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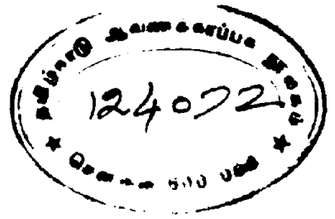

EDITORIAL NOTES

We deeply regret to announce the death of Dr. M. V. Gopalaswami, B.A., B.SC. (Honours), PH.D. (London), one of the senior-most professors of Psychology of this country. He has helped in the development of Psychology in various Universities. As a scientist and as a friend he easily won the respect and admiration of all those who met him. We take the opportunity of publishing a short account of his career as prepared by Dr. M. V. Govindaswamy, Director, All-India Institute of Mental Health, Bangalore.

In the demise of Dr. M. V. Gopalaswami, Psychology in India has lost a great leader. Psychology in our country owes a deep debt of gratitude to his initiative, enthusiasm and mastery over the subject. A student of the University of London, he studied under the celebrated psychologist, Dr. C. E. Spearman, with whom as a collaborator he has worked on some nœgenetic problems. On returning to India with a doctorate from the London University, he was appointed Professor of Psychology at the Maharaja's College, University of Mysore. There he founded and developed one of the best equipped psychological laboratories in India; and organised several interesting research projects. To mention a few are his work on psycho-galvanic reflex, on errors, on intelligence tests, on animal behaviour, on language and on values. He retired from the University of Mysore as Principal of Maharaja's College in 1952 and soon after, he was invited to organise the Psychology Department in the Government Mental Hospital, Bangalore. When in 1954, the All-India Institute of Mental Health was founded in Bangalore, he was appointed as Professor and Head of the Department of Psychology. He was born on 31st December 1896 and

passed away on the 29th of June 1957, while still busy organising and systematising the work of this new department.

Dr. M. V. Gopalaswami's interest was not confined to psychology. He was a man of varied tastes and ideas and among the subjects which interested him were classical and symbolic art, child education, radio, parapsychology, mysticism and photography. His theory of humour, his contributions to the Two Factor Theory, his work on PGR as lie detector and his work on learning are well known in the field of psychology. He was mainly responsible in the starting of nursery schools in Mysore ; the present radio station in Bangalore started its career almost as a personal enterprise of his. He was President of the Psychology Section of the Indian Science Congress in 1929, President of the Regional Psychological Congress held at Mysore in 1956 and the President of the Institute of Human Relations, Bangalore. During his later years, he was very much interested in the problem of values and has done significant work in this field which awaits publication.

A highly talented and great man, with mature ideas and ripe experience, his guidance was always sought after by scholars and institutions. He was kind and gentle, sympathetic and understanding. He carried about him the atmosphere of a serene wise man, ready to humour and to help. His students will remember him as a scholarly teacher with a gift for analysis and his friends and colleagues will treasure the kindly associations with him. The time spent with him was an intellectual adventure.

Some Aspects of Creative Thinking

BY

M. ARAM

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I. Introduction.

Progress in civilization has always been due to creative thinking, in other words, due to new discoveries, new concepts, and new hypotheses. For instance, Galileo discovered the law of inertia which marked the beginning of modern physics. Einstein's discovery of the principle of relativity gave physics a new basis. John Dewey's concept of experience has caused a new "World-view" in philosophy; and the application of that concept to education has given rise to a progressive movement in American Education. The hypothesis of "active non-violence" or Satyagraha as was successfully experimented with by Mahatma Gandhi in India has introduced a new method in political activity.

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The object of this study is to get an understanding of some of the salient aspects of creative thinking as manifested in Galileo and Einstein, the thinking that led to the discovery of the principles of inertia and relativity. Galileo and Einstein were chosen because of their importance and the availability of needed material, especially two chapters from Max Wertheimer's book, *Productive Thinking.*[1] A study of the creative thinking of Dewey and Gandhi is not dealt with in this paper.

In his book "On Understanding Science", Dr. Conant says that science progresses "to the extent that new concepts arise from experiments and observations."[2] According to Conant, the evolution of science is the evolution of new conceptual schemes.

The history of modern physics offers a fine illustration. Galileo was the first to work out a coherent conceptual scheme relating to physical motion. He discovered the law of inertia, established formulae regarding the acceleration of falling bodies and set modern physics in motion. Newton came next and improved upon the Galilean scheme. He invented the basis of differential and integral calculus which "in itself", according to Einstein, "was a creative achievement of the first order"[3] discovered gravitiation and formulated the three laws of motion. Einstein was the latest to create a newer conceptual scheme by discovering relativity. This displaced the Newtonian scheme.

Note :—This paper reports on a study made by the writer while participating in a "Seminar on Creative Research" conducted by Professor Ross Mooney at the Ohio State University, U.S.A.

II. The thinking that led to the law of inertia.

Galileo had a prodigious mind. He demonstrated the error in the Aristotelian theory of falling bodies; developed a thermometer, a compass of proportion; invented a telescope; and also a microscope; discovered the moons of Jupiter; made observations on the moon, nebulae, Saturn, Venus, and Mars; discovered spots on the Sun; wrote on floating bodies; furthered the application of astronomical knowledge to problems of navigation; and developed the first pendulum ever used in a clock.

Galileo in his childhood invented many toys like Newton. He had the good fortune of having a father who declared, "It appears to me that they who in proof of any assertion rely simply on the weight of authority, without adducing any argument in support of it, act very absurdly: I, on the contrary wish to be allowed freely to question and freely to answer you without any sort of adulation, as well becomes those who are truly in search of truth."[4] It is safe to conclude that Galileo owed partly to his father his spirit of inquiry and independence of judgment.

Galileo grew up in a time when Aristotle was considered the ultimate authority. The church as well as the universities took a worshipful attitude to Aristotle. When Galileo disproved Aristotle's theory of falling bodies by dropping from the tower of Pisa two balls of different weights which reached the ground at the same time, his colleagues were frightened. We are told that a colleague refused to look through Galileo's telescope, fearing that some other Aristotelian theory would be disproved.

The growing fear and opposition of his colleagues only intensified Galileo's spirit of inquiry. He continued his research with even greater zest. As a matter of fact, his zest grew to such an extent that when the Duke of Tuscany asked him to return to Pisa, Galileo insisted that he should not be given any teaching responsibility so that he might devote himself entirely to research. In his letter to the Duke, he gives a description of his recent researches: "The works which I have finished are, principally ..... two books on the system of structure of the universe, an immense work, full of philosophy, astronomy and geometry; three books *on Local Motion, a science entirely new, no one, either ancient or modern, having discovered any of the very admirable accidents which I demonstrate in natural and violent motions, so that I may, with very great reason call it new science, and invented by me from its very first principles*: (and).....three books of mechanics..... I have also different treatises (on sound, speech, light and colours, the tide, continuous quantities, the motions of animals, and the compass)....."[5]

The words italicized obviously refer to Galileo's research about the moving bodies and his discovery of the law of inertia which marked the beginning of modern physics.

Ever since Galileo began to think differently from Aristotle and his experimentation and observation gave results that encouraged further research, Galileo became passionately concerned about discovering some coherent inner principle that will explain the motions of falling bodies.

The situation Galileo faced was somewhat like this:[6]

(1) If you hold a stone in your hand and let it go, it will fall down. Heavy bodies do. The old physics said: "Heavy bodies tend towards their home, the earth."

(2) If you give a push to a body, say a carriage, or if you roll a ball straight ahead on a horizontal plane, it will move, will continue moving for a while, will then come to rest—sooner if you push it gently, somewhat later if you push it hard.

This is the simplest meaning of the old "vis impressa" (imposed force). "The moving body sooner or later comes to a standstill if the force which is pushing it no longer acts."

(3) And there are, of course, several additional factors to be considered in connection with questions of movement: e.g., the size of the object, its form, the surface along which the body is moved, the presence or absence of obstacles, etc.

Galileo was not satisfied with the conventional knowledge. He wanted to find out how such movements really proceed. What are the fundamental laws that govern the movements?

How did Galileo proceed thinking about this problem? There were *three* major phases in the procedure.

Phase 1.

Galileo made observations and experiments in the hope of finding out what happens to the speed, if it is governed by any principles. His experimental set-ups were crude. Since the speed of falling bodies was so great that exact measurements were not easy to make, he found a convenient method: he let the spheres roll down in inclined surface. For is not free falling simply a special case, the case of falling at an incline of 90° instead of a lesser angle?

He varied the angles of inclination and studied the change in acceleration. He found that acceleration decreases consistently with the angle of inclination The acceleration became the central fact of study.

Phase 2.

Then suddenly he asked himself, "Is this not just half the picture? Is not what happens when one throws a body upward, when one pushes a sphere in the uphill direction, the symmetrical other part of this picture?"

When a body is thrown up, we have negative acceleration. And symmetrically, the negative acceleration decreases as the angle of inclination diminishes.

Phase 3.

The picture is not yet complete. What happens when the angle of inclination is O and the body is in motion?

This was the crucial question. What *must* happen consistent with the rest of the "picture"? The positive acceleration below becomes zero. And the negative acceleration above also becames zero. What does this mean? If a body moves horizontally in a given direction, it will continue to move at constant velocity—for all eternity, if no external force changes its state of motion.

This is in direct contradiction to the old "vis impressa." "The moving body sooner or later comes to a standstill if the force which is pushing it no longer acts."

Thus the law of inertia was discovered: *that a body upon which no external force is at work permanently maintains its original velocity; it alters its velocity, the change must be referred to an external cause.*

The above discovery made one view physical phenomena in an entirely new light. To quote Max Wertheimer, "Fundamental changes in concepts were involved in the transition from the old view to the new. The meanings of the concepts about motion were radically changed in their place, role and function. The inner connections were viewed in an entirely different structure; a new grouping and dividing took place."

"For example, previously, rest and certain "natural" circular movements were fundamentally separated from, and opposed to, the other movements. Now rest and rectilinear movement are seen together, as structurally equivalent. and separate from, opposed to positively or negatively accelerated movements."[7]

Rising and falling are symmetrical aspects of the same structure, and they are special cases of the whole group of movements in any straight direction. The end of movement is not due to diminishing effects of "vis impressa," but due to external friction. Friction is no longer one of several factors, but has a role opposite to inertia; it is the fundamental cause of the limitation of motion. Force essentially determines acceleration.

The new concepts have given a wonderful new view for understanding a large number of physical phenomena.

In summary, we may make the following observations, that Galileo:—

Was impelled by the desire to discover the inner principle governing the motions of falling bodies.

Was opposed to conventional notions.

Invented convenient experimental set ups (inclined plane).

Observed and reasoned.

Centred his thought on acceleration, the crucial factor in the picture.

Saw the other side of the picture (negative acceleration).

Discovered a gap in the picture (horizontal movement).

Asked, "What should acceleration be consistent with the rest of the picture?"

The answer was the law of intertia. The result was the emergence of a whole new conceptual scheme.

III. The thinking that led to the theory of relativity.

Albert Einstein is well known for what he had to do with the production of the first atom bomb, for the momentous letter he wrote to President Roosevelt in 1939. He is also known for the open letter he wrote to the General Assembly of the United Nations in 1947, for his advocacy of a supra-national world government in the place of the present international anarchy, his concern for the problems of production and distribution, his plea for an organization of intellectuals, and his staunch conviction that the future depends on the moral development of man.

Einstein is a prodigious, many-sided personality. However, he rose to eminence for his contributions to theoretical physics. He is an excellent illustration of disinterested love of knowledge which was his only motivation. He humbly says, "For the most part I do the thing which my own nature drives me to do. It is embarrassing to earn so much respect and love for it."[8]

From his early youth, Einstein was interested in physics and mathematics. Though he was not particularly a good student, he knew more about these subjects than his classmates. Many years later, it was given to Einstein to formulate, first the theory of special relativity, then the theory of general relativity (an extension of the former), and thereby revolutionise the foundations of modern physics.

What were the steps in the gigantic thought process of Einstein which led to the theory of relativity? Max Wertheimer had the opportunity to talk to Einstein about this process. He says, "Those were wonderful days, beginning in 1916, when for hours and hours I was fortunate enough to sit with Einstein, alone in his study, and hear from him the story of the dramatic developments which culminated in the theory of relativity."[9]

The following, brief and simplified account stems almost completely from Wertheimer's report and analysis. (Chapter VII. *Productive Thinking*) Einstein's thought process seems to have *five* important phases:

Phase I. The beginning of the problem.

When he was sixteen years old, a pupil in Gymnasium (Aarau. Katonschule), Einstein got interested in the velocity of light. He asked such questions as: What if one were to run after a ray of light? If one were to run after a ray of light as it travels, would its velocity thereby be decreased? If one were to run fast enough, would it no longer move at all?.....The question of the velocity of light when the observer is in motion puzzled young Einstein.

The same light ray, for another observer, would have another velocity. The velocity in relation to something does not hold to something else which is itself in motion. He said to himself: "I know what the velocity of a light is in relation to a system. What the situation is if another system is taken into account seems to be clear, but the consequences are very puzzling."

The velocity of light seems to pre-suppose a state of "absolute rest"; but from the standpoint of mechanics, there seems to be no "absolute rest." Would operations with light lead to conclusions different from conclusions from mechanical operations?

Back of all this, there had to be something that was not yet grasped, not yet understood.

Phase II. Preliminary findings.

In the Maxwell equations of the electromagentic field, the velocity of light plays an important role. If the equations are valid in one system, they cannot be valid in another. Einstein worked hard to formulate different sets of equations for different systems, but he did not succeed. The conviction grew that there can be no "absolute rest."

The result of the famous Michelson experiment with light went contrary to the fundamental ideas of physics. Michelson compared the time light takes to travel in two pipes if these pipes meet at right angles to each other, and if one lies in the direction of the movement of the earth, while the other is vertical to it. Since the first pipe, in its lengthwise direction, is moving with the movement of the earth, the light traveling in it ought to reach the receding end of this pipe later than the light in the other pipe reaches *its* end. But in the experiment, no difference in time was found. The result contradicted all reasonable expectations.

Einstein was not surprised at the result of this crucial experiment. It seemed somehow to support his thoughts. But the matter was not yet cleared up. Precisely how does this result come about? He was impelled by a passionate desire to arrive at some understanding.

Lorents, a famous Dutch physicist, came out with a mathematically formulated theory to explain the Michelson result. He introduced an "auxiliary hypothesis", assuming that the entire measurement apparatus

underwent a contraction. Einstein looked upon the auxiliary hypothesis *ad hoc*, which did not go to the heart of the matter.

Phase III. Discovering the crucial factor.

Einstein said to himself, "Except for that result, the whole situation in the Michelson experiment seems absolutely clear; all the factors involved and their interplay seen clear. But *are* they really clear? Do I really understand the structure of the whole situation, expecially in relation to the important result?" During this time, he was often depressed.

With a passionate desire to understand, he faced the essentials of the Michelson situation. He re-questioned the time-honoured conceptual scheme. Einstein felt that the measurement of the velocity of light in a moving system is the crucial factor in the situation. How was time to be measured in a moving system? What does simultaneity mean if the term is referred to different places?

Now Einstein began to think hard. And the way in which he thought is interesting. He spoke aloud to an imaginary reader. To quote from Einstein as translated by Wertheimer,[10] "Lighting strikes in two distant places. I assert that both bolts struck simultaneously. If now I ask you, dear reader, whether this assertion makes sense, you will answer, "yes, certainly." But if I urge you to explain to me more clearly the meaning of this assertion, you will find after some deliberation that answering this question is not as simple as it first appears.

"After a time you will perhaps think of the following answer: The meaning of the assertion is in itself clear and needs no further clarification. It would need some figuring out, to be sure, if you were to put me to the task of deciding by observation whether in a concrete case the two effects were actually simultaneous or not."

"Similarly with the concept of simultaneity. The concept really exists for the physicist only when in a concrete case there is some possibility of deciding whether the concept is or is not applicable. Such a definition of simultaneity is required, therefore, as would provide a method for deciding. As long as this requirement is not fulfilled, I am deluding myself as physicist (to be sure, as non-physicist, too!) if I believe that the assertion of simultaneity has a real meaning. (Until you have truly agreed to this, dear reader, do not read any further."

"After some deliberation you may make the following proposal to prove whether the two shafts of lightning struck simultaneously. Put a set of two mirrors at an angle of 90° to each other ( ), at the exact half-way mark between the two light effects, station yourself in front of them, and observe whether or not the light effects strike the mirrors simultaneously."

"Simultaneity in distant places here gets its meaning by being based on clear simultaneity in an identical place."

"Now, how about simultaneity in a moving system? Suppose that I with my mirrors am travelling in a train going in a straight line at a constant velocity. Two shafts of lightning strike in the distance, one near the engine, the other near the rear end of the train; my double mirror being right in the middle between the two. As a passenger I use the train as my frame of reference, I relate these events to the train. Let us assume that just at the critical moment when the lightning strikes, a man is standing beside the tracks, likewise with double mirrors, and that his place at that moment coincides with mine. What would my observations be, and what would his be?"

"If we say that the bolts of lightning are simultaneous with regard to the tracks, *this now means*: the rays of light coming from two equidistant points meet simultaneously at the mirrors of the man on the tract. But if the place of my moving mirrors coincides with his mirrors at the moment the lightning strikes, the rays will not meet exactly simultaneously in my mirrors because of my movement."

