It is unusual to suggest novel physical principles without simultaneously clothing them in mathematical expressions permitting quantitative predictions in particular experiments.

Yet there have been times in the past, and the present moment may also be one, when, owing to a special need for reorientation, the presentation of a speculative theoretical programme, emphasizing new or neglected physical ideas, has proved fertile. One example of special relevance is R. J. Boscovich's *Theoria Philosophiae Naturalis, redacta ad unicam legem virium in natura existentium* (Vienna, 1758. * The mathematics in this work was trivial relatively to the novelty of the ideas, and no new measurements were predicted. Yet its influence on the history of physical ideas was profound. Boscovich's 'Theory' was the formulation of a *programme for atomic physics* which is still being carried out, though some are unaware of this.). [* On the relation of Boscovich's atomism to the present essay, and for references on Boscovich, see W 21, W 24, W 26.]

This Challenge is also the announcement of a programme, and one based partly, like contemporary physics, on Boscovichian atomism. But in several respects it parts company with Boscovich and with the Newtonian residuals in relativity and quantum theory and points towards a new post quantum realm of inquiry appropriate to the late twentieth century. It is a challenge in the sense of an invitation to attempt the solution of a challenging problem by using a particular method.

This is not a personal programme, but that, I hope, of an invisible college of tomorrow. These ideas may be neither new, nor perfect, nor complete. Yet this essay will serve a purpose if it leads to new explorations. It is as a pointer that I ask this statement to be judged. For I have no doubt that these or similar ideas, or other ideas provoked by their inadequacy, will in someone's mind during this century prove fertile. They may help, as James Clerk Maxwell * put it, 'to drive us out of the hypotheses in which we have hitherto taken refuge into that state of thoroughly conscious ignorance which is the prelude to every real advance in science'. [*James Clerk Maxwell, Nature, March 3, 1875.]

L. L. W.

London, November 1959

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PROVISIONAL DEFINITIONS

A One-way Process: Any process in a finite system of primary particles (? a class of stable nucleons) which never completes an exact cycle but moves towards a stable equilibrium state, the terminus (W 20. See References at end.) N.B. This is a non-relativistic concept.

A Diminant: A signless ordering variable, representing some asymmetry or spatial deformation of a system from a state of stable equilibrium, which continually decreases during a one-way process (W 20). An isolable one-way process is one representable by diminants. Equilibrium of any, kind is represented by the vanishing of the corresponding diminant.

Chiral: A three-dimensional form (point-arrangement, structure, field or process) is called 'chiral' which possesses a non-superposable mirror image (Kelvin; W 22, W 24, W 25). Chiral forms need not possess a unique axis.

Spherical Point System: An arrangement of a finite number of points on a sphere in three-space which is distinguished by some extremal property (W 8).

U: A unified theory, containing no dimensionless numbers determined only by experiment, which derives established theories as conditions of the definition of dimensional co-ordinates and of most nearly stationary parameters in terms of the chiral diminants of the one-way processes of partly ordered (spherical and linear) systems constituted of one class of primary point particles possessing no quantitative properties (cf. W 14, W 20).

NOTATION

LATIN LETTERS: DIMENSIONAL CONSTANTS

$\boldsymbol{G}$	Gravitational constant
$\boldsymbol{c}$	Velocity of light
$\boldsymbol{e^2}$	Square of charge on electron
$\boldsymbol{h}$	Planck's constant of action
$\boldsymbol{m}$	Mass of electron
$\boldsymbol{M}$	Mass of proton
$\boldsymbol{M_p}$	Mass of any particle
$\boldsymbol{t_p}$	Mean life of any unstable particle

GREEK LETTERS: DIMENSIONLESS CONSTANTS

$\boldsymbol{\varepsilon}$	Any dimensionless constant of arbitrary value in fundamental theory, expressed in a theoretically significant form less than unity.
$\boldsymbol{\alpha}$	$2\pi e^2/hc$ fine-structure constant 1/137.03(7) . . .
$\boldsymbol{\beta}$	m/M = 1/1836.1(2) . . .
$\boldsymbol{\beta_p}$	Electron mass/mass of any particle
$\boldsymbol{\gamma}$	GMM/e^2, ratio of gravitational to electric actions
$\boldsymbol{\tau_p}$	Ratios of mean lives of unstable particles
$\boldsymbol{\rho}$	Any coupling constant for particle interactions, in dimensionless form

1. ATOMIC THEORY

THE history of physics is richer than any philosophy of physics and it would be unwise to attempt to confine the future within any particular interpretation of the present or the past. Yet a few general notions appear to set the context for all twentieth-century inquiries that conform to the indispensable criteria of the tradition of theoretical physics.

Physical theory seeks to order the measurable, and continually stimulated by experimental discoveries and by deeper insights into the procedures of observation advances from special to physically more general formulations, always retaining the valid aspects of older expressions. 'Order' can, for the physicist, be measured by the smallness of the number of theoretically independent parameters that must be used to cover the phenomena, and an 'ordering process' (whether 'physical' or 'mental') can be interpreted as one in which this number decreases if the process attains its end. The cumulative advance of physical theory, in which idea, mathematics, and observation are inseparable aspects of a single ordering process, is one of the most striking achievements of the human mind.

Those who believed that they had discovered a golden rule to guide the advance, determining how physically more general laws could always be reached by using certain mathematical or logical principles, have so far proved wrong. Important steps are always surprising, and must be so, or they would have been achieved earlier. The more difficult a problem appears, the greater the intellectual shock given by its solution to those whose analysis of the problem has not gone far enough.

But what distinguishes potentially fertile ideas, worthy of study, from empty ones? They are those which retain certain well-proven principles, while generalizing others. The task is to eliminate the unnecessary, to spot redundant restrictions and thereby to disclose a more general form awaiting exploitation.

The ancient well-founded idea which is here retained is the *principle of atomism*, in the form first clearly expressed by Boscovich. Thus the primary assumption will be that *a greatly simplified and even more powerful atomic theory is possible* unifying all aspects of atomism. On the other hand it is suggested that certain conceptions which have enjoyed a long success must now be discarded from basic formulations: linear co-ordinate systems, dimensional parameters, two-entity interactions, and time-invariants. These are to be replaced by dimensionless diminants, * associated with the relaxation processes of finite many-particle systems passing from less ordered to more ordered states. This implies the transformation of physical theory: from a substantive or a field basis, employing localized events or entities with quantitative properties, to a more relational one, employing only the changing finite relations of primary particles endowed with permanence but with no quantitative properties. A unified theory of this general character will be represented by the symbol *U*. But the significance of this brief summary will only become clear as the argument proceeds. [*On diminants, see later, and below.]

The aim is to discover the minimum assumptions from which it appears logically and theoretically conceivable that current theories and recent atomic data could be derived. This suggests that one should *start with the immediate observations interpreted in terms of an adequately powerful idea: relaxing systems of primary point particles.* Einstein believed that the increasing comprehensiveness of successive theories is necessarily associated with greater abstractness of their basic ideas. This may be wrong. It is here assumed-that it is necessary to retreat, as it were, towards a reinterpretation of what is immediately given in visual observations in order the better to advance.

