The Electron Theory of Matter. By O. W. RICHARDSON, Wheatstone Professor of Physics at Kings College, London. Pp. vi + 612. Cambridge Univ. Press. 1914.

THIS is in many ways a very remarkable book. Its scope is broader than that of any book on Electron Theory which has yet appeared, and it has the unique merit of not following even remotely the outline of J. J. Thomson's epoch-making work in this field. The author himself has exhibited within the past fifteen years, an unusual combination of theoretical and experimental fertility, and the present volume represents his digest, from the beginning, of the whole field of electromagnetic theory from both the theoretical and the experimental side. It exhibits profundity of scholarship, breadth of knowledge, enormous industry and a commendable fairness and reasonableness of temper.

The first 216 pages contain mainly the author's own treatment of nearly all of the most important of the classical theorems of electromagnetism such as the various potential theorems and those growing out of the Maxwell equations. From this point on is found a very exhaustive and original treatment of practically all of the newer developments of physics the scope of which can best be seen from the chapter headings. There are eighty pages on the electrodynamics of a moving charge, including a full discussion of the Abraham and Lorenz theorems; sixty pages on relativity; thirty-five on radiation and temperature with Wien's and Planck's contributions; forty on the theory of magnetism with a full review of Weiss' work; seventy-five pages on the electron theory of metallic conduction, thermo electromotive force, and thermoionics; thirty-five pages on "Types of Radiation" corpuscular and ethereal, including recent X-ray theory; thirty-five pages on spectroscopic phenomena; forty on the structure of the atom with Thomson rather overdone and Nicholson and Bohr somewhat slighted; and sixteen on gravitation.

Altogether it is a book of large and permanent value and another testimony to the breadth and fecundity of British science.

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SPECIAL ARTICLES

A SYSTEM OF RECORDING TYPES OF MATING IN EXPERIMENTAL BREEDING OPERATIONS[1]

ALL Mendelian experimentation with bisexual forms implies a system of mating which in practical work is called line breeding. One starts any Mendelian experiment with two kinds of organisms which are crossed with each other to produce the F_1 generation. Then the F_1 individuals are either mated *inter se* or back-crossed to the parent forms. The F_2 individuals may be mated in a variety of ways *inter se* and with the parents or grandparents.

Many of those engaged in Mendelian work must have experienced the same difficulty that the writer has in recording experimental results, namely, that of expressing adequately and completely, and at the same time briefly and simply the general nature or type of the

Diagram I

P generation	BPR♂	× Houdan ♀
F_1 generation	F_1♂	× F_1♀ from reciprocal cross
F_2 generation	F_2♂	× BPR ♀
F_3 generation	F_3♂ *M*	

Diagram II

P generation	Houdan ♂	× BPR ♀
F_1 generation	F_1♂	× Houdan ♀
F_2 generation	F_2♂	× F_1♀ from reciprocal cross
F_3 generation	F_3♀ *N*	

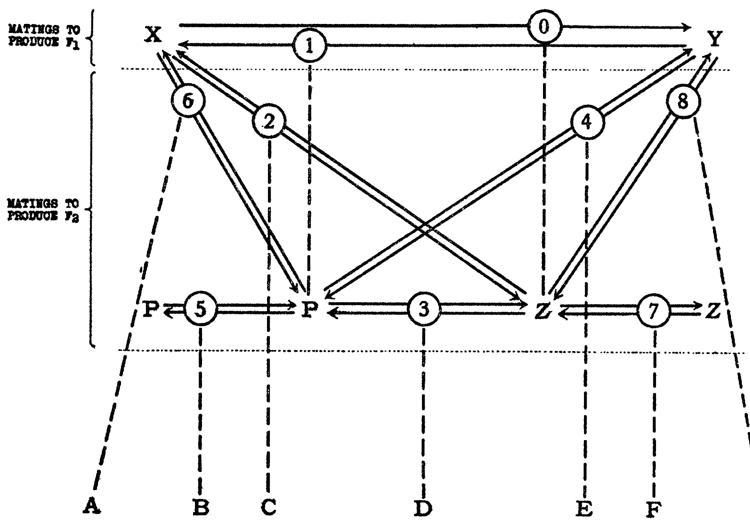
[1] Papers from the Biological Laboratory of the Maine Agricultural Experiment Station, No. 88.

pedigree by which particular individuals in the F_2 and F_3 generations are descended. To illustrate the meaning here let us consider the two individual fowls *M* and *N* produced as indicated in pedigree diagrams I. and II.