"Events which are simultaneous in relation to the tract are not simultaneous in relation to the train, and vice versa. Each frame of reference, each system of coordinates therefore has *its special time;* a statement about a time has real meaning only when the frame of reference is stated, to which the assertion of time refers."

Thus the old thesis that the time difference between events is independent of the movement of the system is shown to be an arbitrary assumption. What is true of time difference is also, obviously, true of space difference. Einstein said: "Every system has its special time and space values. A time or space judgment has sense only if we know the system with reference to which the judgment was made."[11]

Phase IV. Taking the critical step.

At this point the introduction of the observer and his system of reference seemed to introduce an arbitrariness. But in order to reach physical realities, such arbitrariness must be got rid of. Besides, insight into the interdependence of time measurement and movement is certainly not enough in itself. What is needed is a transformation formula that answers the question: "How does one find the transformation from one system to another when they move in relation to each other?"

This led to the critical step—the introduction of the velocity of light as the variant. How would physics look if re-centered with this as a starting point? A new basis for physics was the consequence.

Phase V. Experimental verification.

Some crucial experiments were carried out in order to verify the new thesis and to find out if they fit facts better and give better predictions of physical events than the old theses. The new theses stood the test.

Einstein's formulations made one view physical phenomena in a new light. Fundamental changes in concepts were involved in the transition from the old view to the new. For instance, in the old view time was considered as an independent variable. Now an intimate relationship between time and the physical events was established. In the old view, space was considered independent of time and of physical events. Now space was intimately related to them and space geometry became integrated with dimension of time in a four-dimensional system.

In the old physics, the velocity of light had been one velocity among many. Now it was closely related to space and time and was considered as a fundamental fact in physics as a whole. Its role changed from that of a particular fact among many to that of a central issue in the system. Mass and energy acquired new meanings which led to the law of the equivalence of mass and energy and the famous equation, $E=MC^2$

Let me quote Einstein himself:

> "The special theory of relativity has led to a clear understanding of the physical concepts of space and time and in connection with this to a recognition of the behaviour of moving measuring rods and clocks. It has in principle removed the concept of absolute simultaneity and thereby also that of instantaneous action at a distance in the sense of Newton. It has shown how the law of motion must be modified in dealing with motions that are not negligibly small as compared with the velocity of light. It has led to a formal clarification of Maxwell's equations of the electromagnetic field; in particular it has led to an understanding of the essential oneness of the electric and magnetic field. It has unified the laws of conservation of momentum and of energy into one single law and has demonstrated the equivalence of mass and energy. From a formal point of view one may characterize the achievement of the special theory of relativity thus: it has shown generally the role which the universal constant (velocity of light) plays in the laws of nature and has demonstrated that there exists a close connection between the form in which time on the one hand and the special co-ordination on the other hand enter into the laws of nature."

The application of the principle of relativity to the entire field has led to the general theory of relativity.

In summary, we may make the following observations, that Einstein:

Was puzzled by the relation between the velocity of light and the movement of a system.

Was impelled by a passionate desire to understand the Michelson result.

Re-questioned the theoretical basis of classical physics.

Centered his thought on the crucial factor in the situation (the measurement of time in a moving system).

Rejected the conventional concept of time.

Considered the question of simultaneity which led to the theory of relativity.

Re-centered the field of physics by taking the velocity of light as the variant.

As a result, a new conceptual scheme arose; a new structure of physics took form.

IV. Analysis and conclusions.

According to Dr. Conant, progress in science is due to the emergence of new conceptual schemes. Certainly the law of inertia and the theory of relativity have caused progress in physics.

The situation Galileo faced was different from the one Einstein faced. Galileo started almost "from scratch" and actually put modern physics "on its feet." On the other hand, Einstein was to operate on the basis of a wide, well-established structure, and hence it was that he took as long as seven years to discover relativity. Again, Galileo worked almost single-handed; on the other hand, Einstein used the experiments and findings of other fellow physicists.

However, we do find many common aspects between the thinking processes of these two men whose creative contributions to the science of physics are acknowledged by all. Such common aspects of thinking are what concern us most here.

First, both were impelled by a passionate desire to understand certain physical phenomena—the motion of falling bodies in the case of one, the velocity of light in a moving system in the case of the other. They wanted to know the "how" of the phenomena. In other words, they wanted to get a comprehensive insight into the phenomena. They were faced with a real problem that challenged their utmost efforts.

Second, both were opposed to conventional notions. Galileo was not satisfied with the "vis impressa" theory. And Einstein thought that something was wrong about the assumptions behind the measurement of light in the Michelson experiment. Both rejected the conventional explanations and sought to find answers of their own.

Third, both used experimentation as a method of discovery, and in the case of Einstein, also as a method of verification. Of course, they observed experimental results and *reasoned* about them. But observation and reasoning were not so characteristic of their method as experimentation.

Fourth, both seemed to operate in a "field" situation. To start with, the situation was puzzling. Then they identified the crucial factors in the field— acceleration in the case of one, the measurement of the speed of light in the Michelson experiment or the concept of time, in the case of the other. The picture builds up, as Galileo considers negative acceleration and when he discovers the truth about the horizontal motion, a whole new picture emerges. Similarly, a fundamental consideration of simultaneity leads to relativity, and the critical decision to make light a new variant causes the emergence of a whole new structure. Their efforts were not finished, their discoveries were not complete, until they got at the heart of the matter, in other words, until they got a structural view of the situation. Also, their discoveries were not complete until they got a whole view of the field, in other words, a synoptic perception of the situation.

Fifth, both started with confusion and ended in clarity. In the beginning, the phenomena which were the object of their investigation, were in a condition of chaos. At the end, the shapeless disorder was transformed into significant order, form, system. Einstein himself says, "In every important advance the physicist finds that the fundamental laws are simplified more and more as experimental research advances. He is astonished to notice how sublime order emerges from what appeared to be chaos."[12]

Sixth, both displaced the old notions and established a new system of concepts. The new frame of reference was a better one and hence marked a milestone in the road of progress.

Thus we may tentatively lay down the six salient aspects of creative thinking as manifested in Galileo and Einstein.

1. **A real problem that challenges solution.**
2. **Opposition to conventional notions.**
3. **Experimentation as a method of discovery.**
4. **A synoptic, structural perception of the situation.**
5. **Shapeless confusion giving place to significant form.**
6. **Emergence of a new conceptual scheme.**

Reference may be made at this point to the rare privilege of the writer in that the late Professor Albert Einstein could go over these conclusions and approve of them in January 1953. He slowly perused them and he came to the fourth, he spoke the words "a synoptic, structural perception of the situation" and after a pause asked, "You mean 'seeing the essential', don't you?". It was a delightful rephrasing of a technical expression!

It is proper to repeat here that the above mentioned six are the salient aspects common to the thinking of two creative physicists. Do they apply to other physicists, scientists? Do they apply to creative thinkers in other fields

of endeavour—social sciences, education, art? Separate studies will have to be made.

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ERRATA

Errata for the article Quantum Field Theory and "Goal-directed" Activity. Vol. I, No. 1, *pp.* 8—18.

P. 9. line 6 from bottom

Replace $\frac{\partial}{2\pi i}\frac{\partial}{\partial y}$ by $\frac{h}{2\pi i}\frac{\partial}{\partial y}$

P. 12. line 17 from top (middle of the page)

Replace $\Sigma H_{ik}\, x_i^* x_k$,

by $\Sigma\, H_{ik}\, x_i^* x_k$,

P. 12. line 13 from bottom

Replace $\Sigma\, H_{ik}\, X_i X_k$

by $\Sigma\, H_{ik} \vec{X}_i X_k$

P. 14. line 1

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by

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Quantum Field Theory and "Goal-Directed" Activity†

BY

C. T. K. CHARI

Madras Christian College, Tambaram

PART II

(3) "Purpose" or "Casuality"?

In turning from a general exposition of Wassermann's ideas to criticism, I must first single out his contention that quantum mechanics provides us with a "directivity of transitions" (62, p. 54) which has "no analogue" in classical physics. Henry Margenau (37, Ch. 19, pp. 422–424) has maintained that any law of physics which is expressed in an integral rather than a differential form can be regarded as a potential carrier of Aristotle's "final cause" or "purpose". A well-known example is Hamilton's "Principle of Least Action":

$$\int_{t_1}^{t_2} \mathrm{Ldt} = \text{minimum},$$

where L is a function of the mechanical variables of state, the velocity (v) and the position (x) of a particle now (at time t_1) at a point P. Apparently Nature "wants to" conserve L and adjusts the motion of the particle with this "end in view". Maupertuis, who in 1747 gave the first formulation of the "Principle of Least Action", believed that it exemplified "God's wisdom" (33, p. 133). Since then, the teleological interpretation of the principle has been invoked, in a theological context, by more than one writer, among others, by no less an authority than Max Planck (48, pp. 329–330). Margenau is one of the most recent writers to see in Hamilton's Principle "the closest contact made anywhere between physical science and purpose". René Dugas, in a penetrating survey of the history of mechanics (20, p. 264), has shown how gratuitous are the teleological and theological interpretations of Hamilton's "Principle of Least Action" and Fermat's "Principle of Least Time". The late Hermann Weyl (65, p. 213) cautioned us that to see in the "Principle of Least Action" evidence of a "purposive economy of nature" is unwarranted. Hamilton's quantity of action does not necessarily take on the smallest value possible under the given conditions; it merely takes on an extreme value; it remains unchanged under an arbitrary infinitely small alteration of independent state quantities. Margenau observes (*op. cit.*) that, once (by means of the well-known trick of finding Euler's equations)

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we have converted the integral equation into a Lagrangian differential equation, "purpose" has been transformed into a "cause". I suggest that the whole analogy with "purpose" is misleading in this context.

Wassermann's "field-theoretical" approaches to biology and psychology are apt to revive all the misgivings about the pseudo-reduction of "teleology" to Lagrangian equations. I have explained, in Part I of my paper, how the classical field described by the space-time functions, say $\psi_\sigma(x, t)$, can be developed from a variational principle so chosen that its Euler-Lagrange equations are the field equations. The variational principle can be explicitly connected with Hamilton's "Principle of Least Action" (See 64, Ch. I, Section 1). I have shown how the introduction of the Hamiltonian H makes it possible for us to formulate the canonical field equations in the language of classical mechanics, i.e.,

$$\frac{dq_k}{dt} = \frac{\partial H}{\partial p_k}, \quad \frac{dp_k}{dt} = -\frac{\partial H}{\partial q_k},$$

although the formalism may not be indispensable for obtaining the corresponding equations in quantum field theory. The ψ-field, obtained through the canonical field equations, is equivalent to a mechanical system of particles with infinitely many degrees of freedom. The transition from classical mechanics to quantum mechanics is effected by replacing the canonical variables q_k, p_k by Hermitean operators satisfying the commutative relations:

$$\left[q_k, q_{k'}\right] = \left[p_k, p_{k'}\right] = O, \quad \left[p_k, q_{k'}\right] = \frac{h}{i}\delta_{kk'}.$$

The mechanical properties of the system are determined by its Hamiltonian formally taken over from classical theory but reinterpreted as a Hermitean operator. In the same way, we may consider the properties of a quantized field as determined by its Hamiltonian, $H = \int dx\, H$, or by its Lagrangian, $L = \int dx\, L$, where H and L (the integrands) are the "differential Hamiltonian function" and the "differential Lagrangian function" respectively (64, pp. 2–5). The classical field can be determined by the condition that the integral I shall be stationary ($\delta I = O$) for arbitrary variations, $\delta\psi_\sigma$, and for an arbitrary choice of the integration region. The conditions, however, which must be satisfied by the extremals in the n-dimensional space (namely, the Euler–Lagrange equations) are strong enough to ensure that $\delta I = O$ for curves in the 2 n-dimensional space (Hamilton's canonical equations), the end points being, of course, fixed (43, Ch. 9, p. 316).

If "causality" is *formally* tied up with the use of differential equations, which do not contain time (t) explicitly, the Schrödinger equation assumes that ψ-states are determined by "causality". The statistical interpretation of $\psi|^2$, in the language of "probability", is needed only when we have to do with coordinates and momenta of particles. The various component forms of Schrödinger's equation, belonging to the Sturm-Liouville group (33, pp, 440–443), have the

general form, say, $L(u) + \lambda \rho u = O$, where $L(u)$ is a differential operator defined by $L(u) = (pu')' - qu$. λ is a constant, the eigenvalue of the Sturm–Liouville equation. The equation brings with it the demand that the integral $D(u) \equiv \int (pu'^2 + qu^2)\, dx$ shall be stationary, i.e., either a maximum or a minimum, provided that

$$\int \rho u^2 dx = 1,$$

which is the ordinary "normalizing" condition of which I have spoken in the first part of my paper. If u is an unknown function of x, and $I(u, u', x)$ is a given function of u, du/dx, and x, then the u's which make $\int I dx$ stationary, i.e., $\delta \int I dx = O$, must satisfy Euler's equation:

$$\frac{\partial I}{\partial u} - \frac{d}{dx}\frac{\partial I}{\partial u'} = O.$$

If there is an accessory condition: $\int G(u)dx =$ constant, I in the equation must be replaced by $I - \lambda G$, where λ is an undetermined but constant multiplier. The condition that $\delta D = O$, subject to the "normalizing", is simply the Euler equation given above rewritten with $I = pu'^2 + qu^2 - \lambda\rho u^2$. If we make the substitution, we get the Sturm–Liouville equation with which we started. The process of solving the Sturm-Liouville equation is, in effect, seeking the stationary values of D (u). Although scruples may be raised about the sufficiency of Euler's equation as a condition for stationarity (33, p. 442), it may be said that D has, in general, many stationary values, just as a curve may have many maxima and minima. Schrödinger's ψ–field is sometimes spoken of as a "guiding field" (*Führungsfeld*), a phraseology which may seem to lend colour to Wassermann's views about a unique "directivity of transitions" in quantum mechanics. I suggest that it is indiscreet to take the metaphors seriously. The Euler-Lagrange equations and the Hamiltonian can be *formally* utilized in quantum field theory to emphasize its analogy with the classical field theory. As Margenau has said, the magic of "teleology" vanishes once we replace the integral equations by differential equations.

(4) Whither quantum field theory?

I now come to the far more important question whether quantum field theory, in its present stage of development, can be regarded as mature enough to admit of far-reaching applications to biology and psychology. Opinions about epistemological issues must differ. Not all can share Wassermann's optimism (62, p. 56) about the future of "Lorentz-invariant field functions". F. J. Dyson, in a popular article (21), summed up the issues by saying that quantum field theory, in its present stage, is, by its very nature, *descriptive* and *not explanatory*. It treats elementary particles in much the same way that the 19th-century chemists treated their "elements". It does not attempt to explain *why* such and such particles exist, *why* they have the masses that are actually observed, *why* some of them interact strongly and others not at all. Further, Dyson thinks that serious

difficulties are involved even in fulfilling the modest descriptive aims of present-day quantum field theory. For one thing, we are not sure that we have a complete list of " elementary particles ", even after the discovery of the " heavy mesons " (38) and the " antiproton " (13).

The researches of Peierls (18) and others have shown that " field concepts " necessarily enter into any *relativistic* formulation of quantum mechanics. There are formidable difficulties of interpretation on any relativistic quantum field theory. One of the most impressive features of the theory is the way it lays the foundations for an explanation of the connection between spin and statistics (64, Ch. VI, section 22). The relativistic formulation compels us to quantize the field, by means of commutation rules with negative or positive bracket symbols, according to whether the corresponding particles have integral spin (i.e., obey Bose-Einstein statistics) or half-integral spin (i.e., obey Fermi-Dirac statistics). A natural classification of elementary particles, according to their spin values, seems possible ; the number of available simple fields seems to fit in admirably with what we know about elementary particles. But the prospects are much less rosy when we turn to the interaction of fields. It may be plausible to assume that various fields or particles (the two languages are equivalent, as I have explained) are coupled by suitable invariant terms added to the Lagrangian ; if I am not mistaken, Wassermann (62, p. 54) makes something like the assumption. In the self-energy problems, however, one meets again and again with divergence difficulties. The " cut-off " methods seem more or less arbitrary and somewhat at variance with relativity requirements. Wentzel (64) wrote, in 1943, that the quantum theory of fields can be regarded as " a finished discipline in the same sense as classical physics ", which left the mass and the structure of the electron as unsolved problems. It is not too much to say that the situation has not altered very much in more recent years. Margenau (37, pp. 158–159) has remarked that most of the quantum-mechanical theories break down or fail to make sense in regions of the order of the classical electron (i.e., 10^{-13} c.m.). Wentzel's verdict that the solution " seems to require an entirely new idea, for which the present theories offer not even a starting-point " is still perhaps the only admissible one.

