

in a frame of reference accompanying the Earth a magnetic field H , which is perpendicular to the ecliptic and directed from north to south. On the last page of this article it was also pointed out that a test of this model could be made "by means of satellite-borne magnetometers", and this is what is incidentally being considered here. The same model and test were more fully discussed in three later publications⁸⁻¹⁰.

A more recent development of this model will be published elsewhere. This, by taking account of the polarization of the plasma constituting the solar wind, can account for the observed perpendicular fields B in magnitude as well as in direction and sense, and also can account for the larger changes in B produced by solar disturbances.

As implied in Dr. E. J. Smith's statement (a) in Section 4, apparently no other model has been successfully proposed which accounts for a field like B .

Summarizing, we may now regard the observed interplanetary field F_i as due to motion of the magnetometer relative to a negatively charged rotating Sun from which magnetic lines of force are drawn out into space by a flow of plasma clouds and from which solar disturbances are propagated as generalized magneto-ionic waves.

This hypothesis promises to cover all the facts discovered hitherto. Accordingly it may be used to make testable predictions about the magnetic data from *Mariner 2* which have not yet been published, as well as predictions about the magnetic data from the future space-probe which it is planned to launch towards Mars.

These predictions will include a possible variation of the magnitude of B inversely as the cube of the distance of the probe from the centre of the Sun¹⁰. Thus, as obtained from *Mariner 2*, B will perhaps be found to have increased by the factor $(1.5 \times 10^8/1.1 \times 10^8)^3 = 2.05$ when in the neighbourhood of Venus.

These predictions depend on the assumption that when the Sun is quiet the screening effects due to interplanetary polarized clouds of plasma may be nearly constant in the region between the Earth and Venus.

Many other simple and testable predictions follow from this hypothesis.

(6) Conclusion

It is important to enquire why the fact that the quiet-time field component perpendicular to the ecliptic is almost always directed from north to south has not been pointed out in the publications of the eight principal physicists concerned.

That it is a crucial fact cannot be doubted since, as we have seen, no orthodox theory exists which has explained it satisfactorily. It emerged only because I was looking for evidence bearing on the unorthodox hypothesis that the Sun carries a large negative charge. This demonstrates clearly the heuristic value of the hypothesis.

Certainly this hypothesis appears to contradict terrestrially ascertained laws of electromagnetism and electronics. But that is not necessarily fatal since we have no reliable knowledge about the magnetic fields inside a star like the Sun, which often throws up to its surface such immense and intense fields as those existing at and near sunspots, and therefore (for all we know) even more immense and intense magnetic fields in the solar interior may exist at some places and trap an excess of electrons. Alternatively the hypothesis may result from some unorthodox process in the solar interior like the apparent continual creation of electricity which has been postulated in earlier publications^{7,8}. Consequently this hypothesis cannot be dismissed until it has first been thoroughly tested by means of instrumented satellites. The tests by means of *Pioneer 5*, *Explorer 10* and *Mariner 2* at present seem to support it.

The gap between the orthodox and unorthodox views is fortunately now being reduced by a tendency to admit the possibility that different space charges can exist in the inner and outer regions of the radiation belts¹¹ and that large net electric charges exist on the Moon, Venus and Mercury^{12,13}, which enable these bodies to influence certain terrestrial events such as the occurrence of precipitation, ice-nuclei and micrometeorites in the atmosphere and of geomagnetic storms.

We can now see that it has become essential to have some future space probes carry devices which can determine the concentration of the protons and electrons separately or else the concentration of the protons and of the excess charges per unit volume of the plasma. It would also be of great value to have them carry a device for measuring ambient electrostatic fields ranging from 10 to about 1,000 V/cm; a plate attached to an electrometer and periodically screened by a 'grounded' rotating sector might serve for this purpose.

Note added in proof. A report by L. J. Cahill and P. C. Amazeen (*J. Geophys. Res.*, **68**, 1835; 1963), on the magnetic data from *Explorer 12*, likewise verifies the predictions from my hypothesis about the Sun.

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BIOLOGICAL BASIS OF PERSONALITY*

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LIKE other sciences, psychology has the dual task of: (a) describing accurately, and preferably quantitatively, the material which forms its subject-matter, that is, behaviour; (b) of producing a causal theory which deduces the observed behaviour patterns from more fundamental causes. As human beings are biological organisms, it seems reasonable to expect that ultimately these causes should be looked for in the constitutional endowment of the person, that is, in certain physiological,

neurological, biochemical and endocrinological properties of his body. Genotypic variations along these lines will, of course, interact with the environmental influences to produce the phenotypic behaviour patterns which we can observe and describe, and it is not part of our thesis to deny the importance of environmental differences. However, social psychologists, clinical psychologists and others have, in recent years, stressed environmental influences to the almost complete exclusion of biological factors, and it seemed desirable to redress the balance to some extent by stressing certain facts supporting the view that bio-

* Substance of the Thomas Young Lecture delivered at St. George's Hospital Medical School on June 17.