2. UNSOLVED PROBLEMS

As David Hilbert said, 'Each age has its own problems'. The theory of Quantum Mechanics, as developed in the late 1920s and since extended, covers a vast range of phenomena in a satisfactory manner. A few always retained doubts regarding the epistemological foundations and the clarity of the physical ideas, but these doubts had little force beside the stupendous predictive power of the mathematics over a very large field of phenomena. This power led some to believe that in Quantum Mechanics physics had spoken the final word on the structure of the universe. This flattering conviction survived into the 1940s, but is now disappearing. For it is evident that the following apparently fundamental problems * have so far resisted treatment either by Quantum Mechanical methods or by those of any earlier theory: [*Similar, but more detailed, summaries of unsolved problems have been given by the author in WB, p. 122 (1931), and W 27 (1958).]

Primary problem. Unification within a single elegant theory of all known types of particle and field, and of their combinations into many-particle systems, covering their conditions of existence and modes of interaction. This formulation of the master problem includes as special aspects:

Derivation of the arbitrary pure number constants characterizing the relations of the various particle-fields (α, β_p, γ, τ_p, ρ, . . .) as quantizing numerical operators determining the conditions under which these fields are isolable within the unified theory. What conditions, involving the εs, determine the appearance of a particle with particular parameters, signs, and invariance properties?

Representation of high-energy systems and processes (nuclear theory, unstable particles, mass spectrum, etc.), and of all phenomena where the appropriateness of current methods is limited by the finitude of the εs.

Provision of general methods appropriate to the treatment of many-particle systems.

Elucidation of the status of the logically asymmetrical relations of physical theory and experiment (temporal succession in relaxation or decay processes; failure of invariants such as particle-antiparticle symmetry, parity, etc.) and of their connection with the realm of symmetrical relations, e.g. T, C, and P invariance.

The elimination of marginal blemishes (divergences, ambiguity of boundary conditions, etc.).

It is often necessary to attempt to isolate special problems within a complex of tasks, and to seek to solve each separately. Thus it is conceivable that the next fundamental advance might take place in two parts, separate theories of high-energy phenomena and of complex systems developing independently.

But it appears more likely that the fundamental problems form an integral task which is best approached as a whole: For example, it may be easier to reach a single theory covering both complex systems and high energies, than to treat these realms separately. This allows any proposed generalization of current theory to be examined simultaneously from at least two points of view, so that each aspect provides a check on the suggestions derived from the other: Thus, provided the general outline of a potentially powerful line of advance is already available, it is easier to keep the development of a more general than of a less general transformation of theory on the correct path. More guiding hints and checks are available.

For good or ill our working assumption here is that a theory *U* must either solve or constructively transform the primary problem with its various aspects. This heuristic assumption does not prejudice the possibility that its value may lie in the discovery of its invalidity.

3. ROOT FEATURES OF ESTABLISHED THEORIES

IN selecting an appropriate line of advance towards a comprehensive theory covering complex systems and high energies (in addition to the simpler systems and lower energies already successfully treated) we have first to consider what are the basic characteristics of established theories. We have, as far as possible and wherever it appears necessary, to look beneath orthodox interpretations and to identify the most general characteristics which may be relevant to our task. The present essay is restricted to 'fundamental' matters in the current meaning of the term, as theoretically primary. Whatever ambiguity this possesses will disappear as the argument proceeds, for each theory or programme for research carries with it its own interpretation of what is primary and what secondary.

Classical fundamental theories (i.e. those prior to the introduction of the principles of relativity and of quantization) assumed the existence of *time-invariants which are dimensional functions, in unique Cartesian frames, of length, time, and mass, involving dimensional constants.* These time invariants determine the *reversible processes* of systems composed of either one *field* or one *two-body interaction* (or reducible to these). Though more dimensional quantities could, if desired, be treated as primary, classical theories require at least three.

The presence of each of the various dimensional constants indicates a corresponding type of quantitative equivalence between certain of the apparently independent primary dimensional quantities: length, time, and mass, and therefore a hidden element of redundancy. This redundancy was neglected in classical theories, the complete practical and theoretical independence of the procedures and results of the measurements of the three primary quantities being taken for granted. But in retrospect it is clear that each dimensional constant in classical and subsequent theories implies an element of redundancy in the primary quantities. As Whitehead* pointed out in 1919, 'Always when a possible definition of congruence is neglected, such absolute physical quantities (i.e. the dimensional constants c, etc.) occur'. Thus fertile hints for post-quantum theory are hidden in classical physics, though their general interpretation has not yet been found. This may require a dimensionless super-Minkowski, and he has not appeared. [*A. N. Whitehead, 'An Enquiry Concerning the Principles of Natural Knowledge', 1919, p. 164.]

It will provisionally be assumed that the theoretically primary dimensional constants (here taken to be $c, e^2, h, m; M$), more precisely their dimensionless ratios (α, β), are valid constants, * independent of the circumstances of their measurement in space and time, up to say four significant figures. There are grounds for regarding G and γ as less fundamental in an atomic theory and possibly as varying when measured in different settings. The other 'fundamental' constants will also be provisionally treated as secondary. [*The values for α and β given under 'Notation' are taken from Cohen, Crowe, and Dumond, 'Fundamental Constants of Physics', New York, 1957.]

Classical Thermodynamics demonstrated the possibility of a theory based not only on time-invariants (conservation of energy, mass, or later mass-energy) but also on increasing (or decreasing) statistical functions of a macroscopic system. The classical entropy, S, is a scalar associated with a macroscopic region, definable as a statistical mean based on an assumption of disorder and on postulates of the *a priori* equal probability of certain conditions. This classical macroscopic scalar may require generalization in atomic theory into a 'vector' function of micro-parameters, appropriate to represent partly ordered as well as disordered systems.

Since differences are necessary to initiate one-way processes, it may be convenient, as a more direct representation of the observed facts, to employ decreasing variables or *diminants*, * which vanish when a particular relaxation, decay, or dissipation process reaches its terminus. While probability theory is indispensable in certain realms, it may not be necessary or appropriate to reduce all continuously changing variables to statistical assemblies of sharply quantized values. For example, the finite breadth of certain quantized variables, such as frequencies, might be treated as functions of continuously varying primary parameters, e.g. diminants. [*On diminants, see W 20, p. 14; on one-way processes, W 3, W 4, W 20; also WC, WE.]

Special Relativity Theory exploited *(a)* the space-like reversible character of single-field or two-entity processes; and *(b)* one of the latent equivalences of the three classical dimensional quantities, by providing space-time transformation rules involving new effects at high velocities (four-dimensional calculus linking frames in relative motion, mass-energy equivalence, etc.). Thus the Special Theory illustrated, in respect of c, the general principle that the presence of an appropriate dimensional constant permits, and sometimes invites or even demands, the formulation of explicit rules of equivalence between apparently distinct dimensional functions. But it did not provide any discussion of a possible more general significance of this: that the most comprehensive laws (which can be speculatively contemplated in this century) might entirely dispense with one or more of the current primary quantities, L, T, and M. However, the General Theory of Relativity in effect did just this, though not quite completely; it provided a macroscopic theory on a kinematic foundation, treating only length and time as primary, and reducing mass-inertial-gravitational properties to functions of a non-Euclidean space-time metric.

But the lessons of the General Theory for atomic physics are of limited value and partly negative. *(1)* It is macroscopic only, and its methods are unsuited to current atomic problems. *(2)* It cannot predict the magnitude of gravitational actions. *(3)* It does not entirely discard either time or mass from the dimensional quantities which have to be treated as primary, for it leaves many marginal problems obscure (boundary conditions, types of frame and solutions applicable to various complex problems, relation to atomic and to cosmological properties, etc.). *(4)* These points, still outstanding after forty years, reinforce the doubts, expressed by Larmor and Whitehead amongst others, as to whether a heterogeneous continuum without very powerful restrictive conditions can provide the basis for a theory of systematic physical measurements.