It may be well to glance here at one or two of the technical difficulties encountered. Let us consider the interaction of an electron at rest and light-quanta, assuming that all the numbers n_i of the matrix-element of the light-quanta are zero, and indicating the ground state and some other state (of positive or negative energy) of the particle by the subscripts o and b respectively. The total energy of the system, in the initial state, is the rest energy mc^2 of the electron while the final energy of the system is the energy E_b of the particle plus that of the light-quantum $h\nu_t$. The evaluation of the sum, which is troublesome, gives us, say (36, section 60, esp. pp. 227–230),

$$E^2 = \frac{e^2 h\pi}{ml^3} \sum_t \frac{1}{\nu_t}$$

in which the summation extends over all the eigenfrequencies of the radiation. As the number of frequencies between ν and $\nu + d\nu$ is given by, say,

$$8\pi \left(\frac{1}{2\pi c}\right)^3 \nu^2 \, d\nu,$$

E^2 can also be written in the form :

$$E^2 = \frac{e^2 h}{mc^2 \pi} \int^{\infty} \nu \, d\nu.$$

Since the integral is divergent, the particle, in its interaction with the light-quanta, undergoes an infinite displacement of its energy level. We are led to the conclusion that, besides an infinite Coulomb energy due to the longitudinal field, it would possess an infinite transverse self-energy as well. The occurrence of Planck's constant (h) in the equation signifies that the transverse self-energy is a quantum effect which diverges not only in the second but in all higher approximations. Speaking generally, the application of quantum-mechanical perturbation theory may be expected to furnish infinite correction terms of the energy, provided that there is an infinity of states n for which the elements H_{mn}' of the perturbation matrix differ from zero, rendering possible transitions from m to all these states (36). The transverse self-energy of the electron just considered is but a typical example of divergences of this kind. Another instructive example is provided by the infinite self-energy of a light-quantum necessitated by the interaction of the quantum with electrons in the " negative energy state ", on Dirac's " hole " theory. In this example, the divergence follows from the assumption of the infinity of " intermediate states " into which the system of light-quantum and electrons can pass by the creation of pairs. Pair production is, in a characteristic way, bound up with all relativistic formulations of quantum mechanics (i.e., all quantum field theories).

To be sure, not all the annoying divergences, which jeopardize the relativistic solutions of the many-body problem, originate in quantum mechanics. The infinite Coulomb self-energy of a point-charge confronted even classical theory, which attempted to overcome the difficulty by assigning to the electron an extension of the magnitude, $r_o = \frac{e^2}{mc^2}$. The assumption cannot be reconciled with the theory of relativity according to which any extended body can be deformed. We have to conceive the electron as a system of parts moving relatively to one another. The idea contradicts the picture of an " elementary particle ". On any " continuum " theory (relativistic geometry is essentially that), the concept of an " indivisible particle " becomes meaningless. The classical theory, accordingly, was forced to treat the electron as a " point charge ", with the disquieting result that an infinite self-energy had to be accepted. The electro-static energy of a charged sphere of radius r is, apart from a numerical factor, say e^2/r ; it becomes infinite for vanishing radius (6, pp. 35–36). A point-charge can, therefore, have

an infinite energy, or what amounts to the same thing (on Einstein's theory), an infinite mass. The self-force, i.e., the force which an electron experiences on account of the action of its own field, become infinite, too (64, p. 153). When the energy originates from the longitudinal field, which cannot be quantized, quantum mechanics cannot avoid taking over the divergence from classical physics. But even if we do not attend to the point-character of the particles, quantum mechanics leads to divergences, because of the necessity of taking into account wave-lengths of any shortness, i.e., the need to consider fields with an infinite number of degrees of freedom. The energy of a quantized oscillator is not $h\nu n$ (as Planck originally assumed), where n is an integer, but, say, $h\nu\ (n + \frac{1}{2})$. We have to contemplate, therefore (for $n = O$), a zero-point energy, $\frac{1}{2} h\nu$. Each system which can be regarded (by Fourier's theorem) as the superposition of an infinite number of harmonic oscillators (for instance, a cavity filled with radiation) has, consequently, an infinite zero-point energy (36, section 60). Again, the energy loss of an electron, under certain conditions, is infinite ; the divergence can be eliminated only by taking into account the finite size of the electron (see 28, p. 95). The problem of constructing Lorentz-invariant Lagrangian functions, in quantum electro-dynamics, becomes sometimes extraordinarily difficult, for example, on the non-linear theories proposed by Mie and Born (64, p. 201) for the electromagnetic field and by Heisenberg (38, p. 283) for the meson field.

Wassermann's speculation (62, p. 57) on "perturbations" which are capable of bringing about "transitions" raises uncomfortable questions about the limits of usefulness of the quantum-mechanical perturbation methods. Before action starts, let us say that the system has been in one of the eigenstates of the matrix H_o. Suppose H′ begins to operate and, after a time t, ceases to act. The system is now found in an eigenstate of H_o other than the original one. We may wish to evaluate the probability of finding the system, at time t, in an arbitrarily given final state. We assume that the system is in the state x_k, satisfying the equation : $H_o\, x_k = E_k\, x^k$, once the perturbation has begun to operate. Because of the perturbation, the state changes (36, pp. 132–135) according to, say,

$$\frac{h}{i}\frac{dx}{dt} = (H_o + H')\, x.$$

Resolving the vectors into components relative to the principal system K_o of H_o, we obtain, for $H' = o$, the solution : $x_n = x_n{}^o\, e^{(i/h)\, E_n\, t}$. With a small H′, the probability of the transition is proportional to, say, $|H_{nk}'|^2$. If H_{nk}' vanishes for certain values of n and k, we may assume, as a first approximation, that the probability of the transition is zero. But the transition, in quantum field theory, may be effected through the "intermediate state", say m, i.e., $k \rightarrow m \rightarrow n$, if H_{km}' and H_{mn}' are not zero. The perturbation method yields satisfactory solutions only for a very limited class of problems. In other cases, even disregarding the quantum electro-dynamical self-energies, the sums over the "virtual, intermediate"

states diverge (64, p. 196). Although the probability of a transition to a final state, in which the principle of the conservation of energy is violated, is small, the "intermediate states" may differ in energy from the initial state by any amount. R. W. Ditchburn (18), who cannot be dismissed simply as a prejudiced critic of quantum field theory, gives the following *résumé* of a recent discussion by experts. "The scattering of a photon of frequency ν by an atom, which has two states of energy E_1 and E_0, is regarded as including an intermediate process in which the photon is absorbed and the atom goes from E_0 to E_1 ; but since $h\nu$ is not even approximately equal to $E_1 - E_0$, energy is not conserved in this process. However, there is a second process in which the photon is emitted in a new direction and the atom returns to its original state. The second stage also 'breaks' the conservation law : but the two stages taken together do not, and there is no observable breach of the law. The 'ordinary physicist', who is just reconciling himself to this situation, is then told that he must also accept a situation in which the photon is emitted from the atom in changing from E_0 to state E_1, that is, 'before' the absorption of the incident photon. He is in the position of a bank manager who has agreed, in principle, that he will grant overdrafts and is then approached by someone who wishes to "open an account" with an overdraft!" If an alternative description is wanted, "the field theorist becomes a dishonest accountant who embezzles energy but is never found out, because he makes restitution within a time fixed by the uncertainty relation." All told, Ditchburn is of the opinion that field theorists have apparently "a normal vibration between two states : in one they believe they have solved the problem of the infinities, and in the other, they know that they have not". The first state may have a higher occupation at the present moment ; but the swing to the other state will inevitably come.

The discovery of new particles has vastly complicated the field-theoretical problem. In any interaction between two fields, a coupling parameter appears ; a special case is the one in which the parameter disappears, signifying that the corresponding interaction does not occur. The coupling of the photon and the electron involves the dimensionless constant (Sommerfeld's fine structure constant) :

$\alpha = 2\pi\ e^2/hc \simeq \frac{1}{137}$, if the electron charge e is measured in ordinary and not in Heaviside units. The equations of electrodynamics can be solved as a power series in α. After the first few terms, the contribution of α becomes negligible. In the pion-nucleon coupling of meson field theory, on the other hand, the dimensionless constant, i.e., $2\pi g^2/hc$, is of the order 10. Attempts to solve the equations as a power series in $2\pi g^2/hc$ appear hopeless. Peierls (18), in a recent symposium, referred (perhaps "wistfully", as Ditchburn would have it) to the complacent period in the thirties when it was thought that an understanding of $2\pi e^2/hc$ was just round the corner and that, with this understanding, all problems of fundamental particles and nuclear forces would vanish.

Today even the boldest field theorist does not know where he is going. R. E. Marshak, who five years ago categorically stated (38, Preface, p. v.) that "no genuine meson theory exists, but only plausible conjectures which occasionally illumine the complexities of experimental material", has recently testified (39): "The chief difficulty is the fact that we must deal with a swarm of pions. Our mathematical techniques cannot effectively deal with more than one pion at a time.....The problem appears to be a basic one and it seems likely that only some radically new idea will enable us to solve it". The Chew-Low theory of meson-scattering has figured in some recent discussions (67). Low and Chew appear to have shown recently (11) that the Low equation follows from "causality" rather than from any detailed structure of meson theory. Goldberger's arguments about the real part of the forward-scattering amplitude appear to be based also on causality. Difficulties arise with other particles, too. Wentzel (11) showed recently how very strong "selection rules" must operate to slow down the decay of hyperons in hyperon-nucleon interactions. The annihilation properties of the antiproton for complex nuclei and the cross-section for nuclear interactions have to be investigated in detail (59).

I have neither the space nor even the inclination to go into all the desperate expedients proposed by quantum physicists in their anxiety to surmount obstacles. I have already referred to the attempts made by Born and others to replace Maxwell's equations by a more general, if intractable, non-linear set (6, p. 36). Heisenberg has introduced an S-matrix and associated "fundamental length", l_0, of the order of 10^{-13} c.m. He thinks (37, pp. 158–159) that the Schrödinger time-dependent equation $H\psi = ih\partial\psi/\partial t$ presumes continuous changes in time. If time is quasi-discrete, the quantum Hamiltonian or energy-operator (the classical Hamiltonian, $H = T + V$, T being the kinetic energy and V the potential energy, is a function of generalized coordinates and momenta and $H. = O$ or $H =$ constant; the quantum-mechanical Hamiltonian H, in Schrödinger's fundamental equation $H\psi = E\psi$, is an energy-operator), in its present form, may be inapplicable. March (36, Ch. 10) has proposed the geometry of a *Kleinster Raum* the metric of which is defined in a fundamentally statistical form, i.e., in an integral rather than a differential form (see my discussion in 15, p. 180) and forbids the specification of lengths less than 10^{-13} c.m. $= \gamma$ (say). In this geometry, the line-element of general relativity, i.e.,

$$ds = \sqrt{g_{\mu\nu}\, dx^{\mu}\, dx^{\nu}} \quad (\mu, \nu = 1, \ldots, 4)$$

is replaced by the statistical

$$ds = \int \left\{ \sqrt{(g_{\mu\nu}\, dx^{\mu}\, dx^{\nu})} - \gamma \right\}$$

γ being a small universal positive scalar invariant of the coordinates. D. Bohm (5, esp. last chapter has sketched a theory of "hidden variables" which reduces

to the current quantum electro-dynamics for regions greater than 10^{-13} c.m. but departs significantly from it for smaller regions (e.g., inside the nucleus). We hear (52) that the Russian School headed by Landau is anxious to show that a Fermi particle (electron or nucleon) will not interact at all with a Bose particle (photon or pion) if it is regarded as a point; it has to be of finite size. It would be rash to predict the destiny of any of these theories. One can agree only with E. H. Hutten (26, p. 161) that since Dirac's relativistic formulation of quantum mechanics appeared, no new fundamental theory has been put forward. Yukawa's meson theory and its variants, Pauli's neutrino theory and its variants, the various models ("shell", "drop", etc.) of the nucleus, are but attempts, not always successful, to extend the range of application of quantum-mechanical ideas. Everyone is awaiting a "radical change in our ideas"; but, so far, there is "no sign of it". Without drastic changes, perhaps even in the mathematical framework, quantum field theory may not take its first toddling steps from what Dyson has called the "descriptive" stage to the more ultimate "explanatory" stage when it may, perchance, account for the existence of fundamental particles. Would the final form of the theory be Lorentz-invariant? Nobody knows; there has been no complete fusion, as Hutten (*op. cit.*, p. 161) discerningly points out, of relativistic and quantum-mechanical ideas. It is well known that Einstein could not get on happily with the "dice-playing God" of quantum physics. All this is not to deny, of course, the spectacular successes of quantum chemistry: the fruitfulness of the Heitler-London-Pauling-Slater models; the admirable work of James and Coolidge on the Hydrogen atom; the ingenious explanations of "homopolar" and "heteropolar" bonds; the dispelling of the mystery round Kekulé's benzene formula (17 and 53). We can cheerfully endorse Wassermann's opinion (62, p. 56) of these advances while dissenting from his reading of the epistemological situation in quantum mechanics.

(5) Is a quantum biology possible?

How hopeful can we be, then, of the success awaiting a quantum biology and a quantum psychology? Even if we allow, in principle, for an application of quantum field-theoretical concepts to living and conscious processes, we hardly know where to begin. The leaders of quantum physics do not seem to be agreed among themselves. Pascual Jordan (see 34) has advanced his hypothesis of *Verstärkung*, according to which an unpredictable quantum event, independently of others, initiates a change which is then magnified, avalanche-like, to the biological level of macroscopic visibility. Jordan maintains that "quantum indeterminacy" can play a decisive role in the "triggering" of biological events. The theory has not met with an enthusiastic reception among biologists. Schrödinger (55) is, on the whole, inclined to rule out the possibility. He holds that, apart from enhancing purely accidental characteristics in such events as meiosis, natural and X-ray-induced mutations, "quantum-indeterminacy" plays no great part in biological processes. He believes that just as *macro-order* and

regularity are derived from *micro-disorder* by *statistical thermodynamics*, so may the *large-scale order* of living beings be derived from *small-scale order* by a parallel but *different* type of *macro-law*. He speaks of the biological gene as an " aperiodic crystal " and ascribes to it a higher degree of order than the " periodic crystal ". The statistico-determinism of biological processes, according to Schrödinger, is not less important than the micro-indeterminism of quantum events.

Admittedly, many facts in embryology can be translated into the convenient and ready language of " fields ", as Spemann (57) and Weiss (63, esp. Part 3) have pointed out. Julian Huxley (27) has recently drawn attention to the " *Gestalt*-character of developmental gradient-fields ". A local change, occurring in a growth-gradient (one sex evolves a larger organ, e,g., chela, abdomen), affects the growth-rate of the neighbouring area in an orderly fashion. In regenerating flatworms, depressants alter the size and form of the morphogenetic growth-field as a whole. The change from positive to negative allometry deforms the growth-gradients. Wassermann's suggestion (62, p. 59) that spermatozoa have a " triggering " action in the fertilization of the ovum is not exactly new ; Weiss is known to have advanced it (63, p. 181). J. B. S. Haldane argued, from certain Danish data on the incidence of human mutations, that the frequency of mutant genes is higher among spermatozoa than among ova (see H. J. Muller in 24, Ch. 7). Spermatozoa, because they are so vulnerable to structural change, have been often used in radiation experiments (Muller, *op. cit*). When we set out to explain, however, *in detail*, on quantum-mechanical lines, the " triggering " action of sperms, we soon find ourselves out of our depths. Whether the acid-fast substance (of mycolic acid type, possibly imparted by the cells of Sertoli, see 49) in their heads has any bearing on the interaction is more than we can say. The problem is as baffling as the splitting-off of amido-nitrogen from the polypeptidic chain of the rat brain during physical exertion (see 60b). The introduction of hypothetical " M-fields " and " B-fields ", acting as " slight perturbation fields," helps us not at all. For anything, the new " fields " are as " mysterious, non-physical " as Bergson's *élan vital* or Driesch's " entelechy ".

Wassermann (62, pp. 55–56) complains of the vagueness of the earlier " field-theoretical " approaches to morphogenesis. Yet, it must be said to the credit of the pioneers that they entertained no " unwarranted illusions and expectations ", as Weiss (63, p, 292) put it. Weiss explicitly stated that the field theory of morphogenesis is " an *abbreviated formulation of what we have observed*.....Its *analytical* and *explanatory* value, therefore, is *nil*." The editors of a recent manual on embryology (69) have told us frankly that it was evident to them from the start that the subject had grown in bulk and intricacy to an extent which made it futile for any one individual to wrestle with it. J. M. Oppenheimer, in a historical review of " embryological philosophy " contributed to the same volume, reminds us that " the greatest progressive minds of embryology have not searched *for* hypotheses ; they have looked *at* embryos. " Spemann (57) summed up his

work by saying that " the processes of development.....are comparable, in the way they are connected, to nothing we know in such a degree as to those vital processes of which we have the most intimate knowledge, viz. the psychical ones ". Confessions of this order will not presumably satisfy Wassermann, though at one point (62, pp. 129–130) he too grants that his theory is " not predictive calculus " ; he insists, none the less, that it is not merely descriptive but " interpretative ". If he is right, it is time we stopped looking *at* embryos ; we must search *for* hypotheses. Wassermann would provide us with an " Ockham's Razor " by the use of which we can show that biological and psychological processes are amenable to the same type of laws as physical processes.