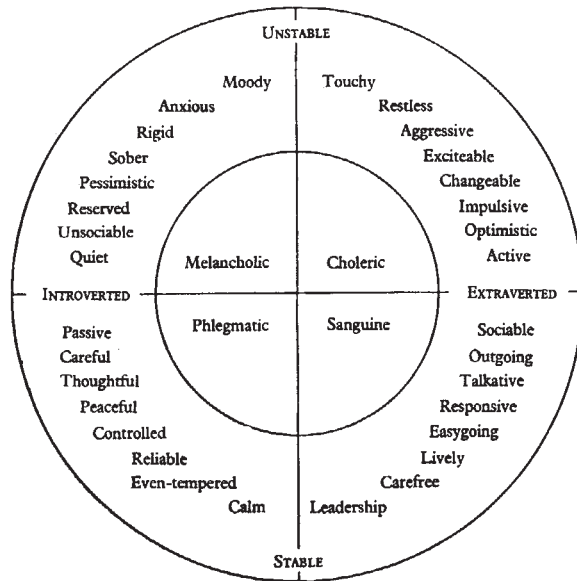


Fig. 1. Diagram showing medieval typology (inner circle) and modern personality description in terms of correlational analysis of trait measurements (outer circle) (ref. 7)

logical factors were of considerable importance in the genesis of individual differences and personality.

Descriptively, there is now considerable agreement among experts that a large part of personality can be reduced to the interplay of two dimensions, one of which is usually labelled extroversion-introversion, the other emotionality, neuroticism, or instability as opposed to stability. This theory goes back at least as far as the great medieval physician Galen, and his doctrine of the four temperaments, and the relation between these temperaments and our two dimensions is shown in Fig. 1; the outer ring of this figure shows the results of large numbers of factor analytic studies of ratings and self-ratings, carried out by such workers as Cattell, Guilford and myself. There is considerable agreement at this descriptive level between medieval theory and modern discovery¹.

My main reason for assuming that these personality dimensions do in fact have a constitutional basis lies in the results from large numbers of experimental investigations carried out on identical and fraternal twins, showing that with respect to both extroversion and neuroticism, identical twins are very much more alike than are fraternal twins. This, of course, is also true with respect to intelligence, and in line with modern genetic theories it is commonly interpreted as providing strong evidence for the hereditary nature of these traits and abilities. The criticism has sometimes been made that possibly identical twins, being so alike, are also treated more alike by parents, teachers, etc., than are fraternal twins who resemble each other less closely. If this were true then the general argument would be weakened, and one would be forced to put a great deal of weight on an interaction effect between heredity and environment. The recent work of Shields², however, suggests that this criticism is not, in fact, valid. In addition to fraternal twins, he examined identical twins brought up separately, as well as identical twins brought up together, and with respect to intelligence, extroversion and neuroticism, he found that identical twins brought up separately were, if anything, more alike than identical twins brought up together. The actual figures of the inter-class correlations were as follows, listing first the value for the twins brought up separately, and secondly, the value for the twins brought up together: intelligence, 0.77 and 0.76; extroversion, 0.61 and 0.42; neuroticism, 0.53 and 0.38; for fraternal

twins the values were: 0.51, -0.17 and 0.11. These results leave very little doubt about the importance of the part which heredity plays in the genesis of these personality dimensions.

The genetic argument can be extended in various ways. Recent work in Germany, for example, has shown that investigations of familial similarity with respect to extroversion and neuroticism show a degree of relationship to consanguinity, which also strongly supports the hypothesis of inheritance. Another line of argument is derived from the fact that criminals, psychopaths and children suffering from behaviour disorders tend to lie in the 'choleric' quarter so far as personality is concerned; in other words, they tend to be extroverted and unstable. Following the work of Lange in Germany on "Crime as Destiny" much effort has gone into the task of locating criminals with twins and checking whether these twins were concordant or discordant with respect to criminality. So far as adults are concerned, out of 225 twin pairs 71 per cent were concordant among identical twins, but only 34 per cent among fraternal twins. So far as childhood behaviour disorders are concerned, the proportions are 87 per cent and 43 per cent, respectively. For juvenile delinquents the proportions are 85 per cent and 75 per cent. Altogether these figures again strongly support the hypothesis that genetic factors are of considerable importance in the genesis of these particular behaviour patterns.