To describe in words how *M* or *N* was bred is a tedious piece of business. They are both F_3 individuals from a cross of the same two breeds of poultry, Barred Plymouth Rock and Houdan. Yet their breeding is very different. It is of the utmost importance in planning breeding experiments, especially when one comes to the matings of F_2 individuals, to have a clear picture in one's mind of the breeding of each individual back to the original cross. The writer has wrestled for some time with this problem and tried out various schemes, such as the use of initial letters, figures for years, etc. None of these has proved satisfactory in practise. It finally seemed clear that the only entirely satisfactory solution (to the writer at least) would be one which was perfectly general. Such a general solution involves two things: first, a complete conspectus of all possible types of mating of the individuals of the P, F_1 and F_2 generations *inter se,* both within and outside their own generations, and second, a simple, pre-

TABLE I

Matings to Produce F_3



F_2 Individuals Mated	Number of Mating	F_2 Individuals Mated	Number of Mating	F_2 Individuals Mated	Number of Mating	F_2 Individuals Mated	Number of Mating
$A \times X$	10	$B \times Z$	46	$C \times F$	51	$E \times E$	19
$A \times Y$	12	$B \times B$	13	$C \times G$	53	$E \times F$	45
$A \times P$	40	$B \times C$	37	$D \times X$	22	$E \times G$	47
$A \times Z$	42	$B \times D$	29	$D \times Y$	24	$F \times X$	30
$A \times A$	11	$B \times E$	55	$D \times P$	52	$F \times Y$	32
$A \times B$	33	$B \times F$	57	$D \times Z$	54	$F \times P$	60
$A \times C$	25	$B \times G$	59	$D \times D$	17	$F \times Z$	62
$A \times D$	35	$C \times X$	18	$D \times E$	43	$F \times F$	21
$A \times E$	61	$C \times Y$	20	$D \times F$	31	$F \times G$	49
$A \times F$	63	$C \times P$	48	$D \times G$	27	$G \times X$	34
$A \times G$	65	$C \times Z$	50	$E \times X$	26	$G \times Y$	36
$B \times X$	14	$C \times C$	15	$E \times Y$	28	$G \times P$	64
$B \times Y$	16	$C \times D$	39	$E \times P$	56	$G \times Z$	66
$B \times P$	44	$C \times E$	41	$E \times Z$	58	$G \times G$	23

ferably numerical, designation of each one of these possible types, each such designation to be of course unique and permanent.

Table I. gives such a general solution of the problem of simply designating pedigree types, through the matings of F_2 to produce F_3. Beyond that it is not practical to go. A word should be said in explanation of the table. Letters denote *individuals* or groups of individuals which are brothers and sisters. Solid lines, with circles in their course, connecting letters, denote *matings* of the kinds of individuals indicated by the connected letters. Dotted lines lead from the mating to the kind of individual produced. Arrow heads indicate the direction of the mating, the arrow being supposed always to pass from the male to the female. Separate numbers are not given to reciprocal matings *after* the matings of the P generation to produce F_1. To designate separately reciprocal matings after that point would greatly complicate the system without any significant gain from a practical point of view. In the later generations, reciprocals may be indicated if desired, by affixing a sub-figure 1 to the designation of the mating.

The numbers within the circles are the designations (or names) of the matings, and from the very nature of the case, these numbers designate not alone the particular mating but also, in F_1 and later generations, the nature of the pedigree of each of the individuals entering that mating. This will be clear as we proceed.