We have a right to ask of any alleged fruitful field-theoretical approach to biophysics and biochemistry whether it sheds light on unsolved problems. Can Wassermann's hypothesis claim to be able to do this ? Although we must await his promised book before pronouncing a verdict, there are few indications that any major problem has been solved. He refers appreciatively (62, p. 54) to N. W. Pirie's work on enzymes and thinks that it may be relevant to hypotheses about the " binding " of " molecular fields " (by the hypothetical " M-fields ", among other fields). Pirie himself (47), in a recent review of a manual on the proteins, prefers to be more modest in his claim. Referring to the suggestion that there is only one active site on some enzymes and that the proteolytic site is used when the enzyme catalyses transpeptidization, he observes: " There may already be abundant hieroglyphs on this Rosetta stone, but neither a Young nor a Champollion to read them ! " Has Wassermann deciphered the " hieroglyphs " on this biochemical " Rosetta stone " which Pirie acknowledges he cannot read ? Pirie also points out that few systematic suggestions can be gleaned from the vast array of the available evidence relating to the kinetics of action of different enzymes on substrates of known structure. The rate of inactivation of pepsin seems to vary inversely with the fifth power of the H-ion concentration over a certain pH range. Two explanations (29, Ch. 8) of the observed facts have been offered. Eyring and Stearn (1939) suggest that there is a rupture of intramolecular bonds resulting in a looser configuration with more freedom of random motion and so a higher entropy. Steinhardt and La Mer (1937) visualize, as one step in the process, the ionization of five protons :

$$PH_5 \rightarrow P^{-5} + 5\,H^+,$$

followed by the inactivation of the remainder of the protein, P^{-5}. According to the equation, the concentration of P^{-5} and, therefore, the rate of inactivation, will vary as the fifth power of the H-ion concentration. The rate constant for the kinetics of enzymes proposed by Eyring, Glasstone and Laidler (29. pp. 147–149), according to the " theory of absolute reaction rates ", may be set down as

$$k = \frac{KT}{h}\, e^{\Delta S^*/R} e^{-\Delta H^*/RT},$$

where ΔH^* is the heat of activation, a quantity very close in magnitnde to the ordinary activation energy ; ΔS^*, is the entropy of activation, K is Boltzmann's

constant, and h Planck's constant. The entropy of activation may physically be said to signify the increase in entropy that the reactants have to undergo to be in the right configuration for reactions to occur spontaneously. High entropy makes the term $e^{\Delta S^*/R}$ large and compensates for small values of $e^{-\Delta H^*/RT}$. The entropy and heat associated with the postulated ionization processes of enzymes are much larger than those figuring in ordinary ionizations. The hypothesis of Eyring and Stearn that intramolecular bonds are broken cannot, therefore, be excluded. The situation is tantalizing. There are indications that the strong intramolecular forces between enzyme molecules are of electrostatic nature (29). " M-fields, " which can " bind " the enzyme molecules by exchanging " extremely small " quantities of energy, are a vast *argumentum ad ignorantiam*. H. J. Muller (45, Ch. 17, p. 300) has observed that living matter can, on occasions, attain energy levels higher than those found in the " plus " tail of the statistically random energy distribution which results from the operation of ordinary thermodynamic principles. The high levels, he says, are perhaps due to mechanisms utilizing the energy-transferring properties of some nucleotides which provide for an accumulation of potential energy from multiple quanta absorbed at different times. The energy can be released suddenly at a high level, sometimes on a molar scale, as in electric organs. The level and type of chemical change involved are largely unknown. Detailed applications of Boltzmann's *H*-theorem (62, pp. 56, 58) to biological processes can be only on paper.

In the field of radio-biology, we have renewed debates over the " direct hit " or " target " hypothesis (Crowther and Blackwood) supposed that radiation has a localized action on a particular biological molecule ; e.g. a gene mutating to white eye in the fruit fly (*Drosophila*) may involve a sensitive area of 12 $\mu\,\mu$, see 24, pp. 238–250, Chs. 5, 6, 8), the " indirect action theory " (Dale, Meredith and Tweedie supposed that the entire solution is affected, 24, Ch. 4) and a suggested *rapprochement* in the shape of a " diffusion model " (see Cornelius A. Tobias in 45, Ch. 19, p. 382). H. J. Muller (24, Ch. 7, pp. 391, 394) tells us that mutations. whether spontaneous or artificial (radiation-induced, etc.) have a fortuitous character appearing to conform to the all-or-none rule of quantum events. This may be hailed as support for Wassermann's hypothesis about quantum-mechanical " selection rules " operating in biological processes. But Muller adds that the majority of mutants, whether occurring spontaneously or artificially, are, to some degree, detrimental ; the lethal mutants outnumber the beneficial ones. There may even be detrimentals without visible effects, i.e. invisible detrimentals (Muller in 24, pp. 390, 396, 436 ; in 45, Ch. 17). We have to face Weyl's shrewd query (65, p. 282), put apropos of Jordan's *Treffertheorie*, as to how representative mutations are of biological processes in general.

A great deal of work has been done, in recent years, on the theory of collisions between electrons (see 42). But so far, no satisfactory treatment has been found for collisions with electrons *bound* in a molecule (See Wallenstein, Wahrhaftig, Rosenstock and Eyring in 45, Ch. 6). The problem is probably vital for Wassermann's proposed mathematical treatment of hypothetical " M-fields " and " B-fields " (62, pp. 57–61 ; 63–65). It is possible to derive a tolerably simple expression for the probability of a free electron losing a given amount of energy in a single collision. But in biological change induced by radiation, i.e., the passage through the molecule, we have to reckon with at least one ionizing and one or more non-ionizing collisions (45, p. 84). An expert (Burton in 45, p. 94) has emphasized " the tremendous gap which separates such fundamental studies of isolated molecules as those presented by Eyring and an understanding of reactions in condensed phases which includes living material. " Another expert (Martin D. Kamen in 45, Ch. 14, p. 259) has protested against " the abstractions derived from the quantum description of molecules like methane or benzene in the gaseous state, or from the radio-chemistry of simple molecules in aqueous solutions ". Such abstractions, according to him, are " necessary but not sufficient for an understanding of the interaction of radiation with biological systems ". A third expert (R. E. Zirkle in 45, Ch. 18, p. 353) thinks that detailed knowledge " implies advances in techniques and knowledge of cell chemistry and physics which almost certainly will not be attained in our time ". All advances in the reasonably foreseeable future, he tells us, will be " rather haphazard ", attained largely by " indirect methods ". When we consider the actual energy transfer from radiation to biological tissue, even in the first hundredth of a microsecond or less, according to P. Morrison (45, p. 12), we see " why facile, all-embracing explanations find little favour with physicists." Our understanding of complex atoms in the field of organic chemistry is still qualitative. Any adequate description of the 3-dimensional network polymer (valcanized rubber) would involve an extremely complex problem of a yet undeveloped statistical topology (53, Appendix, p. 764). Bohr has proposed a special extension of the " uncertainty principle " according to which any attempt to determine the complete chemical structure of the living cell would involve an encroachment of necessarily lethal effect on the cell.

(6) Can psychology use mathematical models ?

It will be said that, notwithstanding all adverse criticism, the domain of sensations *is* promising for an application of " field " concepts. Wassermann (62, p. 65) has laid some stress on visual sensation. Under favourable circumstances, a few photons may suffice to set off a visual process (65, pp. 281–282). Not all light directed at the eye reaches the retina and only a small amount of what reaches the retina is absorbed by it. M. H. Pirenne (46) has shown, on theoretical grounds, that the distribution of the number of " hits " can be regarded as a Poisson distribution. The probability, π_x, of a certain number x of quanta being absorbed is given by the Poisson equation : $\pi_x = e^{-a}\,\frac{a^x}{x\,!}$ (46, pp. 201–203) which is said to be unaffected by the irregularities of the retina and the retinal image.

The probability, P_n, of seeing a flash of light, according to Pirenne (46, pp. 216-219), is

$$P_n = \sum_{x=n}^{\infty} \pi_x = 1 - \sum_{x=o}^{n-1} \pi_x = 1 - \sum_{x=o}^{n-1} e^{-a} \frac{a^x}{x!}.$$

He maintains that the quantum fluctuations dominate the situation even it biological variations make a contribution. Experimenters have plotted the frequencies with which a subject reports seeing a light against the energy V of the stimulating light. With a Poisson distribution, and a mean a per unit, a=KV where K is a small constant, the probability of n or more " hits ", assuming a test area of unity, is (12, p. 183):

$$\sum_{x=n}^{\infty} e^{-a} \frac{a^x}{x!} = \int_o^a \frac{e^{-y} y^{n-1}}{(n-1)!} dy.$$

Barlow (12, p. 183) has argued, however, that there may be spontaneous changes in the visual purple and that these may have much the same effect as the absorption of light. If the average number of these changes is c during the time the light plays on the retina, the probability of n or more " hits " would be

$$\int_o^{a+c} \frac{e^{-y} y^{n-1}}{(n-1)!} dy.$$

R. L. Gregory, Violet Cane, and R. W. G. Hunt (25) have discussed visual thresholds in terms of statistical information available in neural channels. The number of independent observations n is proportional to the stimulus area a. If $\Delta N/N$ is the physiological equivalent of the Weber function, $\Delta I/I$, Hunt thinks that we can derive linearity between log $(N - N_o)$ and log I. He claims that electro-physiological studies have shown that this is approximately true if N is the number of nerve impulses per second per nerve fibre. J. R. Platt of the Chicago University has traced interesting parallels between visual responses and electronic amplification processes. The " interested eye " notes the spatial contiguity of photon patterns and " amplifies " the " signal " into an " immediate " or " stored" specific physiological response.

The crucial questions are about the assumption of " random " variation, whether at the retinal or the central levels. Verplank, Collier and Cotton (60a) and Wertheimer (64a) showed that successive responses to weak flashes of light of constant intensity are positively correlated. May we assume, as Bulmer (8) does, changes *induced* by a sort of Markov process in which the probability of a response depends on, at most, the n preceding responses? Or, must we admit *spontaneous* fluctuations of the threshold? Barlow's assumption that spontaneous changes in the visual purple have much the same effect as absorption of light requires to be scrutinized; likewise Pirenne's suggestion (46, p. 217f) that the method of " partial summation " (estimation of probability effects due to independent light detectors) will prove useful in probing the physiological (as distinguished from the quantum) contribution to visual processes. Various types of non-randomness have to be studied before we can hope to arrive at a comprehensive statistical information theory of sensation, let alone a theory of " central B-fields " interacting with " peripheral B-fields " *via* " intermediary fields ".

Restricted theories of " interneural fields " have been proposed by Hodgkin, Lorente de Nó, Brooks, Eccles and the Gestalt psychologists. (See 71 and 1, Ch. 5). They hardly warrant Wassermann's speculative flights. Serious doubts have been cast on Köhler's electrical field theory of the brain by Lashley, Chow, and Semmes (31), who carried out a delicate experiment, inserting, at crucial points, gold-foil conductors into the brains of two chimpanzees trained in discrimination involving geometrical figures. Considerable disruption of the supposed " electrical fields underlying the perception of " figure " should have been produced in the circumstances ; but the visual perception of objects seemed intact after the operation. The hopes held out by the Gestalt hypothesis of " isomorphism " between perceptual fields and neural fields have not been fulfilled. Wassermann's speculation about " B-fields " interacting with neural matter (and possibly—one cannot be sure of this—preserving the topological relations between the stimulus-patterns and the perceived patterns) cannot claim to be more than an *ad hoc* explanation of certain observed phenomena.

And what success may we predict for " field-theoretical " explanations of " learning " in the near future? The mathematical models of learning have been grouped by Violet Cane (12) under the " deterministic " and the " statistical " types. Gulliksen and Rashevsky proposed deterministic models on the assumption that there are measurable connections between the strength of the stimulus situation and the " right " and " wrong " responses and that the strength of the " right " connections increases linearly with the number of correct responses while the strength of the " wrong " connections decreases linearly with the number of incorrect responses. It was further assumed that the probability of the " right " response at the $(n+1)$th trial, namely, P_{n+1}, is some function of the strengths attained by these connections by that trial. Gulliksen assumed that

$$P_{n+1} = \frac{S_o + hr}{e_o - K(n-r) + S_o + hr};$$

and Rashevsky that

$$P_{n+1} = \int_{-(S_o + hr - e_o + K\sqrt{n-r})}^{\infty} \frac{1}{2} \sigma e^{-\sigma x} dx;$$

S_o, e_o are the initial strengths corresponding to " right " and " wrong " responses, h and k are the rates of increase of S and e, and r is the number of " right "

responses in the first n trials. The very complex deterministic theory set forth by C. L. Hull, which utilizes over 60 " intervening variables ", has been conveniently summarized by Cane (12). After the nth trial, there is a reaction potential, $_sE_R$, given by

$$_sE_R = a\,(1 - 10^{-br})$$

where r is the number of correct responses in the n trials. The probability, P_{n+1}, turns out to be

$$P_{n+1} = \int_{-\infty}^{(C\cdot sE_R - d)} \frac{e^{x^2/2}}{\sqrt{(2\pi)}}\,dx.$$

a, b, c, d are relatively constant for a single experiment, but depend on such factors as the degree of motivation, the size of the reward, the delay in giving the reward, the inhibition involved, reaction-threshold, etc. ; they are expected to vary consistently from experiment to experiment.

Bush and Mosteller (10) have recently set up a " stochastic model " of learning, using the statistical theory of Markov processes and Markov chains. They assume that the occurrence of an event E_i changes the probability of a given response from p to Q_ip where Q_i is some operator. Q_i is taken approximately (10, p. 29) as $a_i\,p + (1 - a_i)\,\lambda i$; and if p refers to a correct response which can be learned perfectly, $\lambda_i = 1$, because $Q_i^n\,p = a_i^n\,p\,(1 - a_i^n)\,\lambda_i \to \lambda_i$ as $n \to \infty$. Otherwsie $\lambda_i < 1$; $|a_i| < 1$ always. Suppose we consider discrimination learning, in which there are two possible events, the " right " choice and the " wrong " choice, the two operators, Q_1 and Q_2 are associated with these ; p is the probability of choosing correctly. Bush and Mosteller find that their set-theoretical models are not always very tractable and resort to difference equations of the form : $Q_1^{n+1}\,p - a_iQ_i^n\,p = (1 - a_i)\,\lambda_i$ and differential equations, e.g. $dy/dn = (1 - a)\,(\lambda_i - y)$, as approximations (10, pp. 61–62).

Violet Cane (12) has expressed grave doubts about the " goodness of fit " of the hitherto proposed mathematical models of learning. She believes that a method for analysing a sequence of events, recommended by the statistician Cox (1955), should be used in the treatment of learning data. What is even more important, she has called into question the tacit assumption, made by many a mathematical theorist, that the original behaviour which is modified is " random " in the statistical sense. On almost all the current theories, she finds that we should expect no time trend in initial behaviour. She cites some recent experiments carried out by Hurwitz (1954), with a Skinner box, as evidence for a time trend in initial behaviour. The mean interval between " lever-pressings " was not constant but dropped over a 30-minute trial. A theoretically significant question about the data, as Cane points out, is whether they can be statistically regarded as arising from a pooled output ; can we entertain the hypothesis that a large number of stimulus-response connections are involved in learning ? Would it fit in with

Lashley's experiments claiming to demonstrate the persistence of learning after ablation of parts of the cortex ? Any rigorous statistical formulation of hypotheses requires far more data. As things stand, I see no way of putting Wassermann's ambitious " field-theoretical " (and presumably statistical) hypothesis about animal and human learning to a crucial test. A theory which " interprets " but does not " predict " may, by its ingenuity, compel our admiration ; but it cannot persuade us of its scientific truth. The striking success of Dirac's quantum field theory, in recent years, is due to its *prediction* of the creation and annihilation properties of particles in pairs (see *Progress in Nuclear Physics*, 3, 1953, listed in 28, p. 156), its *quantitative agreement* with the observed small splittings of hydrogen spectral lines called the Lamb-Retherford shift, etc. For some of the alleged data, on the other hand, used by Eddington in his grandiose speculation on the fine structure constant, chi^2 is not more than 2·9 on 15 d.f., as the statistician Jeffreys (27a, pp. 283–285) showed. The use of " Ockham's Razor " in theoretical psychology, in its present nascent stage, is dangerous ; Cyril Burt has been telling us that the " simplicity " of a hypothesis may be a reason *against* its acceptance in a science the subject-matter of which is as complex as it is in psychology.

(7) One-way or two-way time ?