When we come to look for a biological basis for our two dimensions of personality, we find relatively little difficulty in relation to neuroticism, emotionality or instability. Persons high on this dimension are characterized by very strong emotional reactions to all classes of stimuli, and there is a well-recognized relationship between emotional reaction and the activity of the autonomic nervous system, particularly its sympathetic branch. There is also evidence, again relating largely to twin studies, strongly reinforced by breeding experiments in animals, that the lability of the autonomic nervous system is, to a considerable extent, determined by hereditary factors. There seems little reason to doubt that the biological basis of individual differences in emotionality is closely connected with the activity of the autonomic nervous system¹.

This conclusion needs certain qualifications, particularly in view of the recent findings in the United States of considerable response specificity in the reaction of the autonomic nervous system. Thus it is found that the autonomic nervous system does not act as a whole, but that certain sub-systems may be activated much more strongly than others. It has been found that this specific innovation is characteristic of a given person even though many different types of stimuli may be utilized, and it has been found that this response specificity is preserved over periods of time extending to several years at least. It is likely that this specificity itself is inherited; it represents, as it were, specific areas of strength and weakness of the autonomic nervous system, with the latter acting as a kind of fuse which may be blown in the case of a neurotic breakdown.

When we turn to extroversion-introversion no obvious identification with any structure in the nervous system can be made, but we hope to show that even so it is not impossible to formulate certain hypotheses which have some limited support in the experimental evidence. The beginning of a theory resulting in such a link-up may be found in the postulation by modern learning theories, following Pavlov, of the importance of excitatory and inhibitory potentials in accounting for a large number of laboratory phenomena. In relation to inhibition, for example, it is postulated that massed practice on any task produces inhibitory potentials which depress the quality of the performance which is being practised, so that subjects working under conditions of spaced practice will show superior performance. It is also maintained that this inhibition, being a kind of cortical fatigue state, will

dissipate during rest, thus giving rise to the so-called 'reminiscence' phenomenon, that is, an improvement of performance during rest, as indexed by subtracting performance at the end of the pre-rest period from that at the beginning of the post-rest period. Thirdly, it is deduced from the theory that the growth of inhibition should ultimately lead to the cessation of activity, that is, the occurrence of certain blocks or involuntary rest pauses. All these consequences have frequently been observed, as have others more in the perceptual field such as the so-called 'figural after-effect'.

I have suggested a link between personality and the theory of excitation and inhibition by postulating that extroverts are characterized by the particularly rapid rise of cortical inhibition, its slow dissipation, and its relatively high level. Conversely, introverts are characterized by the slow growth, rapid dissipation and generally low level of cortical inhibition. The opposite prediction is made with respect to excitation, that is, introverts show a high degree of excitation, extroverts a low degree. (It will, of course, be realized that we are talking about cortical inhibition and excitation, not about inhibited or excited behaviour. Cortical inhibition, by depressing the activity of the highest centres, may give rise to uninhibited behaviour².)

Proof for a theory of this kind would, of course, be sought in examining the behaviour of behaviourally extroverted and introverted subjects on laboratory tests of massed and spaced practice, reminiscence, amount of 'blocking', length of figural after-effects, etc. Much evidence has been accumulated in recent years to show that the predicted effects do, indeed, differentiate extroverts and introverts in the predicted direction. Technically much of this work is quite complex, as it is often difficult to rule out irrelevant factors which interfere with the pure measurement of the effects in question. Nevertheless, there seems to be little doubt at the moment that in its broad outlines the theory is supported by the experimental facts amassed so far.

Fig. 2 gives a systematic picture of the hypothetical relations between the genotypic level we have been discussing hitherto, and the phenotypic level of extroverted and introverted behaviour. It will be seen that we postu-