We therefore return to the Special Theory and summarize the suggestions which appear to arise from its empirical success. *(a)* As Boscovich suggested in 1758, and Mach in 1872, it may be possible to base theory directly on the changing spatial relations of physical entities, and to dispense with the introduction of co-ordinate systems as a technique for representing observed relations. This has been proposed more recently by Eddington and Russell. The idea that rods and clocks are not irreducible systems, and that a more general representation of the ordering events not expressible in a fourfold co-ordinate system may ultimately be necessary, was clear to Einstein and Eddington as early as 1921-22. *(b)* It is desirable to carry further the partial reduction of the quantitative duality of time and space achieved by the Special Theory, and to aim at the elimination of multiple dimensionality from basic theory, by showing that the pure number ratios and the various dimensional constants arise from the introduction of linear frames and dimensional methods into a dimensionless theory, as part of the conditions under which dimensional frames of space and time can be defined in terms of the more general concepts of a unified theory. For example, ‘mathematical points’ would only be allowable in physical theory where the theory provides them with a definition in observable physical terms. *(c)* Just as velocities greater than c are not permissible in the Special Theory, so, in a unified dimensionless theory, the conditions determining the permissibility of linear co-ordinate representations may set limits to the permitted values of other dimensional quantities, for example in treating very small or very large systems.

Quantum Theory. Here we must consider not only the more fully systematized mathematical theory of Quantum Mechanics, but also a wider context of empirical facts, such as the theoretically arbitrary dimensional constants and the various particle parameters with their signs.

Quantum theory stresses a number of non-classical properties which apparently characterize micro-phenomena: the statistical indeterminacy and complementarity of the basic variables; the need for abstract representations in higher complex spaces with a high degree of invariance and inter-convertibility (until experiment reveals unexpected non-equivalences); the Pauli principle and similar rules imposing aspects of order on the potential disorder of the structural units; the need for partial second quantization; and finally the strangeness of the new realms of the nucleons, high energies, transient particles, strong and weak interactions, and complex systems, where Quantum Mechanical methods which have grown from a classical foundation achieve much but have hitherto failed to provide clues to more extensive but physically simple generalizations.

All the methods of Quantum Mechanics, from its earliest successes to the recent speculative theories of baryons, mesons, and leptons, depend on the initial separation, as frequencies (energies) or decay rates, of phenomena which correspond to single terms in a power series in some e. Examples are: the series in powers of a in optical spectra; in powers of $\sqrt[4]{\beta}$ in the stationary states of molecules; and in powers of the ratio meson/nucleon mass in tentative theories of the nucleus. Thus Quantum Mechanical methods are approximative in a sense which challenges the search for closed expressions equivalent to these series.

Now all the series in εs result from the selection of stationary parameters with high invariance properties as theoretically primary. The closed expressions to which these series are equivalent might discard this restriction and represent some primary continuous variable with lower invariance properties. Moreover, the separate treatment of individual terms in any series implies provisional neglect of the vector signs and phase relations which link the phenomena represented by the terms. Hence this unknown primary continuous variable may express vector asymmetries and phase relations, or their equivalent in some generalized representation. This connects with the fact that the *P, C, T*, invariances which are normally assumed, appear to neglect finite residuals, i.e. latent asymmetries, determined by the finitude of the εs.

Quantum Mechanics, in the narrow sense, covers only those properties which have been fully systematized in a probabilistic interpretation; quantum theory, as yet incomplete, seeks to cover all quantized phenomena: the atomicity or discreteness of electric charges, of action or angular momentum in atomic systems, and of mass (or equivalent lengths). A complete quantum theory should treat all the fundamental constants except *c*, which is a non-quantized relation between space and time measurements. But it is improbable that a complete quantum theory is possible except as part of a theory including c as well as e^2 and h. However that may be, the universal discreteness of e and of h challenges interpretation.

It is not yet known how far the above non-classical apparent properties of the micro realm are necessary elements in any representation of the observations, and how far they are imposed on the phenomena by the methods of quantum theory and can be either discarded or transformed in a more powerful theory. For example, the form taken by quantum indeterminacy might be the consequence of applying a theoretical system with too many degrees of freedom, a signal of a redundancy in current theory.

In any case the mathematical theory of Quantum Mechanics, by representing all the equivalences of current theory (mass-energy, energy-frequency, and the other coordinate and sign invariances) in a comprehensive *abstract* system, has cleared the ground for new *physical ideas*. Quantum Mechanics has reduced the physical content of theory to the minimum compatible with the retention of dimensionality (L, T, M), reversibility, and two-particle interactions as primary. Beyond that Quantum Mechanical methods may be inappropriate. But the theory has successfully brought physical theory and experiment to the borders of a new realm where the crucial problems are not adequately interpreted as measurements of theoretically unambiguous quantities, but involve also determinations of the presence or absence of certain types of temporal or spatial asymmetry, and for this no general theory exists. The breakdown of parity is one sign of a new orientation of inquiry, theoretical and empirical.

The treatment of stationary values of dimensional quantities as isolable and primary in Quantum Mechanical theory tends to conceal the theoretical significance of the dimensionless variables, e.g. t_0/t, v/c, etc., involved in interactions, decay processes, relativistic corrections, etc. But established theories and their models can provide no suggestions regarding the appropriate form of any dimensionless quantity $Q' = f(l_0/l, t_0/t$, etc.) which is not expressible as a product of powers of the primary quantities,* yet may be required in a unified theory. [*See W 13.]

It is here that physics enters the realm of many-body actions, which may be velocity-dependent or angle-dependent, and may necessarily involve radiative dissipation of energy, e.g. neutrinos. This is the realm in which new ideas, not contained in classical, relativity, or quantum theory, are required, appropriate to the relaxation processes of complex structured systems.

Returning to the established methods of Quantum Mechanics it is evident that *(i)* the dimensional constants, equivalences, etc., of quantum physics; *(ii)* the form of the principle of indeterminacy; and *(iii)* the rules of partial ordering, such as the Pauli principle, reinforce the tentative inference made from relativity theory: that the classical foundation on which the two great theories of this century have been constructed involves a double parametric redundancy: excessive dimensionality and excessive analysis into separable entities, whereas the observed facts may only compel the assumption of certain changing spatial relations of simpler non-analysable particles, here called primary. These primary particles may be permanent Boscovichian point centres (a class of stable nucleons?), appearing singly in different circumstances as neutrons and protons, and displaying in complex extended systems propagated modes of system deformation identifiable as electrons, photons, and the various other particle-fields. On this view ‘fields’ are modes of deformation of systems of primary particles representable by collective co-ordinates.

Thus the success of relativity theory and quantum theory suggests the following policy: start by assuming a less complex foundation, simpler both in dimensionality and in structure: the changing spatial relations of one type of primary stable particle and discover what can be achieved on this basis. The multiplicity of dimensional constants means that a unified theory should employ a drastically reduced number of degrees of freedom, or the equivalent, in representing atomic systems. Moreover, a theory which derives all known fundamental εs must be in a position to show how all known particles can be represented in terms of a single class of particles, or some equivalently simple basis.