Any far-reaching hypothesis about living and conscious processes would have to elucidate their essential " irreversibility " or " one-wayness ". It may be said that the explanation is readily furnished by statistical thermodynamics. I must ask whether the " thermodynamic irreversibility " follows directly and unambiguously from the *fundamental* equations of quantum mechanics. The claim is at least disputable, as anybody will gather from my criticism, formulated elsewhere (15, esp. 169–170), of the views put forward by Max Born and Landé. R. C. Tolman (60, Ch. XI, sec. 95, pp. 397–400) and Hans Reichenbach (50, Ch. IV, pp. 149–150) have shown that the Schrödinger equation governing changes of an isolated (conservative) quantum-mechanical system satisfies the requirement of *formal reversibility*. In determining the probability amplitude and its complex conjugate, we can choose either the equations :

$$H\psi\,(q, t) + \frac{h}{2\pi i}\frac{\partial}{\partial t}\,\psi\,(q, t) = 0 \text{ and}$$

$$H\,\psi^*\,(q, t) - \frac{h}{2\pi i}\frac{\partial}{\partial t}\,\psi^*(q, t) = 0\ ;$$

or, equations of the form :

$$H\,\psi^*\,(q, -t) - \frac{h}{2\pi i}\frac{\partial}{\partial(-t)}\,\psi^*\,(q, -t) = 0$$

and $$H\,\psi\,(q, -t) + \frac{h}{2\pi i}\frac{\partial}{\partial(-t)}\,\psi\,(q, -t) = 0.$$

We have a *formal two-wayness* of transitions between two sets of probability distributions of measurable quantities (see 16). S. Watanabe (61) has recently carried

out a thorough mathematical investigation of the "symmetry of physical laws in space-time" and various "balance theorems". He maintains that, in quantum physics, as in classical physics :

$$\mathfrak{Q}_{ij}^{\infty} = \mathfrak{Q}_{ji}^{\infty}.$$

The time average of transition probabilities from Si to Sj is equal to the time average of transition probabilities from Sj to Si. This is also equal to the time average of the probability of return to the original state. Some of Watanabe's theorems follow from the ergodicity of Markov chains. It can be shown (19, esp. pp. 83–84 ; 171–173) that any Markov process reversed in time is a Markov process still. Watanabe (61), Rosenfeld (51) and Glasstone (22, Ch. VII, esp. pp. 313–314) have, in effect, shown that quantum mechanics, like Newton's mechanics, can yield an irreversible thermodynamics only by the addition of statistical principles of interpretation (see 32) as ancillaries to its primary dynamic laws. Thermodynamic arguments have significance only when the system includes a large number of micro-states or particles (54, Ch. VI, p. 139 ; also 58).

It is true that when a quantum-mechanical system is coupled indivisibly to a classically describable system undergoing irreversible changes in the process of securing "information", it behaves asymmetrically with respect to "past" and "future". Some, like Landé (30), have construed this metrogenic quantum asymmetry as signifying a unique "direction" of time, which has no analogue in classical physics. Schrödinger (56), Ludwig (35), and Blatt (4), however, have demurred to the use of the metrogenic quantum asymmetry as a basis for explaining the phenomenal, macro-irreversibility; their objections seem to me to be both pertinent and forcible. Hutten (26, p. 145) contends that the entire history of philosophy, from Heracleitus to Whitehead, is witness to the enormous difficulties which human intelligence has found in fashioning a "process-language" as distinguished from a "thing-language". The attempts made by mathematical physicists like E. A. Milne (41) and L. L. Whyte (66) to define time as "trend" or "one-wayness" in the universe have not won general approval.

The issue has an important bearing on the mathematical status of various "automata" (Ashby's "homeostat", Grey Walter's "electronic tortoise" which can learn to go to a box to be fed, Shannon's "maze-solving mouse", Edmund Berkeley's "Squee" which can pick up nuts, the "reading machine" of McCulloch and Pitts, etc.) which are alleged to reproduce the feats of "memory" and "intelligence". In Wiener's discussion (68) of "feed-back" mechanisms. there is considerable emphasis on "irreversibility"; he seems to elevate thermodynamic laws to a fundamental status. Similarly, Ashby (3, esp. Appendix, pp. 215–219), after writing down the "canonical equations" for his "homeostat" (and availing himself of tests related to Nyquist's criteria used in the theory of electrical circuits and servo-mechanisms), tells us that his "absolute system", whatever the "machine" providing it, is "essentially irreversible" (*Ibid.*, p. 215),

I submit that the claim to "basic irreversibility", in *mathematical physics*, is dubious. No statistical interpretation of modern physics so far proposed has been able to eliminate completely and convincingly the "reversibility" inherent in the basic concepts. The use made of Markov processes and Markov chains in recently proposed stochastic models of learning requires to be examined from an *epistemological* as well as from an experimental angle.

I should like to point out that "automata" do not and cannot solve all the problems centering round the status of human intelligence and memory. Elsewhere (14) I have observed that it is possible to argue, from an extension of Gödel's theorem on "undecidability" (see 44, esp. pp. 84–86) in modern mathematical logic, that the human mind can solve some problems which no "automaton" can. Nobody has constructed a "machine" capable of inventing mathematical theorems, sonnets or social systems. Mario Bunge, in a devastating criticism (9) of the ideas put forward by McCulloch and others, observes that whereas machines are only *products* of culture, their designers are also *producers* of culture.

(8) Is a "person language" dispensable ?

I shall close my paper with a compelling question analogous to one formulated by J. H. Woodger (70, p. 309). Is it sound empiricism or good science to postpone a study of "persons" until we have completed our "behavioural studies", our investigations of "automata", and our mathematical researches into "Lorentz-invariant field functions"? Hull and Wassermann may possibly offer us long-term programmes ; but we must doubt whether their programmes can be carried through. Are there any valid reasons for *not* regarding a "person language" as adequate for many, if not most, purposes of scientific psychology? Why *must* we translate the language into *some other* language, whether of "space-time fields" or of various "psychoids" and "entelechies"? Stern's dictum that there is "No Gestalt without a Person who forms the Gestalt" (*keine Gestalt ohne Gestalter*) should at least serve to remind us of the *psychological* relevance of most variables handled in dealing with human beings. *Perceived* space and time are relevant to *perceivers* (see my discussion in 15b). The attempts made to reduce human "interests", "desires", "attitudes", "traits", clustering round "I-Thou" relationships to an "I-It" or an "It-It" language are more ingenious and time-consuming than convincing. Personalistic psychology does not square very well with categorized abstractions ; it needs today a more flexible logic and a wider epistemological outlook. I believe that much of the otherwise fruitful psychoanalytic speculation requires to be re-examined in this new context. Two distinguished psychologists, G. W. Allport and A. H. Maslow (2 and 40) have admonished a younger generation which has fallen for the glamour of mathematical physics and a rodentomorphized "laboratory psychology". On more technical grounds, I have argued elsewhere (15a) for an epistemological integration of the academic "Western psychology" with some, if not all, of the "Eastern presuppositions".

Is the approach to " person " and " person language " I am recommending altogether out of favour with the leaders of mathematical physics? Hermann Weyl (65, p. 284) saw no loss of self-respect involved in trying to acquire knowledge " from within ", instead of cleaving, in a mistaken dogmatism, to the supposed " objectivity of theoretical constructions ". In a lecture delivered at the University of Leipsig, Heisenberg (23, p. 93) said: " We are now more conscious that there is no definite initial point of view from which radiate routes into all fields of the perceptible, but that all perception must, so to speak, be suspended over an unfathomable depth ". Schrödinger (55, p. 88) has regretted the accidents of history which has made the Upanishadic *Atman = Brahman*, or *Deus factus sum*, appear so alien to the " Western " idiom. The recognition of the depths of consciousness was considered " the quintessence of insight into the happenings of the world ". Let the " field theories of behaviour " wander where they will; they will, sooner or later, bring us face to face with the enigmas of the " personal ", the " interpersonal " and the " trans-personal ". Or, is it only one enigma: that of Human Personality with *all that it implies?*

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A Study of the Development of Imagination in Children.*

BY

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Introduction

Imagination is one of the distinctive aspects of the human personality. The term " imagination " has evoked considerable amount of interest among psychologists recently due to its influence on human adjustment and development. Imaginative capacity in all its variety and many sidedness, is a gift of nature. It is a truism to state that there is not a single individual who is deprived of this wonderful creative mechanism. As a functional property, it pervades our whole mental life. As a result of this fund of creative energy, the individual is able to invent new things, produce fine works of art, create thrilling novels and further makes use of imagination in scientific thought, aesthetic appreciation and practical life. Even the child makes use of this process a good deal as seen from the characteristic tendencies in the early years of childhood, like the long periods of day dream, the tendency to invent " imaginary companions ", to take a temporary retreat from the world of reality into a world of fairy land—all these tendencies mark the " age of imagination ".

Imagination has the power to alter the face of the world, to bridge distance, and to annihilate time. Like an alchemist it can transmute, refine, transform; like the artist it is skillful to glorify and to enrich. On the moral side of life, it knows how to comfort and encourage, to inspire and control, to animate and to rejoice.(6) Hence rightly it may be regarded as an indispensible factor that goes to make the development of personality. In popular usage, imagination commonly implies something free, spontaneous, fanciful and unreal. To Woodworth " imagination is mental manipulation of facts previously perceived".(8) The facts are not only recalled or revived but modified to certain extent by rearrangement, so as to present finally a novel result that may never have been perceived. " A typical product of imagination is composed of parts perceived at different times and later recalled and put into a new relationship."(8) Warren refers to this as " the reorganisation of data derived from past experience with new relations into a present ideational experience."(9) This rearrangement and creation involve two steps. The preliminary step consists of getting a combination of stimuli from past elements of experiences and the second step is the response which consists in placing the experienced facts into a new relationship. Hence the creative nature

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depends upon the utility of the past elements, in the power to dissociate them from their former setting and their different novel reassociations that are ever changing and ever more extensive in its nature.

The product of this mental process may either be productive or reproductive. Productive imagination includes passive and active types; passive, in the case of day dreaming and reverie. The more strictly creative and constructive imagination which is highly purposeful and controlled by experience is classed under active type. The terms constructive and creative, denote some degree of originality, inventiveness and creativeness. Creative imagination is much more constructive with greater degree of inventiveness. All creative imagination will be constructive, but not all constructive imagination will be creative. So creative, imagination implies the most productive phases of constructive imagination.

We must always be aware of the fact that imagination is never free It is highly determined and controlled by needs as well as by the content of unconscious. Needs, subjective complexes, past experiences, psychological conditions of the unconscious and the conditions of the sense organs determine to a great extent the "mental process", namely, imagination. Hence it has been receiving much attention during recent times for the light it throws on the study of personality and mental hygiene.

Aim of the present study

The present enquiry is directed towards finding out "the development of imagination in children." A study of this kind is a long-felt need in this part of the country. It is a well-known fact that children have fertile imagination and it will be of great scientific interest and educational significance to know the contents of imagination in children. Apart from the theoretical value of the present problem, the results of the study, it is hoped will be useful in the day to day dealings with young children while imparting education to them in a more appealing way.

Procedure adopted in conducting the study

The investigator considered different techniques adopted for the study of imagination in children such as doll play, verbal description, drawing picture T.A.T., ink-blots, etc. It was thought fit that these different methods are effective in individual testing which will facilitate an intensive study of small samples As the present investigation aims at "a study of the development of imagination" which needs a fairly good sample of subjects drawn from different age groups, it was found that these techniques could not be appropriately used. Only ink-blot method was found to be most suitable to test large samples and hence it was chosen.

For this purpose, Rorschach Test cards were used. The Rorschach Test consists of a standard set of ten ink-blots, five in various shades of grey and five partly or entirely coloured. Although the Rorschach method

shows possiblities in revealing the role of the individual's inner mode of experiencing the world, it may also contribute much to our knowledge on the side of the mental content of the individual. But the purpose of the present study is with reference to imagination only with no diagnostic or clinical aim. It is also assumed that the blots will not only serve as stimuli but will also give a special meaning to the subject, if the individual's imagination can create or prompt something out of the blot, for imagination is not a passive perception of meaning but active creation of meanings. The individual's reaction will reveal how personally he views them and what he reads into them. Further more, the responses will not be based upon simple perception and description of what is portrayed in the blots, but perception will be followed by imaginative reconstruction also. Hence an attempt has been made to determine the precise role of the thought patterns that occasion imagination.

Pilot study

A pilot study was undertaken as it was considered a necessary step before any investigation is attempted. For the pilot study twenty pupils, ten boys and ten girls, between the ages 10-12 were tested. Before administering the test, the subjects were made clear as to what is meant by "Imagination", which was none other than the main purpose of the test with the following instruction: "In order to find out your imaginative capacity, I am going to give you a test. I will show you ten cards with figures separately. Look at each figure in the card carefully and write the answers in the particular column allotted for each figure, as to how these figures appear and what do these resemble to you. This is not an examination, hence, there is no specified good or bad answers to testify your ability." The Tamil translation of the above, printed in the answer sheet, was read out slowly and distinctly by the instructor. The investigator proceeded to administer the test only after getting the full satisfaction that the subjects understood the instruction clearly.

Then the blots were shown to the pupils one by one in a fixed position for a minute according to the serial number of the blots. For the next following minute, they were allowed to answer in the particular columns allotted for each blot in the imagining for the past one minute. Thus the blots were properly exhibited for two minutes inclusive of the one minute which was allotted for writing the responses. At a time only ten pupils were tested in three rows, as it was thought to be difficult for the pupils to perceive the blots if they are in a longer row with more heads to stand in a line.

Analysis of the responses

With regard to the analysis of responses, the method of classification used in Rorschach Test was not used due to its complex nature. Hence a scheme of analysis was devised with slight modifications on the classification of responses used by the previous investigators on this topic. In this scheme

of analysis scoring was done according to the type of associations given by the pupils. The associations distributed themselves into the following groups:—

(1) *Animal responses.*

(2) *Human responses.*

(3) *Nature responses*—that is responses dealing with geographical features.

(4) *Plants, flowers and trees.*

(5) *Inanimate responses*—i.e., objects including all lifeless objects and highly constructed machinery.

(6) *Supernatural responses.*

(7) *Birds.*

(8) *Insects.*

Under each item in the above classification there are four sub-divisions, interpreted namely, (*a*) as a whole, (*b*) as parts, (*c*) as stationary and (*d*) as movement.

For the pilot study, analysis of responses was done according to the above classification group. But it was thought convenient to include the items, namely, (*a*) birds and (*b*) insects with the animal responses so as to form a broad category, since birds, insects and animals belong to the more or less same group and form a part of the environment. Thus for the pilot study, the analysis scheme consisted of only six items. For each individual the total number of responses based on the above type of associations were taken to be the scores.

From the analysis of the responses it was found out that animal, inanimate, and human responses were given importance.

Though the number of associations given by the subject within the specified time, was taken to be the scores, association with life and movement were considered to be of high imaginative capacity rather than the associations that were stationary. According to the method of analysis of the Rorschach Test, the letter 'M' that is movement, denotes the imaginative capacity. For the present study as the Rorschach Test Cards were administered, the fertility of imagination for the investigator, seems to depend on the mobility of the objects and ability to construct the imaginative ideas into a coherent whole, rather than the number of associations reported against time. Hence for the final investigation this aspect of study has been taken into consideration to grade pupils according to their imaginative capacity.

Further, from the pilot study a considerable amount of interest for colour in the form of "fire and blood" was found to be expressed. So it was felt necessary to include the items, namely, "fire and blood" in the scheme of analysis which has been used for the final investigation. Thus the analysis sheet of "imagination test" was formed.

Subjects for the main study

The subjects for the study were 120 girls studying in the various schools in Madras. Their ages ranged from 8 to 11. In each age group thirty subjects were tested. In addition to the 120 subjects tested, thirty boys of ten years of age were also put to the test, in order to study the sex difference in imagination by comparing their performance with that of the girls of the same age group.

Administration of the test and collection of data

The method as well as the instruction were almost similar to that of the pilot study. Small children of ages eight and nine were hardly able to understand the instruction and pains were taken to make everything clear to them.

Scoring

Scoring was done on the basis of the items mentioned in the analysis scheme.

Statistical treatment of the data

It will be rather convenient to study each age group separately in order to observe any clear cut tendencies in the exercise of imaginative faculty. Hence the percentages of responses for each age group was worked out and compared with the results of the other groups. This will clearly indicate significant tendencies in each age group. The statistical techniques used in the investigation to test the level of significance of differences are critical ratio (C.R.) and chi-square test (x^2) which was converted into contingency co-efficient (C).

Results

The results are presented in the following tables:—

TABLE No. I—**Showing kinds of responses to Imagination Test according to Age groups**

Contents of imagination: Age group	Frequency	Human responses	Percentage	Rank	Animal responses	Percentage	Rank	Inanimate responses	Percentage	Rank
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
8	30	88	13·21	3	301	45·2	1	123	18·47	2
9	30	96	14·9	3	282	43·72	1	99	15·34	2
10	30	135	18·0	3	307	41·0	1	140	18·8	2
11	30	103	15·3	3	299	44·5	1	134	20·0	2
	120	422			1,189			496		

Contents of imagination—*contd.* Age group	Frequency	Nature responses	Percentage	Rank	Plant responses	Percentage	Rank	Supernatural responses	Percentage	Rank
		(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
8	30	62	9·31	4	61	9·16	5	26	3·9	6
9	30	55	8·53	5	58	8·99	4	46	7·13	6
10	30	72	9·37	4	51	6·9	5	33	4·4	6
11	30	47	7·0	5	56	8·4	4	27	4·2	6
	120	236			226			132		

Contents of imagination—*contd.* Age group	Frequency	Fire responses	Percentage	Rank	Blood	Percentage	Rank	Total
		(21)	(22)	(23)	(24)	(25)	(26)	(27)
8	30	4	.6	7	1	.15	8	666
9	30	6	.93	7	3	.46	8	645
10	30	6	.7	7	4	.5	8	747
11	30	4	.6	7	...	...	8	670
	120	19			8			2,728

From the consolidated Table I, we observe that children belonging to the age group eight are found to be interested in giving out animal, inanimate and human responses including geographical features and plant life which come in order of preference. It is also noticeable that they have no special interest for certain items, namely, fire and blood.