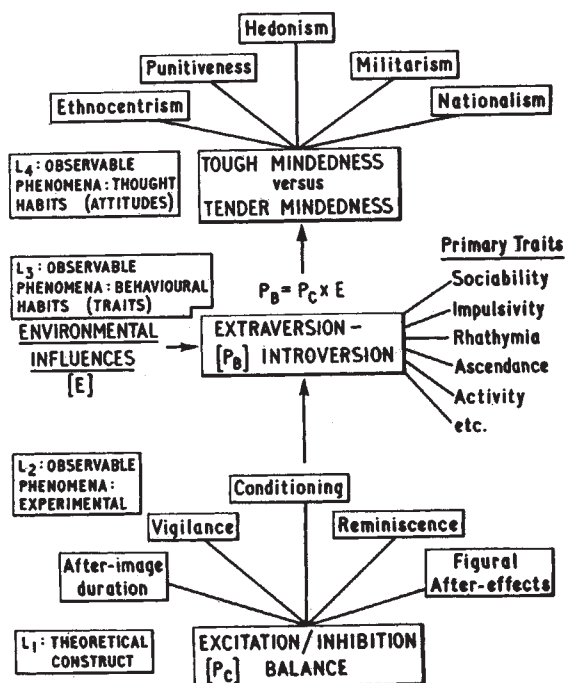


Fig. 2. Diagram illustrating relationship between genotype and phenotype in the personality field (ref. 8)

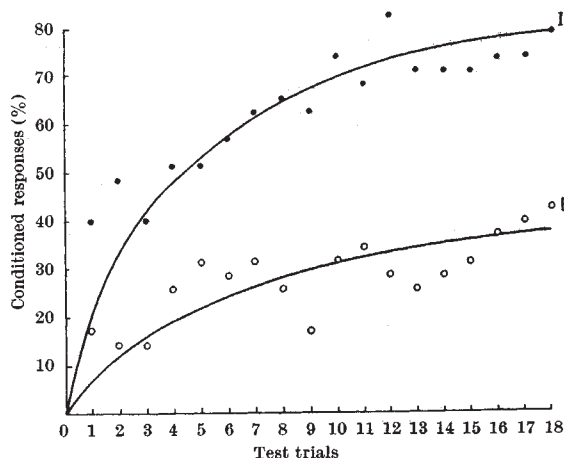


Fig. 3. Rate of eyeblink conditioning in groups of introverted and extroverted subjects (ref. 9)

late several different levels, going from the hypothetical excitation-inhibition balance at the bottom, which we considered to be the physiological basis of our constitutional personality (P_C), to the higher levels of behavioural personality (P_B), which is a product of constitution and environment, and which manifests itself in the form of behavioural habits or traits such as sociability, impulsivity, ascendance, etc., or in terms of thought habits or attitudes. (There is an empirical relationship between tough-minded attitudes and extroverted behaviour patterns.)

The relationship between levels 2 and 3, that is, observable, experimental phenomena, and the observable, behavioural phenomena, is a very complex one which will undoubtedly repay intensive study. We can only discuss here very briefly one particular link as an illustration of the type of argument and empirical demonstration which requires to be adduced. It will be noted that among the laboratory phenomena at the second level I have listed Pavlovian conditioning; the hypothesis states that the process of conditioning produces inhibitory potentials, that it does so more strongly in the extrovert than in the introvert, and that consequently introverts should condition better than extroverts. Fig. 3 shows the results of some experiments in which introverted and extroverted subjects were given the eyeblink conditioning test in which a sound delivered over earphones constitutes the conditioned stimulus and a puff of air to the cornea of the eye the unconditioned stimulus, producing closure of the eyelid. It will be seen that the hypothesis is supported by the data, introverts showing about twice as high a level of conditioning as do extroverts.

Modern learning theorists have hypothesized that neurotic symptoms, such as phobias, anxieties, obsessional and compulsive behaviour patterns, etc., are nothing more than conditioned autonomic and skeletal responses, and that they can be extinguished according to the rules which govern the extinction of such conditioned responses in the laboratory; there is much empirical support for such a contention. Now it will be clear that such conditioned responses are more likely to occur in individuals predisposed to the development of conditioned responses by the possession of a central nervous system which conditions easily. Thus we would expect, on the basis of these theories, that neurotics of this type would be introverted from the descriptive point of view, and would also condition extremely well. There is much impressive evidence to support both these deductions^{4,5}.

It has also been argued that the process of socialization, by means of which the young child learns the mores of his society, is mediated by Pavlovian conditioning, and it would seem to follow that psychopaths ('moral imbeciles'), and criminals generally, should be found largely

among persons who are extroverted and who condition poorly. (The argument is, of course, exactly the opposite to that which applies to the neurotics discussed in the previous paragraph.) The evidence is indeed very strong that persons in these groups are extroverted and there are several investigations which show that they condition very poorly, if at all. Pavlovian conditioning, therefore, seems to provide an efficient bridge between our level 1, that of the theoretical construct of the excitation-inhibition balance, and level 3, that of observable behavioural phenomena.