Summary of inferences from the successes and apparent limitations of established theories

Our provisional conclusion is that the necessity for dimensional constants, indeterminacy, and rules of ordering implies the possibility of a drastic reduction in the present complexity of theory, the unification of the arbitrary array

of empirical particles being assisted by a reduction in the number of primary dimensional quantities. This radical suggestion rests on a strong logical basis. For dimensional principles not only express symmetrical relations, but are the consequence of treating such relations as primary. In a theory based on asymmetrical relations it would be appropriate for all symmetrical relations to be simultaneously derivable subject to certain conditions being satisfied. But these conditions can only be defined in the terms of the more comprehensive theory.

In searching for a General Law of which established expressions are Limit Laws or special cases, it may not be necessary to employ the complex abstractions of non-linear, non-local, or similar fields. 'Field' parameters are always measured in physical systems constituted of selected nucleon patterns (spectroscopes, linear or circular accelerators, etc.). This means that a simpler alternative is available. Instead of treating particles as 'quantized fields' the observed field parameters can be interpreted as collective parameters representing modes of deformation of special sets of nucleons. Analytical interpretation in terms of separable particles may have been carried too far, and it may be possible to simplify theory by confining it to the direct treatment of observables as representing states of those extended systems of special structure which provide the indispensable setting for all exact observations.

4. DIMENSIONLESS CONSTANTS

THESE suggestions are not reliable inferences from recent physics; they go beyond the firm ground of tried principles and accepted facts. But they claim attention because they are supported by many arguments, and can thereby be given more definite form as a coherent system of ideas, sufficiently precise to invite mathematical exploitation. One of these arguments arises from a survey of the history of physics over the last hundred years. Trends can be misleading, but a long-term tendency which clearly has not yet reached its culmination should not be neglected.

Physics is a matter of observable parameters and their relations, and one of the most widely confirmed principles is that the functional relations of observed variables involve certain constants: c, e^2, h; G, M_p, t_p, etc. Without the theoretically arbitrary values of these constants current theory can make no predictions; with them these theories contain an element drawn from experiment which is not yet theoretically predictable. These dimensional constants both permit the predictive success of current theories and display their theoretical incompleteness. The inference is clear; the constants c, e^2, h, etc., link the facts and theories of the past to the more complete theory of the future which must, for example, show why the Correspondence Principle only works for electrons and photons provided $2\pi e^2/hc$ is given the value 1/137.03(7). . . .

When the history of the theoretically fundamental constants is examined we find a tendency for their expression to shift from dimensional towards explicitly dimensionless orms,* in a non-trivial, physically significant manner. [*Planck's introduction of 'natural units' (1906) was trivial, since it did not lead to the discovery of any new properties, as did the use of Atomic Numbers, Packing Fractions, etc.]

As experiment and theory have advanced and more constants have been discovered the facts have permitted, and the theories have tended increasingly to require the explicit use of dimensionless constants. This is clearest in the case of the fine-structure constant which appears to be of special theoretical importance. Unlike the series of constants β_p, τ_p, which serve appropriately to calibrate measures of length and of time respectively, α combines three dimensionally contrasted constants and thereby connects three basic phenomena: the atomicity of charge, of action, and the length/time relation associated with the propagation of light.

But the same tendency is also present, though perhaps less significantly, in other cases. While certain aspects of current theories can be converted at will into many contrasted dimensional expressions, it has become increasingly evident with each successive decade since 1910-20 (when it was already noticed by several advanced thinkers *) that the dimensionless ratios of the constants are what matters. By 1937 Zwicky** could suggest that 'scientifically speaking history means the change in time of dimensionless ratios of significant physical quantities', an idea which has been implicit in many recent cosmological speculations and has still to find its fertile application to atomic theory.[* Einstein, Jeans, and others.] [**F. Zwicky, Proc. Nat. Acad. Sci., 23, 106, 1937. See W 14.]

Now let us take a glance at the historical facts.

HISTORICAL CHART

Of early empirical Determinations (Det.) and Theoretical Exploitations (Expl.) of fundamental constants, in explicitly dimensional and dimensionless forms

DIMENSIONAL

1600	*Age of Dimensional Constants (1676 . . .?)*		
	1676	c	(Det. Romer)
1700			
	1798	G	(Det. Cavendish)
1800			
1860			
	1865		Loschmidt est. diam. of a molecule
1870	*c. 1870*	c	(Expl. Maxwell)
	1874	'e'	(Johnston Stoney est. *e)*
	c. 1875	M_P	(Det. of particle masses begun)
1880			
	1885	R	(Rydberg const. Det., and Expl. by
			Balmer)
1890			
	c. 1892	'e/m'	(Larmor, Lorentz develop 'electron'
			theory)
	1897	e/m	(Det. Thomson, Kaufmann, Wiechert)
1900	*1900*	h	(Det. and Expl. Planck)
1910			
	1911	e, m	*(e* Det. Millikan)
	1913	R	(Bohr derives Rydberg const.)
1920			
1930			
	1932	t_p	(Det.)
1940			
1950			
	1959		All *theories* still explicitly dimensional

Note on above Chart. 'Det.' is used to refer to a new experimental measurement which permitted the calculation of a constant. The work cited is not necessarily the earliest, though possibly the most important. The early definition of macroscopic dimensionless groups, such as the Stokes-Reynolds number (1850), is neglected.

HISTORICAL CHART

DIMENSIONLESS

Age of Dimensionless Constants (ε) opens *c*. 1900

1897-1900	β, γ calculable
1900	(e^2/hc) calculable
1909	Einstein calls attention to primary importance of (e^2/hc), and in effect defines *problem of* α.
1910	Atomic numbers substituted for nuclear charges (Van den Broek, Moseley)
1916	α (Expl. in Sommerfeld's theory of rel. fine-structure)
1919	Weyl calls attention to α and the cosmological pure numbers
1920	Packing Fractions (Det. Aston, etc.)
1925 onwards	εs subject of increasing attention (Eddington, Dirac, Milne, Jordan, Landau, etc.)
1928	Jordan suggests that three relations should exist between the six fundamental dimensional constants.
1932	Bohr calls attention to one aspect of the significance of α, β_p, τ_p (earliest Dets.)
1947	Ratio strong/weak interactions Det.
1959	Many *facts* most significantly expressed in dimensionless form.

This movement from the unquestioned employment of dimensional constants towards increasing explicit use of dimensionless ones is not an arbitrary or trivial phenomenon ascribable to changes of fashion selecting at random between theoretically equivalent representations. For:

1. It only becomes possible with the *increasing scope of physical experiment and theory*.

2. It renders possible new theoretical methods which are not only mathematically more elegant, but physically more significant since they represent important features of the empirical situation: the partial or approximative character of the particles and fields which the experimental arrangements are expressly designed to isolate, as far as that is possible. For example, Bohr* pointed out in 1932 that 'the idea of point charges in the theory of atomic and molecular structure is only justifiable by the smallness of e^2/mc^2 relative to the size of atoms, i.e. by the smallness of α relative to unity'. Thus the success of current theories depends on the smallness of the εs relative to unity, which alone permits first, the isolation of the various fields; and secondly, the study of their 'interactions', both represented by successive terms in approximative series in powers of εs. The εs appear to be *separators* (i.e. numerical *quantizing operators* approximately separating most nearly stationary linear parameters), which link the partly separable facts and theories of the past to the unknown unifying theory of the future. [*N. Bohr, J. Chem. Soc., 1932 (I), 378. Also: 'The whole attack on atomic problems leaning on the correspondence argument is an essentially approximative procedure made possible only by the smallness of (α) which allows us to a large extent to avoid the difficulties of relativistic quantum mechanics in considering the behaviour of the extranuclear electrons.' The problem of α, etc., 'lies outside the scope of the present formulation of quantum theory in which the complete independence of these two fundamental aspects of atomicity is an essential assumption' (pp. 378-9).]