Similarly the responses of the children of the age group nine, reveal that animal, inanimate and human responses stand pre-eminent, and responses dealing with nature occupies the fifth rank whereas "nature response" occupies the fourth rank in the eight year age group.

In the age group ten we observe that the responses have been given similar importance as that of the age group eight.

In the age group eleven also there is no change except in the responses dealing with plant life which predominate the "nature responses".

Table I illustrates that animal, inanimate and human responses have been given much importance. This feature is found to be in common with the four age groups studied with regard to the contents of imagination.

TABLE No. II.—**Showing the Responses of Boys and Girls of the age group 10**

Contents of imagination Age group 10	Frequency	Animal responses	Percentage	Rank	Inanimate responses	Percentage	Rank	Human responses	Percentage	Rank
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Boys ...	30	353	43·3	1	174	21·6	2	129	16·0	3
Girls ...	30	307	41·0	1	140	18·8	2	135	18·0	3

Contents of imagination—*contd.* Age group 10	Frequency	Nature responses	Percentage	Rank	Plant responses	Percentage	Rank	Supernatural responses	Percentage	Rank
		(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Boys ...	30	74	9·2	4	39	4·83	5	19	2·35	6
Girls ...	30	72	9·7	4	51	6·9	5	33	4·4	6

Contents of imagination—*contd.* Age group 10	Frequency	Fire responses	Percentage	Rank	Blood responses	Percentage	Rank	Total responses
		(21)	(22)	(23)	(24)	(25)	(26)	(27)
Boys ...	30	11	1·36	7	7	·86	8	806
Girls ...	30	5	·7	7	4	·50	8	747

Sex Difference

This statistical analysis of the responses of boys and girls of ten years age, tested to find out sex difference in contents of imagination, are shown in the tables.

TABLE No. III.—**Showing the statistical analysis of the responses of boys and girls of 10 years age**

Sex	Frequency	Mean	S.D.	S.E.	C.R.	Significance
Boys	30	27	19·6	3·64	...	...
Girls	30	25	14·46	2·69	.44	Nil

From the above table it is found that C.R. is not statistically significant and hence it is really satisfying to affirm the fact that there is no sex difference in the age group ten, in the sample tested. So it is better to view the whole sample tested including the boys, as a single homogeneous group, since the group have features much in common.

It was felt necessary to find out the significant relationship between age and the contents of imagination.

TABLE No. IV.—**Showing the relationship between age and contents of imagination.**

Age group	Frequency	D	S.D.	C.R.	Significance
8 and 9	30 + 30	1·17	3·337	.35	Nil
9 and 10	30 + 30	—2·33	3·984	.584	Nil
8 and 11	30 + 30	·17	3·231	0.526	Nil
9 and 10	30 + 30	—3·5	3·118	1.122	Nil
9 and 10	30 + 30	—1·00	2·072	.482	Nil
10 and 11	30 + 30	2·50	3·004	.832	Nil

A study of the figures in Table IV shows that there is no significant relationship between age and contents of imagination as the critical ratios are not found to be statistically significant.

Socio-economic status and Imagination

In order to test the significance of relationship between socio-economic status and imagination, thirty-five students from the sample were selected at random. The socio-economic background of these children were classified according to the following five-point scale, namely, higher class, higher middle, middle, lower middle, and poor class. The following table presents chi-square (x^2) calculated to find out the relationship between socio-economic status and contents of imagination,

TABLE No. V.—**Showing the relationship between socio-economic status and imagination**

Frequency	Relations expected	df	x^2	Contingency co-efficient	Significance
35	Socio-economic status and contents of imagination	12	13.85	.53	Nil.

x^2—13·85

df = 13 p. lies between .30 and .50, hence is not significant.

From the Table V, it is observed that there is no significant relationship between contents of imagination and socio-economic status.

Fertility of imagination

The responses with life and movement were separated from the original scores to test whether there is any difference in the fertility of imagination between age groups.

TABLE No. VI.—**Showing the fertility of imagination on the basis of movement responses**

Age group	Mean difference	$\sqrt{S.E._{1}^2 + S.E._{2}^2}$	C.R.	Significance
8 and 9	3·32	6·16	·538	Nil
8 and 10	4·90	6·25	·78	Nil
8 and 11	9·63	6·63	1·045	Nil
9 and 10	1·58	6·63	·24	Nil
9 and 11	6·31	6·92	9·11	Nil
10 and 11	4·93	6·92	·712	Nil

A study of the figures in the above Table VI shows that there is no significant difference amongst the age groups in the fertility of imagination. However it may be observed that as age advances, there is a tendency to be more imaginative.

Summary of the results and conclusion

The present investigation is an attempt to study the development of imagination in children between the ages 8 to 11. For this purpose, data were collected from 120 girls and 30 boys, by administering the Rorschach Test. From the nature of the test, it was assumed that the Rorschach technique or any ink-blot test will reveal to a great extent the imaginative capacity of the indivduals which would facilitate to understand the contents of imagination at particulr age levels. From the analysis of the data collected, it has been found out that

(*a*) there is no significant relationship between age and the contents of imagination.

(*b*) there is no sex difference in the contents of imagination in the age group ten.

(*c*) Socio-economic status has no influence on the performance of the group tested.

The results of this study as compared with the findings of others

(1) Children have deep interest for animals and human beings. This result agrees with the findings of Cicely Parsons (3), Ruth Griffiths (7) and F. C. Bartlett (2).

From the present enquiry, habits of living, father's occupation and other environmental factors seem to have no real influence upon the contents of imagination. This result disagrees with the findings of G. Dearborn (3).

From the conclusions drawn, it is quite clear that children in general have deep interest for animals, inanimate objects, human beings and plant life, their colours, and sounds in particular. Good illustrations with vivid pictures and colourful charts are the best ways of arousing their interests and enriching their contents of imagination. Hence perceptual learning must go hand in hand with conceptual learning.

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Musical Aptitude and Appreciation among High School Students*

BY

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Introduction:

This investigation in musical aptitude and appreciation was in the nature of a preliminary experimental study with the following limited aims:

(*a*) to construct and administer a test in the appreciation of music suitable to school children in this part of the country;

(*b*) to check up results obtained by Carl E. Seashore as far as the measurement of aptitude is concerned with the help of the "Seashore measures of musical talents" and

(*c*) to see whether there is any correlation between the aptitude of children as measured by the scale constructed by Seashore and the appreciation of music as evaluated by our exploratory test.

Description of the Tests:

(*a*) *Appreciation*: The word "Appreciation" is capable of being interpreted in several ways. But as we had to devise a test for school children who had almost no training in music, we interpreted the word in a simple and restricted sense, viz., the ability to find the better of two musical forms, presented one after the other immediately. Like the Meier-Seashore art judgment tests, the test employs the method of paired comparison. A part of a melody is sung or played on the violin for a period of time not exceeding one minute. After a brief interval of five or six seconds, the same melody is rendered in a different manner. The children must judge which of the two renderings was better. There is always some difference and one tune is made definitely better than the other. Six elements, with five test items in each, were chosen for appreciation. The first three types were given vocally and the other three were rendered on the violin.

The first element emphasises the value of "Sangatis" and 'Gamakas' in Carnatic Music. For instance the 'pallavi' of the song, "Seethapathe Na Manusuna" (composed by Sri Thyagaraja in Raga Khamas) was first sung with no 'sangati', utterly plain and unembellished. Then the same line was sung

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with 'Gamaka' and also a Sangati' thrown in. Naturally the second version was the better of the two. The subjects were asked to find out which of the two renderings was better and write it (either one or two) in the test blank.

The next element chosen is the tempo of a song. A portion of a song is sung in its usual tempo as prescribed by the composer or as accepted by tradition. Then it is rendered at a quicker or slower speed. The subjects were asked to record the one which they liked. Now we come to the third element. The meaning of the words of a song, and the particular context in which the song was composed have a great influence in the choice of the *raga* and *tala* for the particular piece. For instance, when Hanuman goes to inform Bharata that Rama is on his way to Ayodhya and therefore he (Bharata) should not lose his patience, the urgency of the situation and the anxiety to save Bharata from committing suicide by falling into fire and the happy news that is being conveyed are all very well brought out in the bright piece "*Vandan, Vandan, Bharata*" sung in Raga Mohana. But when the same song is rendered in Raga Nadanamakriya in a slower tempo, the meaning is utterly lost. Five examples like the one described above were given, and the subjects recorded the one they liked better. The other three elements were rendered on the violin. Two of them touch upon the technique of violin play. Students of Carnatic Music know what are described as 'Sahitya Vil' (சாகித்ய வில்) and 'Swara Vil' (ஸ்வர வில்). With respect to songs, the 'Sahitya Vil' is more melodious than the 'Swara Vil.' Five examples are played in these two ways and subjects judge which they like better. Again, when the bow is applied very near to the bridge and with some force the volume becomes very loud and sometimes gets even screechy. On the other hand, it becomes softer when the bow is applied at the proper point on the bridge. A portion of a song is rendered in these two ways and the subjects are asked to find which rendering is more pleasing to the ear. The last test item makes use of the effect of consonance and dissonance. We present two pairs of notes one after another. One pair contains notes which produce the effect of consonance (like Shadja and Panchama). The second pair contains notes which produce the effect of dissonance (like Shadja and Kakali Nishada). The subjects choose that pair which gives them a sense of satisfaction.

Thus there is a total of 30 items in the appreciation test. Each right response was given a score. A lady with high professional attainments rendered the test items. The tests were administered in two sessions. Owing to the enormous notational difficulties the music presents in its printing, we have not given the full test here. A copy of the test blank is given as Appendix I.

(*b*) *Aptitude*:—Seashore's "Measure of Musical Talents" are a battery of six tests, testing (1) Pitch discrimination (2) loudness discrimination (3) Sense of time (4) Sense of timbre (5) Sense of Rhythm and (6) Tonal memory.

These tests were given under good experimental conditions.

Subjects:—192 boys and 83 girls, all studying in the Vth Form were given the aptitude tests. 81 boys and 72 girls were given the test in appreciation. An additional number of 80 boys were tested in the two measures, viz., sense of pitch and sense of intensity. Among these children, only 119 were given both the aptitude and appreciation tests. The boys had no music lessons either in school or at home. All the girls had about 1½ hours of tuition in music every week in school.

Results:—The scores obtained by boys and girls in the appreciation tests are given below.

Marks	Girls	Boys	Total
13	...	2	2
14	...	4	4
15	...	6	6
16	...	7	7
17	...	5	5
18	...	6	6
19	5	9	14
20	3	8	11
21	4	9	13
22	7	11	18
23	12	4	16
24	9	5	14
25	12	3	15
26	9	1	10
27	9	...	9
28	2	1	3
...	72	81	153

It will be seen that no girl has scored less than 19 whilst the range of marks for boys extends from 13 to 28. This superiority is no doubt due to the training (about 2 periods of 45 minutes each a week) which the girls have had.

The answers for the aptitude tests were corrected as per the instructions given in Seashore's "Manual of Instructions and Interpretations" and the boys and girls were grouped in ten ranks. According to the norms given by Seashore all scores must fall within these ten ranks, as each rank, for him, represents 10 per cent of the total sample. But our results show that some boys and girls fall outside these ten ranks. The scores obtained by the subjects in the aptitude tests are to be found in the tables given below:

Pitch:

Seashore's norms for each rank	Rank	Girls	Boys	Total
46—50	1	3	3	6
44—45	2	3	7	10
42—43	3	4	16	20
40—41	4	5	9	14
38—39	5	6	20	26
36—37	6	7	14	21
34—35	7	7	18	25
32—33	8	14	19	33
28—31	9	8	56	64
25—27	10	13	68	81
Subjects who get less than 25	...	13	42	55
Total ...	...	83	272	355

Intensity:

Seashore's norms for each rank	Rank	Girls	Boys	Total
44—50	1	13	94	107
42—43	2	15	29	44
41	3	7	20	27
40	4	10	26	36
39	5	8	20	28
38	6	8	11	19
36—37	7	11	19	30
34—35	8	4	21	25
31—33	9	3	16	19
25—30	10	3	12	15
Subjects who get < 25 ...	...	1	4	5
Total ...		83	272	355

Rhythm:

Seashore's norms for each rank	Rank	Girls	Boys	Total
28—30	1	10	29	39
27	2	4	18	22
26	3	15	15	30
25	4	12	21	33
24	5	9	21	30
23	6	7	17	24
22	7	1	8	9
22	8	2	7	9
20—21	9	15	25	40
15—19	10	7	31	38
Subjects who get < 15 ...	...	1	...	1
Total ...		83	192	275

Time:

Seashore's norms for each rank	Rank	Girls	Boys	Total
43—50	1	3	10	13
40—42	2	13	23	36
39	3	6	14	20
38	4	4	8	12
36—37	5	8	29	37
35	6	7	8	15
34	7	10	18	28
32—33	8	13	25	38
29—31	9	12	27	39
25—28	10	5	20	25
Subjects who get < 25 ...	...	2	10	12
Total ...		83	192	275

Timbre:

Seashore's norms for ranks	Rank	Girls	Boys	Total
43—50	1	11	15	26
41—42	2	16	11	27
39—40	3	17	10	27
38	4	11	5	16
37	5	7	16	23
35—36	6	8	24	32
33—34	7	6	30	36
31—32	8	4	18	22
29—30	9	1	27	28
25—28	10	2	30	32
Subjects who get < 25 ...	...	...	6	6
Total ...		83	192	275

Tonal memory:

Seashore's norms for ranks	Rank	Girls	Boys	Total
29—30	1	3	5	8
27—28	2	9	12	21
25—26	3	14	16	30
24	4	7	3	10
23	5	10	3	13
21—22	6	13	13	26
19—20	7	9	27	36
17—18	8	4	24	28
15—16	9	8	27	35
8—14	10	6	61	67
Subjects who get < 8 ...	...	...	1	1
Total ...		83	192	275

The following points may be considered as significant:

(*a*) We have calculated the arithmetic mean of the scores made in Pitch by the subjects whose performance in this test was correlated with their performance in the appreciation test. It is 32.26. The Standard Error of this mean is equal to 0.6094, calculated according to the formula, $SE_{mean} = \frac{\sigma}{\sqrt{N}}$, [in page 184 of Garrett's book] 95% of the means of other samples like the one we have taken will lie between the values of $32.26 \pm 1.96 \times SE_{mean}$ i.e., between 31.07 and 33.45. As the range of fluctuation is narrow our sample seems to be normal. Similarly the arithmetic means for Intensity, Time, Rhythm, Timbre and Tonal Memory were separately calculated and the range of fluctuation, in each case, for 95% of the means of other samples like the one we have taken was calculated. In all the cases this range was found to be narrow. So the sample may be taken as normal.

(*b*) Generally it can be stated that the scores for the five measures of Pitch, Intensity, Time, Rhythm, and Tonal Memory do not follow the pattern indicated by Seashore. This fact compels us to come to the conclusion that local norms will have to be worked out, if we want to use these tests here.

(*c*) The low scores made by our sample in the sense of Pitch agree with the results of some other investigators who found that in general the scores for the pitch were lower than the scores for other components. (2)

(*d*) We found an interesting result regarding the sense of Intensity. Nearly 30 per cent. of our sample scored enough marks to put them in the first rank for this test. Comparing with Seashore's sample, it would appear that our boys and girls are superior in their capacity for discriminating loudness. The explanation which we would like to offer is this: Children of the West are accustomed to the hearing of 'heavy music' (in the sense that Western music is harmonic in character and highly orchestrated); our children hear the melodic type of music and the number of instruments heard at a time is comparatively smaller in number. Thus our people are perhaps better able to discriminate the strong tone from the weak tone. But Seashore believes that this measure, along with his other measures, can be applied without any reference to environmental conditions. Further investigation in this matter is necessary to find out the real fact.

Correlation between Aptitude and Appreciation:

Table showing correlation coefficient between appreciation and other factors of musical aptitude.

1.	Pitch and appreciation	=	— .26
2.	Loudness and do.	=	+ .06
3.	Rhythm and do.	=	+ .09
4.	Time and do.	=	+ .01
5.	Timbre and do.	=	+ .21
6.	Tonal Memory and appreciation	=	+ .43

We find that the highest correlation is between tonal memory and appreciation. Correlation was found to be statistically significant. It is an established fact that musical memory is an important factor in the proper appreciation of music.

Suggestions:

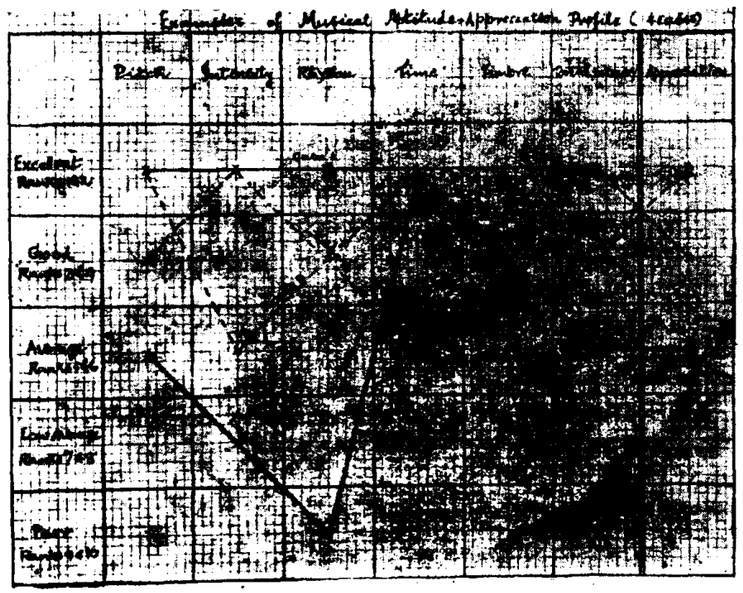
(*a*) As pointed out earlier, Seashore's battery can be used for assessment of aptitude only with modified norms.