Is it possible to locate any structure within the nervous system which may be responsible for individual differences in these mysterious processes of excitation and inhibition? I would suggest that the ascending reticular formation may fit this prescription reasonably well. This formation, which is located on the spinal cord from the brain stem through the mid-brain to the diencephalon, provides an alternative pathway for ascending impulses proceeding from the periphery to the cortex, impulses travelling along the classical afferent pathways entering the reticular formation via collaterals from the afferent, and giving rise to impulses that are not only directed to the primary cortical projection area but may also be projected profusely over a wide area of the cerebral cortex. Parts of the formation (the so-called ascending reticular activating system) are known to be involved in cortical facilitation; they thus fit in with the psychological concept of 'excitatory potential', while the so-called 'recruiting system' acts as

a suppressor and thus has affinities with the psychological concept, 'inhibitory potential'.

Evidence for this identification is largely indirect, the strongest argument in favour being perhaps that deriving from the action of stimulant and depressant drugs. These are known to shift a person's position on the extroversion-introversion dimension in the direction of greater introversion (stimulant drugs) or in that of greater extroversion (depressant drugs), and it is known that these drugs on the whole tend to act through the ascending reticular formation⁶. This hypothesis linking psychological concepts with physiological structures is offered only very hesitantly; it will undoubtedly require much modification before being found acceptable. However, it does serve to unify several quite distinct lines of research and may, in turn, give rise to experimental studies likely to clarify the issue and to reveal to us more directly some of the biological roots of personality.

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A THEORY OF CROSSING-OVER BY MEANS OF HYBRID DEOXYRIBONUCLEIC ACID

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THE term 'crossing-over' was introduced into genetical literature by Morgan in 1912 to describe the phenomenon he had discovered whereby new combinations of linked characters arose. Several theories to explain the process have been put forward in the intervening half-century. Ideas suffered a radical change in 1955 when the classical theory of reciprocal recombination was overthrown. This followed acceptance of the notion that, within small segments of the hereditary material, the products of recombination are not always complementary. Lindgren¹ had first suggested this on the basis of his work with *Saccharomyces cerevisiae*; but the idea did not gain wide support until Mitchell² demonstrated the phenomenon in *Neurospora crassa*. One of the first examples of non-reciprocal recombination which she found was remarkable in that conversion (as the non-reciprocal process is often called) had taken place in opposite directions at allelic sites.

In attempting to formulate a general theory of the mechanism of recombination, a difficulty has been the diversity in the results obtained with different organisms. In *Aspergillus nidulans*, where in ordinary linkage studies there appears (unlike *Neurospora*) to be no interference between cross-overs, Pritchard³ found it necessary to postulate the frequent occurrence of more than one cross-over in short segments, which he called regions of 'effective' pairing, while non-reciprocal recombination has been somewhat rarely recorded⁴. In *Ascobolus immersus*, on the other hand, Lissouba and Rizet⁵ and Lissouba *et al.*⁶ have shown that non-reciprocal phenomena occur regularly at loci concerned with spore pigmentation, and moreover that a polarity is evident in the data. Within a group of apparently linearly sited alleles, if one is found to show conversion more frequently than another placed to the left of it, then the right-hand

member of any other pair of them is found to show a similar difference from the left-hand member. Such polarity has not been demonstrated in *Neurospora*.

Variability is also shown within species. In *Neurospora*, Lindgren and Lindgren⁷ found a significant excess of two-strand double cross-overs across the centromere of one of the linkage groups, while others (for example, Stadler⁸) have found no such chromatid interference. In *Ascobolus*, Lissouba *et al.*⁶ have found that within a series of multiple alleles different pairs may show diversity in the relative frequencies of occurrence of reciprocal and non-reciprocal recombination.

Copy-choice Hypothesis

The hypothesis that has most frequently been used to explain non-reciprocal recombination is the theory of 'switch synthesis' or 'copy-choice', which relates recombination to replication of the hereditary material. This hypothesis requires that homologous chromosomes shall be paired, at least at certain points along their length, at the time of replication and that the new strands may be replicas of one parental strand in one region and of the other one in another region (Fig. 1). This idea provides a neat explanation of how within a tetrad one site may show a 2 : 2 ratio and a neighbouring one a 3 : 1 ratio.

The theory has been extended by Lissouba *et al.*⁶ to take account of their observations on polarity, by postulating that the direction in which replication occurs is from left to right, that is, towards sites with the higher conversion frequency, and, furthermore, that once a copying 'error' has been started it continues to the end of the group of sites. They have coined the term 'polaron' for such a group of sites within which crossing-over appears to be absent.