3. It permits the use of *new mathematical functions*, alien to dimensional physics. Buckingham* showed in 1914 that 'every complete physical equation can be expressed in dimensionless form', but the reverse is not true, for dimensionless secondary quantities of the form $Q' = f(l_0/l, t_0/t, v_0/v, etc).$, are not, in general, expressible in the traditional form for physical quantities, i.e. as a constant X product of powers of primary quantities. ** Thus the use of dimensionless quantities permits the employment of new classes of mathematical functions. Moreover, groups of the form (l_0/l), etc., constitute dimensionless variables of the kind now used in representing high energy processes. [* E. Buckingham, Phys. Rev., 4, 345, 1914.] [**See W 13.]

4. These more general functions Q' may, for example, represent angular relations hitherto relatively neglected in fundamental physical principles.

Thus the movement towards dimensionless formulations has all the marks of being part of a transformation to a more powerful method which has not yet been found. That is a reasonable interpretation of recent history, and it becomes the more convincing when it is realized that α, which may be a master key to the required transformation of theory, has led the movement towards physically significant dimensionless expressions. However, it must be remembered that α and β may be derivable together and that a might appear as the ratio of two constants ($\alpha.\beta^s$) and (β^s) in a theory treating nucleons as primary.

An historical survey of all the investigations that have been made since 1909 in relation to α alone would require a major volume. * Here we can only note a few important stages in the slow movement towards a valid interpretation of α: [*See W 6, for further details on the history of a. Also H. S. Allen, The Quantum, London, 1928, pp. 178-83.]

1900 The dimensionless group e^2/hc is calculable.

1909 The primary theoretical importance of this group is recognized (Einstein). Since e^2/c and h have the same dimensions, they should be traceable to a common source. 'The same modification of the (Maxwell-Lorentz) theory which contains a as a consequence, will also have the quantum structure of radiation as a consequence.'

1910 Haas uses the group (e^2/hc) to derive Rydberg's constant, with error of a factor of 8.

1913 In Bohr's theory of the hydrogen spectrum and of Rydberg's constant $\alpha = v/c$ (v = electr. vel. in most stable orbit).

1914 Lewis and Adams propose first theoretical derivation of α. Jeans associates atomicity of e and of h, since $hc/2\pi = (4\pi e)2$.

1916 α is used in relativistic theory of fine-structure of hydrogen spectrum (Sommerfeld).

1928 Spin properties of electron are derived from a linear relativistic wave equation, with solutions involving power series in α (Dirac). More serious attempts are made to derive α (Eddington, etc.). α and atomicity are speculatively linked with stability (Perles), with fundamental lengths (Fürth, Whyte), and with coordinates (Whyte).

1931 Wigner publishes a systematic classification of atomic energy states and transition probabilities as even and odd terms in a power series in α.

1932 Current atomic theory, being based on classical analogies, is recognized to be an approximative method which works solely because $\alpha<<1$ and $\beta<<1$ (Bohr).

1935 'The explanation of (α) must be the central problem of natural philosophy' (Born). Euler and Kockel propose a derivation of α.

1953 An attempt is made to derive α, etc., from non-linear field theory (Heisenberg).

1959 Though α has been variously linked with atomicity, the assumption of point centres, stability, lengths, and the use of co-ordinates, no definite advance has been achieved towards its derivation as part of a unified theory, 60 years after this dimensionless group was first calculable. For example, Eddington's derivation of α throws little or no light on the primary problem.

It has been argued elsewhere* that dimensional laws are *incomplete*, because they do not show how the variables are measured, but leave that to a separate theory of measurement; misleading, because they implicitly claim general validity and do not indicate that they are approximations which fail beyond certain limits; and *contain a redundant element*, because they do not exploit the equivalence evidenced by the presence of dimensional constants. Sufficient has already been said to suggest that appropriate dimensionless expressions might eliminate these three blemishes simultaneously. For dimensionless variables *(i)* express ratios; *(ii)* can define the range of validity of dimensional expressions; and *(iii)* can represent angles and their changes from which linear ratios and differential coefficients representing their changes (ratios of velocities, accelerations, masses, etc.) might be derived, given an adequately powerful principle of quantification. [*See W 14, p. 7.]

The transformation from dimensionless (? angular) expressions to dimensional ones may involve two steps linking three types of formulation:

I. Postulates of *U*. (Chiral diminants of angular systems.) These postulates applied to compound systems to permit the definition of stationary dimensionless parameters of certain kinds under special conditions expressed by:

II. $F_1 = \varepsilon.F_2$ where F_1 and F_2 are dimensionless but bear a geometrical correspondence to dimensional functions now in use, so that by the introduction of arbitrary units of *L, T*, and *M*, II becomes, say,

III. $(h/2\pi).F'_1=(e^2/c).F'_2$ (where ε is taken to be α).

This hypothetical procedure follows both Einstein's 1909 suggestion and the principle* that 'the essence of a derivation of α, β or γ is the postulate that two physical quantities hitherto treated as independent have a common origin and have identical meaning in relation to ultimate physical structure provided that an appropriate numerical factor is introduced'. In the above F_1 and F_2 have the same meaning in *U* provided ε is introduced appropriately. The 'special conditions' defined by II express the fact that F_1 and ($\varepsilon.F_2$) mean one and the same thing in *U*, e.g. are two ways of representing one angle. [*See WB, p. 117.]

The first aim of *U* is to explain how the numbers 1/137.03(7) and 1/1836.1(2) . . . come to be the primary quantizing operators of atomic physics. In relation to this task a and P are not coupling constants, linking known fields, but separators which determine the conditions under which certain aspects of a single phenomenon can be treated first in isolation, and then as interacting in various manners, corresponding to the terms of power series in α and β. The efficacy of the quantization principle associated with *h* rests on the smallness of these numbers, and the presence of dissipative effects is due to their finitude. To throw light on this situation a new kind of physical or geometrical model is required: one which not merely represents the correct dimensional relations as determined by experiment, but shows how two dimensionally equivalent but quantitatively distinct magnitudes may be expressions of a single underlying factor. Since 1905 we have become accustomed to recognize the existence of a single unique velocity *c*; a theory of α and β must teach us to recognize three such velocities of contrasted geometrical types: *c*; $2\pi e^2/h$; and (say) $2\pi e^2/h.\beta^s$; as consequences of one hitherto concealed principle.

On the present view α, β, and the other εs are, together with the appropriate integers, pattern analysers which determine the conditions under which contrasted pairs of most nearly stationary lengths, etc., are definable. *The εs are quantizing operators which connect pairs of isolable, most nearly stationary spatial components of the one-way processes of complex systems*. If this is correct the still hidden principle must express the existence of calculable geometrical relations linking pairs of contrasted extremal components of a single process in appropriate sets of primary particles.