(*b*) The correlation coefficient between tonal memory and appreciation is significant. Therefore the appreciation test designed by us may be used along with the aptitude tests.

(*c*) The measure on tonal memory is an important one and it should find a place in tests for aptitude, perhaps with some weightage.

Musical Aptitude Profiles:

For the direct understanding of an individual case, Seashore has recommended the preparation of a talent chart and a talent profile for that person. In view of the data that we have collected, we have modified his scheme and have attempted to prepare musical aptitude profiles as in the manner shown below. We have changed Seashore's six point scale into a five point one, by combining 'Superior' and 'Excellent' into one class. Appreciation also is included in our profile, the scores made by the pupils having been classified as 28 to 26 'Excellent', 25 to 23 'Good', 22 to 20 'Average', 19-17 'Low-Average', and '16 to 13 Poor'. As a sample we give below the profits of four subjects. Musical success depends on many factors. Therefore we have to be extremely careful in prognastic statements. Provided the boy or girl shows a general ability as indicated by these tests and certain other performance and appreciation tests, we can, on the basis of the chart, give guidance as to the instrument he or she can choose and in regard to allied matters. A chart of this kind will prove to be extremely useful to the guidance counsellor, to the music teacher, to the parent and to the pupil. But in the interpretation of these charts one must be extremely guarded.



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APPENDIX I

A TEST IN THE APPRECIATION OF MUSIC

1. Name

2. Age

Please answer the following questions as clearly as possible.

(1) If you are not already learning music, would you like to begin now?

(2) What kind of music do you like?

(*a*) Carnatic (*b*) Hindustani classical style (*c*) Film music (*d*) Western Music.

(3) Name the instruments which you would like to learn. Choose it from the list or give yours, if it is not there.

(*a*) Violin (*b*) Veena (*c*) Flute (*d*) Mridangam (*e*) Tabla (*f*) Sarangi etc.

(4) If you are already learning music, how many hours per week do you spend on it both for learning and practising?

(5) Do you understand Tamil or Telugu or both?

You will now hear six tests. After hearing the explanations and instructions please write 1 or 2 in the places provided, according to your choice:

Test items	Test A	Test B	Test C	Test D	Test E	Test F
a ...						
b ...						
c ...						
d ...						
e ...						

Effect of Low Socio-Economic Status on Emotional Instability

BY

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Introduction:

While investigating the problems of delinquency and crime earlier, the present investigator (Shanmugam 1946 and 1949), found that almost all the delinquents came from the low socio-economic families. A survey of the socio-economic status of the inmates of Mental Hospital, Madras, also revealed the same fact. Studies in other countries as reported by Healy (1924), Burt (1935), Dollard Miller et. al (1939), Tappan (1949) and Sheldon and Gluek (1951) corroborate the same fact. In may be argued that individuals from higher strata of society, coming in conflict with state laws under the existing state of affairs may not find their way to the certified institutions and jails. Similarly, individuals enjoying better economic status when they become victims of mental diseases, may not get admitted into mental hospitals. For they could afford the costly treatment under a private practitioner and also they could avoid the stigma attached to them, if they are in-patients in a mental hospital. But, still the fact whether there is any relationship between socio-economic status of an individual and his emotional balance needs verification. The present paper presents the results of such a study.

Problem of the present study :

The problem of the present investigation may be stated in the following form and tested against the null hypothesis. The hypothesis is that no difference exists between groups of subjects belonging to high and low socio-economic families in respect to emotional instability than due to chance fluctuation.

Subjects:

Total number of subjects included for this investigation was 874. Care was taken to include subjects from only two different socio-economic families, i.e., high and low. In doing this both the total family income of the subjects and their parents' occupational status were taken into account. If subject or subjects' parents belonged to professions like doctor (medical), engineer, large-scale business with a monthly family income of Rs. 1,500 and more, they were considered to belong to high socio-economic family. If subject or subjects' parents belonged to occupations like cooly, blacksmithy, fitter, turner, driver, etc., with a monthly total family income of Rs. 80 and less, they were classified as belonging to low socio-economic families.

There was not much difficulty in getting samples of children and adolescents of both low and high socio-economic families. Again there was no difficulty in getting adult men belonging to low socio-economic families.

But there was considerable difficulty in securing samples of adult (men) belonging to high socio-economic families. Not that there were dearth of such people. They were too busy to co-operate for academic investigation like this.

To get samples of children and adolescents belonging to low socio-economic families, the investigator went to four Corporation schools in Madras, selected at random. In these schools, mainly boys from low socio-economic families study because of free education and also because of certain amenities like free midday meals, milk, etc. To get samples of children and adolescent boys from high socio-economic families, the investigator visited the Besant School, Adyar, the Madras Christian College High School, the P. S. Secondary School, and the Wesley High School in Madras. To collect data from adults belonging to high socio-economic families, the investigator visited high ranking officials and businessmen in Madras. To collect data from adults belonging to low socio-economic families, the investigator availed himself of the help offered by the members of the Socio-Literary Association, Madras, who visited slum areas in Madras like the Austin Nagar, Ganeshpuram and poor localities in Alwarpet, Choolai and Perambur, to collect the data.

The Personality Inventory :

The Personality Inventory which the author (Shanmugam 1946) has devised for use in Madras State and which has been in use in Madras for different investigations (Lohidakshan 1954 and Jothi Bai Samuel 1957) was used in this study. The Inventory consists of items borrowed from Woodworth's 'Personal Data Sheet', Thurstone and Thurstone 'A Neurotic Inventory' and Eysenck 'Medical questionnaire'. The Inventory consists of 100 questions, referring to somesthenic tendencies, neurasthenic tendencies, anxiety, depression, paranoid tendencies, sleep difficulties, excitability, hyper-sensitivity, etc.

Administration and collection of data :

In administering the test and collecting the data different procedures were adopted. In the case of literate adults, printed inventories with instructions were distributed individually and collected later, as soon as they completed filling in. To collect data from children and adolescent boys, the investigator went to the schools mentioned earlier, where mostly particular class of children and boys study. The tests in these cases were administered in groups. Similar procedure was followed in the case of subjects from low socio-economic families. But there were a few in this group who were illiterate and in those cases, the inventory was administered individually and orally and their responses were recorded by the administrator of the test.

Out of the total number of 1,654 subjects to whom the Inventory was administered, 874 subjects only were found to strictly fulfil the require-

ments for this inquiry. For instance, giving the test in the group situations, though care was taken to select only those schools, where particular class of children and adolescent boys studied, other classes of subjects, lower and middle, a few subjects belonging to higher-middle, were also there. Just for this purpose, the present investigator did not want to separate particular group of boys from the class, for it would have meant duplication of work for the author, and administrative difficulties for the authorities of the school.

Though the techniques adopted for collecting the data varied, care was taken to see that the actual results were not affected by this. In giving the instructions in the group and in the individual situations, care was taken to see they were all uniform.

Analysis of the data :

After collecting the data the results were scored with the help of a prepared key. The total symptomatic responses for the Inventory for each subject, to which the term ' gross score ' was given, alone was taken into account. The ' gross score ' was taken to refer to the level of emotional instability. That is, subjects getting larger score were considered to have greater tendencies towards emotional instability. The reliability of the Inventory for the whole group was found out by split-half method (odds and evens) by applying Spearman-Brown Prophecy formula. The collected data, in addition to the study of the main problem, namely, influence of the socio-economic factors on emotional instability, lent themselves for the study of the influence of the factor of growth on the emotional instability. Thus the hypothesis for this study was finally formulated in the following form :—

(1) No difference exists among the scores of children, adolescents and adults in respect to emotional instability other than what could be due to chance fluctuation alone.

(2) No difference exists between subjects from high and low socio-economic families in respect to emotional instability other than due to chance fluctuation.

(3) No difference exists between subjects from high and low socio-economic families under each group, children, adolescents and adults, in respect to emotional instability, other than due to chance fluctuation only.

In order to classify a subject as a child, adolescent or adult, the following procedure was adopted. If a subject was found to be below the age of 14 he was classified as a child; if he is found to be between the ages 14 and 19, he was considered to be an adolescent ; and if he is between 25 and 50 he was considered as an adult. In the present group, the ages of subjects ranged from 8 to 48. In classifying the subjects this way, the investigator had the following definitions in his mind. Childhood as the period of infancy, i.e., after three years to the age of onset of puberty, puberty

being the capacity for reproduction. Adolescence as the period beginning with puberty and attainment of complete sexual maturity. Adulthood as the period beginning with sexual maturity till the age at which capacity for reproduction starts declining. It was empirically decided that on an average, the age of onset of puberty is 14 ; similarly it was decided that the age of attainment of complete sexual maturity is approximately twenty and the age of decline of capacity for reproduction is approximately fifty. Applying such a criteria, it was possible there was some overlapping. But this cannot be helped because there is no single criteria to decide whether a particular individual belonged to this or that group, as it is possible in the case of female sex. Particularly, it will be difficult to apply any other procedure other than this in a large study like this. It is felt that this is the best procedure available for the present study.

Table I. Showing the distribution of Personality Inventory scores in the high and low Socio-Economic Groups

Score	High	Low	Total
65	...	1	1
60	...	1	1
55	...	2	2
50	1	9	10
45	1	12	13
40	8	16	24
35	16	25	41
30	49	68	117
25	76	92	168
20	114	95	209
15	65	64	129
10	76	54	130
5	13	16	29
Total N ...	...	419	455	874

Table II showing the significance of difference between the mean scores of high and low Socio-Economic Groups

	High	Low	
Mean	22.107	25.21	
S.D.	8.067	10.348	
S.E.	.394	.485	
Mean Difference			3.103
$\sqrt{S.E_1^2 + S.E_2^2}$			.624
Critical Ratio			4.972
			Significant at 0.01 level

A study of the above table will show that the mean score of the low socio-economic group is significantly greater than the mean score of the high socio-economic group, the mean difference of 3.103 being significant at 0.01 level of probability (C.R. 4.972). This indicates that the subjects from low socio-economic group are characterised by greater emotional instability than the subjects from high socio-economic families.

The total group was classified into children, adolescents and adults to see whether a particular period is characterised by greater emotional instability.

Table III showing the distribution of scores for children, adolescents and adults

Score	Children	Adolescents	Adults	Total
65	...	1	...	1
60	...	1	...	1
55	...	2	...	2
50	...	10	...	10
45	...	13	...	13
40	3	20	1	24
35	8	26	7	41
30	32	58	27	117
25	33	55	80	168
20	74	60	75	209
15	39	33	57	129
10	59	30	41	130
5	2	8	19	29
	250	317	307	874
Mean	21.94	27.805	21.40	
S.D.	7.55	9.946	7.302	
S.E.	.476	.559	.416	

Table IV showing the significance of difference among the means of children, adolescents and adults

Groups	Mean Difference	$\sqrt{SE_1^2 + SE_2^2}$	Critical Ratio	Significance
Children and Adolescents ...	5.86	.734	7.983	Yes
Children and Adults ...	.54	.632	.854	No
Adolescents and Adults ...	6.405	.697	9.189	Yes

As may be seen from the Table II, there is greater variability as indicated by the larger standard deviation in the adolescent group as compared with the groups of children and adults. When the mean scores of these different groups are compared, as in Table III, it is found that the mean score of the adolescent group is significantly greater than the mean score of children's group and the adult group. The mean difference between children and adolescent groups, is significant (C.R. 7.983) at one per cent level. Similarly, the mean difference between adolescent and adult group is significant (C.R. 9.189) at one per cent level. The results indicate that adolescents are characterised by greater emotional instability as compared with children or adult.

To see whether the factor of low socio-economic status is important in all stages—childhood, adolescent and adult—the subjects were classified into three groups, and each group was further classified into high and low socio-economic groups. The results are presented in the tables below.

Table V referring to the distribution of scores in the Personality Inventory for groups of children, adolescents and adults, according to high and low socio-economic status

Score	Children		Adolescents		Adults	
	High	Low	High	Low	High	Low
65	...	...	...	1	...	...
60	...	...	...	1	...	...
55	...	...	...	2	...	...
50	...	...	1	9	...	...
45	...	...	1	12	...	...
40	....	3	8	12	...	1
35	5	3	6	20	5	2
30	14	18	21	37	14	13
25	16	17	19	36	41	39
20	35	39	37	23	42	33
15	20	19	20	13	25	32
10	30	29	24	6	22	19
5	...	2	5	3	8	11
	120	130	142	175	157	150
Mean ...	19.95	21.655	23.375	31.40	19.715	19.07
S.D. ...	6.655	7.29	9.215	11.01	6.875	7.41
S.E. ...	.608	.639	.773	.832	.548	.605

Table VI showing the significance of difference between the means of different groups given in the above table

Subjects	Mean Difference	$\sqrt{SE_1^2 + SE_2^2}$	Critical Ratio	Significance
Children—high and low	1.705	.882	1.218	No
Adolescents—high and low ...	8.025	1.35	7.07	Yes
Adults—high and low	.645	.816	.79	No

Results presented in the tables above show that the difference between the mean scores of children and adults of high and low socio-economic families are not significant (C.R. 1.218 and 0.79 respectively). But the mean difference between the scores of adolescents of high and low socio-economic families (8.205) is highly significant (C.R. 7.07., significant at one per cent level). The mean score of the adolescents belonging to low socio-economic group being higher. We may, therefore, infer that adolescents belonging to low socio-economic families are characterised by greater emotional instability as compared with adolescents of high socio-economic families.

Summary of the results and discussion :

874 subjects (male) in the city of Madras were studied with the help of a Personality Inventory to find out whether there is relationship between the socio-economic status of an individual and the emotional instability score. It was also aimed to find out whether there is relationship between growth and emotional instability. It was found that:—

(1) There was difference in the emotional instability score of subjects belonging to high and low socio-economic families, the mean score of the subjects belonging to low socio-economic families being significantly greater than the mean score of the subjects belonging to high socio-economic families. It was inferred that there is relationship between low socio-economic status and emotional instability.

(2) There were significant differences between the mean emotional instability scores of adolescents and children and adolescents and adults; the mean scores of adolescent group was significantly greater than the mean scores of children and adults. It was inferred that the period of adolescence is characterised by greater emotional instability as compared with childhood and adulthood.

and (3) There was significant difference in the mean emotional instability scores of adolescents of high and low socio-economic families, the mean

score of adolescents of low socio-economic families being significantly greater than the mean score of adolescents of high socio-economic families.

The results of the present study indicate that low socio-economic status has adverse effect only on the adolescents belonging to low socio-economic families. Strangely this factor has not shown its importance at the childhood stage or at the adult stage. The conclusion has to be accepted with certain reservations. For the investigator has not controlled important variables such as, intelligence, educational level, and home conditions, (like the broken home, etc.). But still, the results corroborate the fact of delinquents coming mostly from low socio-economic families. The fact of being poor itself may not be directly related to emotional instability. But it is likely that the concomitance of poverty may have some bearing on the emotional balance of an individual.

The results of the present study indicate a further line of research. An intense study of this aspect of the problem, namely, why the adolescents belonging to low socio-economic families are characterised by greater emotional instability, will throw enormous light on the problems of delinquency and mental diseases on the one hand, and on the problem of strikes in schools and factories which are becoming frequent even for trivial causes and what is important, for principles which contradict each other. Such a suggestion from a study of this kind will be hazardous. But still, it is worth attempting, for the adolescence of today is a citizen of tomorrow.

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Symbolism in Marriage Ritual of the South Indian Brahmins*

BY

V. C. VIMALA

Introduction:

Social institutions centre around a number of fundamental needs, permanently uniting a body of people in a co-operative task, and having its particular body of doctrine and technique. The Family is one such institution, which has assumed tremendous importance in the history of man. The term family has been used to denote four kinds of groupings — (1) The small group of parents and children; (2) The bilateral group comprising all individuals related through the father and through the mother; (3) The unilateral group of individuals related through the father only, or what is known as the Patriarchal family; and (4) The unilateral group of individuals related through the mother only, or what is known as the Matriarchal family. The small group of parents and children is the most widespread of all institutions, and the only one to be found universally among human beings, among the sub-human primates, and even among the birds. It is a group of habitually interacting individuals, and is derived from certain basic considerations that are essential. The four factors usually mentioned by Anthropologists and Sociologists as those governing the conditions and origins of family and marriage are:—(1) Sex, (2) Care of the infant; (3) Economic security; and (4) Religious beliefs. These four factors necessitate a union of the male and the female of the species, a union that is permanent.

In most societies the permanent union of man and woman is established by ritualistic observances, which differ from one group to another, according to the complexity of social organisation and its position in the cultural scale. In elaborately organised societies the ritual is complicated by religious and sociological considerations. Marriage in India provides a very clear illustration of such complication.

In India, the Smriti and Sāstra writers, almost without exception, hold marriage to be the most important of all the Samskāras, or purificatory acts, that are essential for the individual's attainment of the status of a member of society, generating fresh qualities in him, and removing evil taints from him. Marriage is perhaps the most picturesque and the most elaborate of these ceremonial performances. Unfortunately however, the ritual appears to be quite unintelligible to the average individual nowadays.

* Based on the thesis approved by the University of Madras for the degree of Master of Letters. The research work was done under the supervision of Dr. G. D. Boaz, Professor of Psychology, University of Madras.

Aim, Scope and Significance of the Study:

Our study was undertaken with a view to make a survey of ritual performances during marriage among some Hindu communities of South India, and to arrive at their significance to the performers. As the study progressed, we found the quantum of work assuming such vast proportions that we decided to limit ourselves to one community only.

All through the study, one guiding precept has been kept in mind, viz., that no act, and especally, the one connected with the solemnisation of marriage, can be without motive. In our quest for the motive we have observed religious and sociological principles throughout, the psychological interpretation being based on them for the most part. Psycho-analytical concepts have been employed in the explanation of certain parts of the ritual; common-sense explanations have been preserved wherever they have been found most suitable, for very often the simplest is also the truest.

This study is among the first of its kind, for though several works have been published that deal with the ritual of marriage and related ceremonies, very few of them have stopped to examine the possible significance of each rite. Our study is in the nature of a pioneering effort, and if the only purpose accomplished by it is the stimulation of interest in the significance of ritual performed during marriage and during other Samskāras, we shall be satisfied that it has been worthwhile.

Sources:

The details of the ritual were obtained from various sources. Marriage ritual is one of the chief topics treated by the Grihya texts which deal exclusively with domestic ritual. The subject forms part of the concern of writers on Dharma Sāstra also. Classics like the Raghuvamsa and Harsacarita also describe marriage as do the Silappadikāram and the Kamba Rāmāyanam. The Mahābhārata is an excellent source book on the subject.

Besides the study of these works, actual observations of the ritual as performed were also made.

A questionnaire was prepared and distributed to 200 married people, men and women, mainly with a view to get their reaction to the various rites at the time of marriage and to find out how a memory of these rites was helping them, if at all, in their later married life. The investigator was sorry that on the whole this source of information was a failure, as only 20 people returned the filled in questionnaire, and even of these, the majority gave very scrappy information, which they were unable to supplement on being interviewed in person. We had therefore, to abandon this method of collecting material for our study.

Some important marriage rites:

Our study shows us the gradual elaboration of marriage ritual with the ages. The marriage ritual of the Rig Veda is much simpler than that of the Atharva Veda, which itself is much simpler than the account given by the Grihya texts. The ritual as now performed, includes a number of rites not mentioned by the ancient-texts. Sociological changes might account for these modifications. As social organisation grows more complex the ritual prescribed to mark any change of position of the individual within that organisation also becomes more complex, affecting a larger proporation of society than before, and conforming to more social obligations.

We shall here confine ourselves to the description and analysis of some important rites performed during South Indian Brahmin marriages.

Kāsi Yātra:—The bridegroom starts out alone towards the north, wearing sandals on his feet, holding an open umbrella over his head, a bundle of clothes and rice under his arm, and a staff or walking-stick in his hand. His destination is supposed to be Kāsi, (the modern Banares) and his aim, to make his own living. Before he goes very far however, the bride's father meets him and promises to give his daughter in marriage. The bridegroom is made to stand with his feet inside a round plate and the bride's father places a silver coin on each foot and washes it with water.

Exchange of Garlands:—The bride and the bridegroom exchange garlands three times, the bride first removing a garland from her neck, and placing it round the bridegroom's. Their maternal uncles stand near by and help them to take up each garland from their necks. Formerly it was the practice for the maternal uncles to carry the bride and bridegroom on their shoulders for the exchange of garlands. Exchange of garlands is followed by " Unjal " or swinging.

Kanya Dāna:—The bride is given away formally to the bridegroom, who accepts her, promising not to wrong her " In the attainment of Piety, Wealth and Desire ". The bride and bridegroom are made to face each other, while their Gotras and Pravaras are recited three times, together with their immediate ancestry. At this announcement, their hands are joined together and a little water is poured on them.

Yugachhidraprokshana:—The bride is made to sit on her father's lap while he sits on a seat of dried grass containing paddy-grains. A small ring of darbha grass is placed on her head, and a verse is recited inviting the bridegroom's parents, brothers and sisters to approach and witness the rite being performed on the bride, beseeching the glory and mercy of the Sun.

A yoke on which turmeric paste and kumkum have been smeared is placed over the darbha ring and water is poured through the hole in the

yoke on to the bride's head. A verse is recited beseeching the deity Indra to cure the bride of all skin diseases and give her glory equalling that of the sun, just as he cured Apāla of skin diseases by pouring water on her through the hole in his chariot.

The gold Thāli, (or Māngalya), threaded on thick yellow cord together with round gold beads, is placed over the yoke hole and water is poured over the gold, through the yoke hole and darbha ring on to the bride's head.

The Māngalya-dhārana:—The bridegroom ties the Thāli around the bride's neck. After he has made one knot, his sister ties two more knots on the Thāli.

Yoktra bandhana:—The bridegroom ties a rope of darbha grass round the bride's waist.

Pānigrahana:—The bridegroom takes the bride's hand in his, holding all her fingers inside his palm, and leads her to the fire established on a consecrated spot.

The Vivāha Homa is performed, oblations of ghee being offered to the fire.

Lāja Homa:—Ghee is poured over the bride's hands; then her brother, or someone acting in that capacity, pours puffed rice into her hands; ghee is then poured over these grains, which the bride sacrifices into the fire without opening her hands, as with a spoon.

Āsmāropana or Āsmārohana:—The bridegroom leads the bride round the fire, her right hand in his, with their right sides nearest the fire, and taking up her right foot, places it on a grinding stone kept north of the fire.

Agni-Pradakshina:—Agni-Pradakshina is circumambulation of the marriage fire. The bridegroom leads the bride three times round the fire.

Saptapadi or The Rite of the Seven Steps:—The bridegroom leads the bride seven steps to the north-east, with the Saptapadi mantra—"One for sap, two for juice, three for the prospering of wealth, four for comfort, five for cattle, six for the seasons. Friend be with seven steps. So be thou devoted to me."

Hridaya Sparsa:—The bridegroom touches the heart of the bride, with his right hand, reaching over her right shoulder.

Suryodikshana:—The bride is asked to look at the sun.

Dhruva-Arundhati Darsana:—The bridegroom points out the Pole Star and the star Arundhati to the bride.

Grahapravesa:—The bride and bridegroom are conducted to the bridegroom's house. The bridegroom holds the bride's hand as described under Pānigrahana, and they enter the house together, with their right foot forward. Oblations are offered to the fire preserved after the Vivāha Homa, and verses are recited indicating the establishment of the household fire. A young boy is seated on the bride's lap and fed with fruits and milk.

The possible significance of the rites:

Kāsi Yātra is said to be symbolic of the bridegroom's journey to Kāsi, the seat of learning, and the objects he carries are the articles necessary for the journey—a bundle of rice for food, change of clothes, sandals to protect the feet, umbrella to provide shade for the head, and staff for support, and defence against dangers on the way. But on the way he attracts the attention of the bride's father, who sees in him a fit mate for his daughter and receives him with appropriate honours.

Exchange of garlands is a natural sequel to Kāsi Yātra. The bride provided he is willing to marry the bride, the father being eager to give away his daughter and attain the merits arising from Kanyā dāna. And since it is not mentioned by the ancient texts, we may conclude that it is a fairly recent introduction into the ritual.

Kāsi Yātra may be a step in the weaning of the bridegroom from parental ties, and the widening of his horizons, enabling him to gain new experiences.

Exchange of garlands is a natural sequel to Kāsi Yātra. The bride and groom are strangers to each other, and the exchange of garlands affords them a chance to see each other under pleasant circumstances. The festivities seem to have as their aim the production of a suitable atmosphere for marriage.

The presence of the maternal uncle may signify that he gives up his claims on the bride, it being quite a common practice for maternal uncles (or their sons) to marry their nieces (or cousins).

Swinging is an excellent means of sexual stimulation, and the swinging that follows the exchange of garlands seems to be a very wise introduction into the ceremonial of marriage in a community where sex is strictly taboo, especially with unmarried young men and women. Hitherto the erotic impulses of the bride and bridegroom have been severely repressed, but now they can be roused so that eagerness for marriage is created. This is done unobtrusively, so that social standards will not be violated, in an atmosphere of general merriment. This rite may be compared with the western custom of going for a drive after marriage.

Kanyā dāna appears to be the ceremonial gift of the bride to the bridegrooms; but she is a gift with some conditions attached. The recital of the

gotras and pravaras of the bride and bridegroom during Kanyā dāna may be an assurance given to the bride and groom, and also to the guests, about their respective parentage and descent.

Yugachhidraprokshana:—The yoke may symbolise the bride's union with and dependence on the bridegroom. She is symbolically yoked to the man as an animal is yoked to a vehicle or to the plough. Both must always function in union, or they would lose their usefulness; a man and woman should always complement each other's attributes and function as one unit, losing any value to society if separated.

This rite is said to have a legend behind it. A female rishi, Apāla, the daughter of Atri, was a very beautiful woman, afflicted however, with some skin eruptions. The god Indra, having seen her in her father's hermitage, fell in love with her, and she became aware of it through penance. She took a pot and went to the river to fetch water. Seeing the Soma plant on the edge of the water, she pressed its juice in her mouth and invoked Indra, and Indra drank the soma juice from her mouth after he had eaten cakes and meal from her house. In accordance with her wishes, Indra made Apāla 'faultless limbed and fair skinned' by passing her through the aperture in his carriage.

The legend seems to imply union between Indra and Apāla, the skin eruptions signifying Apāla's burning passion, the drinking of the juice in the mouth suggests kissing, the bath the actual sexual intercourse, and the disappearance of the eruptions, the satiation of passion. In the rite, the bride is perhaps believed to represent Apāla and the bridegroom Indra, the whole procedure being symbolic of the sexual union of the bride and bridegroom.

The fact that the bride sits on her father's lap during the rite suggests that she is really being freed of all Oedipal longings, and longings for any male personified by a deity and thus rendered less revolting to social codes. Any reciprocal longings the father has for his daughter may also be satisfied by means of this rite.

The invocation of Indra during the rite, and the participation of the father in the rite appear to suggest that the rite is one for fertility, brought about through ceremonial defloration by the deity or by the father. It may be built on the belief that children are incarnations of ancestors, or the gifts of deities and that motherhood can come into effect only after such a ceremonial act or repeated acts.

The pouring of water on to the bride's head through the hole in the yoke over which gold is placed, suggests that the bride is purified with water that has itself been purified having been in contact with gold, gold being commonly believed to possess the property of removing all evil from anything with which it comes into contact.

Māngulyadhārana and Yoktra bandhana, appear to satisfy the establishment of the bridegroom's authority over the bride. Having freed her from all previous attachments, the bridegroom marks her with the sign of her union to him, and thereafter she becomes his exclusively. The Māngalya itself, may be an amulet, worn to protect the bond of marriage from evil influences.

Pānigrahana, we believe signifies the bridegroom's taking charge of the bride, an implicit promise to keep her under his protection always, and to lead her safely through all enterprises. The method of holding hands is suggestive of the absorption of all the bride's interests and energies in the bridegroom.

Homa in the ritual:—Fire is believed to be the messenger of the gods, and oblations are made to the fire to be conveyed to other gods. This is perhaps because fire makes food invisible, by consuming it; the gods being invisible, their food is made invisible also, and mixed with the natural elements.

Lāja Homa is the offering of a special kind of food to the gods, by the bride, who prays to be united with her husband, and freed from other attachments. The part played by the brother in this rite may be taken as an indication of the incestuous nature of these attachments.

Āsmārohana or *Āsmāropana* appears to be based on the principle of sympathetic magic. By contact with the stone, the bride perhaps draws into herself its attribute of firmness, able thenceforth to remain constant in her affection for her husband, and able to withstand bravely the assault of adversity.

Agni-Pradakshina:—Circumambulation is a mode of paying homage, bond between husband and wife, the heart being generally regarded as the and is a common aspect of Hindu religious observances, particularly those connected with worship and prayer. Since fire is believed to be the messenger of the gods homage might be paid to fire so that it may be carried to them.

Saptapadi:—The verse recited during the performance of the rite indicates that the rite is symbolic of the life of the bride and bridegroom as a married couple. Life is traced step by step, and the seal is set on the partnership by the seventh step. In Hindu thought the number seven is the number of completion.

Hridaya sparsa probably indicates the formation of a new emotional centre of emotion. This rite probably reveals the recognition of the psychological necessity for the physical union to be supplemented by an emotional affinity.

Suryodikshana:—The sun is the universal father symbol, and by asking the bride to look at the sun, the bridegroom perhaps gives her a last chance

to satisfy all her infantile longings for her father with the implication that she will thereafter devote herself to her husband alone.

Perhaps by looking at the sun, the giver of warmth and life to the Universe, the bride is expected to become like him, the giver of warmth and life to the home. Besides, she may derive radiance and power from the sun, and thenceforth strive to emulate his example of not showing special favours to anyone, behaving alike to everyone round her.

A warning might be implicit in the rite. The sun is "the all-seeing eye" and so the bride must never do anything that might not have its approval.

Suryodikshna might also be taken as a fertility rite, the sun being a symbol of fruitfulness, and giver of life.

Dhruva-Arundhati Darsana:—In Hindu mythology, Dhruva is the epitome of firmness of purpose and Arundhati, of chastity. By pointing them out to her, the bridegroom enjoins firmness and chastity on the bride.

Grahapravesa symbolises the establishment of a home by the bride and bridegroom; and the seating of a young boy on the bride's lap is probably a fertility rite, which ensures that the bride will soon have a son of her own.

The dress of the bride and bridegroom:—The bride has to wear her sari so that one end of it passes between her legs, and the whole effect is that of a pair of trousers. This mode of dress is compulsory once a woman is married; even if she does not habitually do so, a married woman is expected to wear the sari in this special way during the performance of other rituals, and if she crosses a threshold or door step without the sari between her legs, she is supposed to be stepping over the body of her recumbent husband. This belief may be rooted in the conception of the threshold as symbolic of the male and crossing it as symbolic of sexual intercourse.

The threshold is believed to be the haunting ground of evil influences, and the prescribed mode of dress may afford protection from below from all these evils. The motive of modesty may also be behind this concept.

The bridegroom's dhoti also, worn as prescribed, shows this "trouser-effect", and is believed to confer on him the status of master of ceremonial performances. This may have the same motives of modesty and protection.

The similarity of the dress of the bride and groom could be construed as evidence of the original matriarchy of a patriachal society, it being believed that the woman-like dress of priests in some cults is the survival of matriarchal antecedents.

Invocation of deities during the ritual:—Marriage ritual is marked by a constant invocation of deities, and it is interesting to note that the deities

invoked during marriage are not those familiar to one as the Hindu hierarchy of gods, but are those that were worshipped by the Rig-Vedic people. A study of the characteristics attributed to these deities by the Rig-Veda itself indicates that they were reflections of the needs of the people. The preservation of their worship during ritual performances points to the conclusion that they serve some basic need in man, a need engendered not only by man's feelings of inferiority and craving for protection, but chiefly by the existence of a Supreme Being whose various manifestations are worshipped, and who exerts a natural pull on human beings, making them innately religious.

We have seen from the above study of rites performed during marriage, that they mark a shift in the individual's position in society, a change from the status of student and bachelor to the status of a householder. In other words, the rites imply the passage of the individual from one institution to another. Such rites have been called Rites of Passage, and mark the separation and transition of the individual from one institution and his incorporation into another.

Separation involves a reduction or a complete cessation of the interaction of the individual with group (or individual) with which (or whom) he has hitherto been in contact. In the ritual outlined in the preceding pages, separation from previous attachments is indicated by the rites of Kāsi Yātra, Kanyā dāna, Yugachhidraprokshana, Lāja Homa and Suryodikshana. All these, with the exception of Kāsi Yātra signify the weaning of the bride from parental and other influences. The bridgegroom seems to require less of this ritual freeing, probably because he has already been subjected to it during his initiation into Veda studies.

Transition is the period during which the individual reacts in his new relationships and is indicated by rites in which the bride and bridegroom participate together, such as the Exchane of garlands, Swinging, Pānigrahana, Homa, Asmārohana and Saptapadi; in performing these rites, the bride and the bridegroom learn the nature of the relationships that have to be assumed and the adjustments they have to make in their own reactions to the relationships.

Incorporation is the entry into society as a member of a new institution, and is indicated by Grahapravesa.

Thus we see that the marriage ritual is oriented towards the production of a new dignity in the bridal couple, and it is explaining to them, especially to the bride, of their new obligations and the conduct expected of them thereafter; it is also a rehearsal of their future life and duties, and serves to get them used to each other.

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