5. TOWARDS A BROADER FOUNDATION

IF a theory *U* is possible, the various aspects of our problem must be multiply inter-related. Yet it will be convenient to summarize and extend the argument by restating it in sections dealing in turn with the following partially separable aspects of the proposed transformation:

dimensionality
status of co-ordinates
temporal relations
vector character
epistemology
many particle effects
primary particles.

Though this procedure is useful, each section uses terms whose meaning depends on the others. For, as we shall see, the transformation involves the reinterpretation of apparently independent ideas as related inferences, valid only under correlated conditions, from a single primary conception.

Subject to this caution, it is suggested that the transformation to *U* involves, as regards:

Dimensionality: Conversion of current dimensional theory to explicitly *dimensionless* geometrical expressions of a new type, only permitting the introduction of dimensional parameters (linear space co-ordinates, time co-ordinates, localizable quantities, masses, charges, etc.) under restrictive conditions expressed in the values of the εs. This conversion is intended to permit the use of a wider class of mathematical functions for the representation of physical quantities, so that from a single prior form all the known particle-fields, and their separators, the εs, may be derived. The aim is an angular *geometrical atomism (θ),* as opposed to the *mechanical atomism* (*L, T, M*) of Newton, and the kinematic atomism *(L, T)* of Boscovich. * The dimensionless geometrical parameters treated as primary may be angles (plane or skew). [*On the kinematic character of Boscovich's theory, see W 21, W 24.]

Status of co-ordinates: The elimination of the use of linear co-ordinate systems from basic laws, so that one aspect of *U* is strictly *relational*, involving only the finite spatial relations of primary particles; these relations being in general those of ordering, the quantitative relations of standard dimensional types entering only as ratios linking (nearly stationary) parameters of finite systems; and no quantities being point localized. The justification for this is mainly epistemological. Since ordering relations alone are directly observed the changing configurational relations of complex systems invite representation without co-ordinates.

It will be noted that a relational basis probably requires the treatment of e^2, not *e*, as primary.

Temporal relations: The generalization of the traditional Newtonian-Hamiltonian foundation in which reversible* basic laws, when either exact initial conditions are unknown or the system is too complex to permit exact representation, lead by the assumption of random distributions and the introduction of statistical methods to the macroscopic description of irreversible processes of increasing entropy. Instead *one-way processes* are to be postulated as fundamental and represented by *diminants* (functions of spatial relations which decrease as a system moves towards equilibrium), permitting the derivation of the ratios of most nearly-stationary parameters, as special cases determined by geometrical (angular) conditions. This inversion of the classical method is logically simpler, and may prove theoretically more general, because that method requires the introduction of an additional element alien to its primary concepts: an independent physical principle relating temporal succession (increasing entropy) to probability (statistics of micro-states). The methods of Quantum Mechanics *plus* the Statistical Theory of Fluctuations and Entropy appear to be inappropriate for treating the one-way transformations of partly-ordered structured systems, i.e. where structural relations are indispensable and a scalar entropy is either not definable or inadequate. [*The invariance of the solutions of the basic equations under the replacement of t by -t was, for example, explicitly assumed by Einstein, Berl. Akad. Sitz. Ber., 1925, p. 419.]

This transformation is from a theory based on symmetrical relations to one treating asymmetrical relations as primary, a point to which we shall return at the end of this chapter.

It is necessary here to emphasize the fink between two aspects: temporal relations and the quantization of traditional parameters. As has already been suggested, 'the finite value of α is due to the fact that the stationary states are complementary components, only separable with a finite error, of a basic one-way process'.* [*Quotation from W 20.]

Vector character: The presence of both polar and axial vectors (in a system defined in terms of co-ordinates) implies that the system, however represented, is chiral,* i.e. non-superposable on its mirror image (if such an image can be defined). This suggests that *U*, if it retains three-dimensional spatial relations as primary, must employ basic expressions which are chiral. The demand for a broader foundation means that both non-chiral diminants and time-invariants, where required, must be represented as special cases of a general chiral diminant deformation of the system. States of electric and magnetic polarization, indeed all electromagnetic effects and other skew-symmetric phenomena, must be represented as nearly, stationary aspects of the relaxation processes of chirally deformed systems. [*Chiral, see W 22, W 25.]

Epistemology: Quantum Mechanics treats the interactions of separable quantitatively defined systems, e.g. physical systems and measuring instruments, and seeks to define the limits (indeterminacy, etc.) of this procedure. *U* would combine system and rod (or clock, etc.) and their interactions as components of a single system-process in which only asymmetrical ordering relations are defined, and treat quantitative (dimensionless) ratios of internal parameters as secondary. This expresses the following factually valid and deeper interpretation of 'measurement': all 'determinations of quantitative parameters' are inferences from either *(i)* the observation of a spatial or temporal asymmetry in a finite system-process, or *(ii)* the observation that whatever asymmetry, if any, may be present is below the limits of observation. All spatial measurements depend in general on the principle of the vernier (or the equivalent), and all temporal measurements on the recognition of the asymmetrical relation of succession between two perceived events, *A* and *B* (*B* recognized as *later than A*). The inference or assertion that two lengths or times are quantitatively equal always goes beyond the actual observation, which is that there is no observable degree of inequality. Moreover, this inference not merely exceeds the observed phenomenon in exactitude, but also changes its character: from the determination of an ordering asymmetry, spatial or temporal, to the assertion of a quantitative equality.

This quantitative refinement and qualitative transformation of the actual observations is neither epistemologically justified nor theoretically necessary, and may, if desired, be discarded. If possible *U* should satisfy the most severe epistemological condition: that the theoretical derivation of any parameter should correspond to the empirical procedure of its measurement. Parameters and their signs should only be theoretically definable in the circumstances under which they are observable.

In the theory *U* objective nature is not the realm of quantity, but of *order*, i.e. of asymmetrical ordering relations. Physical observation is the determination of order in finite systems; quantitative relations express restricted aspects of the observable order, and also much that is never observable. The root source of all quantitative relations lies, not in any basic quantitative properties of particles, but in the equivalence of all primary particles, expressed in the geometrical conditions under which one-way processes display stationary parameters. The main task of *U* is to determine the conditions of valid quantification, in the general sense of the legitimate introduction of equalities. This is the deeper meaning of 'quantization' in terms of *h* or *e*.

Many particle effects: Established theories were based originally on the treatment either of single fields or of the interactions of two entities, whereas *U* involves the use of methods essentially appropriate to the deformations of (partly-ordered) many-particle systems, covering as special cases effects in which only two particles enter. Instead of treating two-entity interactions as first order effects and multiple interactions as of higher order, many-entity system parameters are to be treated as fundamental. But the processes of such complex systems are no longer regarded as due to 'actions' or 'interactions' of their parts. In a theory which discards co-ordinate systems, treats the changing pattern of the relations of permanent particles as primary, and represents this pattern directly, the traditional concept of the action of one entity on another disappears. It is replaced by the system diminants, which represent the relaxation processes of the system as a whole, and only in limiting cases does it become meaningful to consider two entity 'interactions'. Indeed in a relational theory whose only terms are point-particles the conception of separate point-localizable *events* also disappears.

Thus *U*, by placing the primary emphasis on system variables (diminants), implies the generalization to changing (relaxing) partly-ordered systems (combining spherical and linear ordering) of the static symmetry theory of the fully ordered 230 crystal .groups. The smallest partly ordered sets of primary particles are spherical or central (nucleus, atom), but these sets are often arranged in linear arrays: molecules, crystals, etc.

Primary particles: Since the aim of *U* is to combine formal elegance with physical validity, the uniquely simple and preferable atomistic assumption (which should be granted as much attention as any alternative less radical but more arbitrary assumption) is to start with one class of primary permanent point particles possessing no quantitative properties. As has already been pointed out, a theory which could derive all the εs would necessarily be able to reduce all particle parameters to functions of systems composed of only one class of particle. These primary particles constitute the permanent terms of the observed changing spatial relations. The thirty or more different known types of 'elementary particle' are then either

a. Such primary particles (? a class of permanent nucleons with identity), in situations where quantitative parameters may in *co-ordinate theory* be ascribed to them, subject to certain conditions; or *b*. Propagated nearly-stationary components of the decreasing chiral deformation (excitation) of extended systems of primary particles, represented by collective parameters. These are not true constituents of material systems, but field quanta.

It appears that nucleons are unique amongst the 'observed particles' in that in current theory:

i. Excluding high energy nucleon pairs, a class of nucleons can be defined which are permanent and possess a basic unit of mass which is not convertible into radiant energy;

ii. Nothing is ever directly observed where there are no nucleons to define a frame, i.e. it can be assumed that only nucleons, or systems of nucleons, interact with each other. All fields and radiative interactions can be regarded as occurring between nucleons or systems of nucleons, or as localized in relation to such systems.

In 1931, before the discovery of the unstable particles, it was suggested by the author * that 'theoretical microanalysis, after passing the valid limit to micro-structure, will yield spurious ultimate units of increasing complexity in place of the simple ultimate units required by an ideal theory'. This prediction has been fulfilled, for the 'elementary particles' discovered since 1932 are 'spurious' in the sense of being unstable, and display all the signs (instability, complexity, etc.) of being non-elementary quantized fields which have been treated as 'particles', i.e. structural units, as the result of the application of atomic ideas to high energy processes in a manner which conceals their origin in sets of nucleons. [*WB, p. 131.]

But the reinterpretation required in *U* extends also to electrons and photons, i.e. to all particles other than one class of stable nucleons. All particle parameters are observable only in relation to physical systems and frames constituted of nucleons. The fact that $\beta << 1$ implies that the approximative methods of Quantum Mechanics based on the separation of electron and photon from nucleon parameters can only be applied if an approximate *nucleon* pattern is assumed *before* the corrections determined by *electron* fields is applied $\beta << 1$ involves the prior theoretical status of nucleons in *U*, and a derivation of β therefore implies, with high probability, the reduction of electron parameters to functions of nucleon arrangements (or the equivalent).

We therefore reach the conclusion that the parameters and structure of all the elementary particles other than nucleons must in *U* be properties of particular states of deformation of systems of primary particles.

Summary. The argument has led to the following heuristic assumption: that

> *U must employ chiral dimensionless diminants, representing deformations of partly ordered, centred and linear, systems composed of one class of primary point particles without quantitative properties.*

Though novel, this is a physically simple conception. From this single primary idea it appears conceivable that a system of contrasted but correlated quantitative principles may be derived. The required transformation is complex, in that it possesses many aspects, but it is also in one respect simple. For the deductive structure of *U* in all its aspects must possess the form:

Asymmetrical relations permit the derivation of multiple symmetrical relations, as correlated special cases under particular conditions. Moreover, this deductive structure also expresses the structure of isolable temporal processes: *Asymmetries decrease in isolable processes*. * ['C'est la dissymetrie qui crée le phénomène' (P. Curie).] The invariance of effects can be wider than that of their causes, and is so in all complete one-way processes. The basic law is an inequality linking temporal succession with smaller spatial differences. [*See WS, W 19, W 23; also WC, WD, WE. The principle that 'asymmetries decrease in isolable processes', which I have called the 'unitary principle', has a long history (see WC, pp. 19-32). Curie's observation quoted in the text was made in 1894. Jaeger called attention to a tendency towards symmetry in his 'Lectures on the Principle of Symmetry', Amsterdam, 1920 (p. 183). Various formulations can be found from Herbert Spencer (1862) to Whyte (1931), Sellerio (1935), and Renaud (1935).]

The reverse procedure of treating symmetrical relations as primary, and asymmetrical as either arbitrary or as the consequence of statistical effects, is more abstract, less powerful, and leads to paradoxes and inconsistencies where its basis is too narrow. By the selection of an appropriate co-ordinate system the processes of particular ultimate constituents can usually be made reversible in that frame; but the decrease of any asymmetry of a complex system as a whole cannot be analysed away by the choice of a suitable co-ordinate system and demands the employment of the asymmetrical relation of succession for its representation.

Numerical relations, holding between the members of a given class of parameters, which appear arbitrary while that class is treated as primary, can in principle be theoretically derived only by representing them as correlated special cases of a more general class. Applying this principle, we infer that the εs, which determine the quantitative relations holding between (*P, C, T*) invariants, must be derived as correlating special cases in a theory which treats chiral, centred, one-way processes as primary.

The proposal to discard time invariants from basic theory and to extend the conception of one-way processes from the macroscopic realm of random systems and scalar entropy to that of micro-structures challenges accustomed ways of thinking more than any other aspect of the present programme. This is particularly so for those who have been trained to accept either Classical or Quantum Mechanics as the unique basis for physical theory. But there is a deeper reason. Temporal invariance expresses a basic preference of the human intellect in its search for simple fundamental concepts.

This difficulty might conceivably be reduced by introducing the proposed method merely as an alternative or complementary procedure for representing other aspects of physical phenomena which does not contradict established principles, but answers different questions. For example, it appears that *U* treats a different class of systems as isolable, i.e. non-conservative systems in which certain functions decrease and vanish and there is a virtual loss of energy by radiation (e.g. neutrinos, and other radiative dissipation).

But this easy way of reducing the challenge is only partly legitimate. For if *U* can be developed and confirmed its methods must in certain realms contradict the predictions of established theories, showing that their valid scope is restricted by boundaries definable in *U*. In this sense *U* is more extensive and fundamental, not alternative, and its success must be proved by its ability to make valid predictions contradicting earlier theories.

The main task of theoretical research leading towards *U* is to identify the structural asymmetries, or diminants, whose most nearly stationary components correspond to the various types of quantized field or particle. The non-invariant, i.e. *variant* (chiral, centred, diminant) aspects of the interactions of *T, C, P* invariants must be identified and located in particular experimental arrangements of stable nucleons.

6. OTHER VISTAS

THE development and successful application of a theory *U* would have consequences both for natural philosophy in general and for the special branches of exact science. The following suggestions are speculative but they serve the purpose of illustrating the character of *U*.

Order, clash, and disorder. Fundamental theory has hitherto found it possible relatively to neglect partly-ordered systems, even the two limiting cases of perfect crystalline arrays at zero temperature and of random 'thermal' disorder in macroscopic regions being only somewhat indirectly related to fundamental physical principles. Order-disorder transformations are regarded as of importance only in special fields, such as the theory of crystal lattices. This is partly due to the minor role given to explicit statements of initial and boundary conditions in the formulation of classical and relativistic laws. No general principles for the treatment of the interaction of contrasted forms of order, or of the transformations of order and disorder, have yet been provided.

In a theory based on the characteristic diminants of contrasted structures a new factor emerges: the principle that the tendencies of two systems will in general clash, though one or the other process may dominate and proceed while the other is arrested, deformed, or reversed.

This *principle of clash* is a necessary part of any general theory of diminants, and clash will be absent only when special relations of identity or complementarity hold between the two systems, i.e. when they can be treated as components of a higher stable system determined by its own characteristic diminant. Thus the concept of a universal order of nature implies, in a structural theory of order, the frequent inevitability of clash leading to deformations, transformations, and disintegrations. Indeed, clash only disappears entirely if and when the universe attains a static terminus. Clash is an inescapable element in any complex changing order.

Moreover, the ancient antithesis of quantitative atomism versus conceptions of overall form is resolved in a single view of changing point patterns. The 'form' loses its vagueness and becomes a definite changing pattern of points, while the 'particles' lose their quantitative properties and become simply the end-points or terms of the spatial relations which constitute the pattern. The reality underlying both subject and object, in the assumptions of theory as in the facts of observation, is to be found in changing patterns of physical points, what is observable being their ordering asymmetries.

Theory of organic systems. * A surprising feature in the present state of exact science is the absence of any general theory, hypothetical or developed, of the character of the unified organization of living proto-organisms, cells, and multi-cellular organisms. In spite of the advances made in bio-physics and -chemistry, e.g. on the polymeric helices in DNA, etc., no testable hypothesis regarding the nature of the general integration of processes within organisms has yet been proposed. This is not necessarily due either *(i)* to the impossibility of such a theory; *(ii)* to the complexity of living systems; or *(iii)* to lack of essential empirical data. For it may be a consequence of the absence of any general method for treating partly ordered systems, with their one-way structured transformations. If this is so, any advance towards *U* may be helpful to exact biology in suggesting useful hypotheses and crucial experiments. For there can be little doubt that such conceptions as *centred systems, partly* *ordered systems, hierarchies of structure*, and one-way processes are indispensable to biology. It is a long journey from the articulation of individual atoms in a molecule to the unity in complexity of the human brain, but a serious start cannot be made until appropriate methods are available. [*See W3, W 18, W 19, W 20, W 23; also WA, WC, and on more general aspects: WD, WE.]

Cosmology. If the extrapolation of the dimensional quantities developed in ordinary scale physics is subject to more comprehensive restrictions in the micro and the cosmic realms, generalizing the one already known: *v* not greater than *c*, certain aspects of current theories of the size and age of the universe may be either invalid or empty. For such terms may not apply. Current extrapolations to cosmic distances and times cannot be relied on as either quantitatively valid or scientifically meaningful until the laboratory measures on which they are ultimately based are better understood, i.e. until a unified particle theory provides a satisfactory foundation for physics. It is possible that the elimination of redundancies in the concepts of fundamental physics may simultaneously remove the puzzling ambiguities that now arise in considering cosmological initial and boundary conditions. Alternatively, a clarification in cosmology might provide a hint for atomic physics. The nucleus and the cosmos may be related, not merely by quantitative relations, but by a common structure still hidden from our understanding.

7. CONCLUSION

THE purpose of this essay is to promote the development of mathematical expressions leading to empirical tests.

The following examples of special mathematical and theoretical problems arising from this programme are given to indicate that the method leads directly to significant unsolved problems capable of precise formulation.

Mathematical

1. The tetrahedron being the three-dimensional point arrangement involving fewest points, the relaxation towards regularity of a chirally deformed tetrahedron determined by a single diminant (e.g. a skew tetrahedron with congruent scalene faces having as sides 1, $1 + \delta$, $1 - \delta$) is the most elementary example of a chiral one-way process. Does the representation of this process in any Cartesian frame bear a significant relation to the vectors of co-ordinate physics? If not, what more complex point arrangement does provide an appropriate model?

2. What spherical sets * of a finite number of points (say $4 < n < 100$) possess extremal properties of any kind? For example, which minimize the Coulomb potential if the points are taken to represent classical electrons confined to the surface of a sphere (Thomson's problem); which maximize the least distance between any pair (Fejes' problem); and which discriminate as unique extremals of some unknown function the two sets of numbers determining nuclear and chemical stability respectively (magic numbers, and periods in the periodic table)? [*See W 8.]

3. What mathematical expressions are required for a general theory of partly ordered systems containing both spherical arrangements and linear groupings of these? The task is to select appropriate functions of the arrangement which decrease as it changes towards a state of higher order representable by fewer parameters, and to determine the most nearly stationary parameters characterizing this one-way process. If a theory *U* is possible, the master problem of theoretical research is the identification of those chiral diminants which allow the properties of all known stationary states to be derived as necessary relations characterizing their most nearly stationary components.

Theoretical

1. (For experimental physicists and physicist-engineers as well as theoreticians.) Is it possible to describe, or represent, all the various experiments in which the different parameters of the elementary particles are determined in terms solely of the changing relations of systems of primary point particles? What equilibrium, cyclic, and deformed states, and what one-way processes, are necessary in such a representation? This implies that all rods, clocks, and other instruments are to be treated as point arrangements partaking in the processes of the experiment.

2. If the εs are separators, i.e. quantizing operators linking pairs of contrasted nearly stationary components of a one way process in a complex system, what are the necessary and

sufficient mathematical conditions for the derivation of the εs, assuming that these conditions arise solely from a description of the corresponding experiments in terms of one class of primary point particles? For example, what mobile geometrical model of a system of separate permanent physical points at once illustrates the experimental determination of α and provides its theoretical derivation?

3. Can the theory of torsional-compressional vibrations in elastic media be generalized to provide a theory of the propagated chiral deformations and relaxations of infinite regular linear arrays of spherical point sets? Does the distribution of the deformation of particular sub-sets of such arrays correspond to the field equations of particles such as photons, electrons, etc.?

These problems do not exhaust the issues raised by this programme.

The *primary problem* has been defined as the unification of all types of particle and field, including their interactions and combinations.

This *Challenge* suggests that this problem must be solved by identifying all the invariants of current theory, and their interactions, as special components of variants: chiral, centred, one-way processes in complex systems of primary particles; and invites the attention of mathematicians and physicists to this task.

NOTES

PAPERS BY L. L. W. ON EXACT SCIENCE

N.B. To facilitate reference: relatively comprehensive. summaries of the argument, leading towards this essay but usually more specialized, are given in W 6, W 8, W 13, W 14, W 17, and W 20; also in WB, WC. The following ideas appear in papers and books from these dates onwards: one-way processes (1927); eliminating co-ordinates, using dimensionless variables representing angles, possible derivation of α, etc., as ratios of lengths (1928); chirality (1944, 1957); spherical point arrangements (1952); diminants (1955). On the development of these ideas see WC (Preface).

W 1 Zeit. f. Phys., 56, 809, 1929. 'On the characteristics of a unified physical theory. I. The presence of a universal constant with the dimensions of a length.' (In German.)

W 2 Zeit. f. Phys., 61, 274, 1930. 'Ditto. II. Rulers, clocks, and a possible alternative to 4-co-ordinate representation.' (In German.)

W 3 Libr. of Xth Int. Congr. of Phil., Amsterdam, 1948. I. 298. 'One-way Processes in Biology.'

W 4 Nature, 163, 762, 1949. 'Tendency towards Symmetry in Fundamental Physical Structures.'

W 5 Nature, 166, 824, 1950. 'Planck's Constant and the Fine-Structure Constant.'

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