This table is to be read in the following manner: Individual *X*♂ is mated with *Y*♀ to produce F_1 individuals *Z*, and this mating is designated 0. Individual *Y*♂ is mated with *X*♀ and produces F_1 individual *P*, and the mating is 1. The F_1 individuals, mated in all possible ways *inter se* and with the parents *X* and *Y*, as indicated in matings designated 2 to 8 inclusive, produce seven kinds[2] of F_2 individuals, *A* to *G*. These seven sorts of F_2 individuals bred in all possible ways *inter se* and with their parents and grandparents produce 56 sorts of F_3 individuals, as indicated in the lower half of Table I. As already noted, separate account of reciprocals is not taken.

The use of the table may be indicated by some examples. Suppose one wishes to mate in an experiment the two birds called *M* and *N* in an earlier paragraph of this paper. He will wish to indicate in some way in his notes the previous breeding history of each of these birds. If he does this verbally—and hitherto this appears to have been the only way of reaching such end—he must say of individual *N*, for example, something like the following: "This F_3 bird was produced by the mating of an F_2 male with an F_1 female produced by mating a Barred Plymouth Rock male with a Houdan female. The F_2 male was himself produced by the mating of an F_1 male, out of the cross Houdan male by Barred Rock female, on a pure Houdan female." Quite apart from the amount of space involved in such a setting forth of the facts, it is very difficult to form quickly a clear mental picture of the bird's pedigree from this tedious verbal exposition. Suppose we are using the system of pedigree designation discussed in this paper we could then cover all the facts set forth above about bird *N* by merely writing in our notes

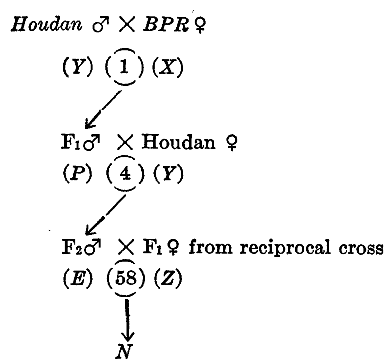
"*Bird N (58) BPR-Houdan series,*"

and to describe completely the mating of *M* with *N* we have merely to write

"*F_3♂M (22)× F_3♀N (58) BPR-Houdan series.*"

The figure 58 in the case of *N* means that she was produced from a mating of the type indicated in the table as *E* × *Z*, and the des-

DIAGRAM II



[2] "Kinds" referring here only to the manner in which the individuals have been bred.

ignation of such a mating is 58. This will be made clear by repeating the pedigree diagram of bird *N, Diagram II.*, and adding to it the proper letters and mating designations from Table I.

The simplicity of the scheme is obvious. No argument appears necessary as to its usefulness in experimental breeding operations. The writer has found it extremely helpful and clarifying.

A word should be added in regard to the system by which the numbers have been assigned to the matings. It might at first sight appear as though the arrangement were an entirely haphazard one. It is not. On the contrary the numbers will be found to conform to the following general principles, which seem likely to be of aid in practical work, as tending to make it easy to recall from a number just what its particular pedigree looks like.

1. All even numbers refer to back-cross matings.

2. All odd numbers refer to co-fraternal or intra-generation matings (not back-crosses).

3. Matings below 2 are of parental generation individuals: between 2 and 8 inclusive are of F_1 individuals; matings over 10 are of F_2 individuals.

4. Even numbers from 10 to 36 inclusive designate back-crosses of F_2 individuals with their *grandparents*, or individuals of the grandparental generation.

5. Even numbers from 40 up designate back-crosses of F_2 individuals on F_1 individuals.

6. In the case of the odd numbers from 11 up it is, *in a general way*, true that the smaller the designating number of a mating the more closely related to each other are the two individuals entering that mating likely to be. This principle of assigning the numbers could not be so precisely followed as the preceding five, but still is perhaps worth a little.

In using this system in one's notes or writing it is of course essential to have the basic table always at hand. If the plan should appeal to any number of experimental workers it would be a simple matter to have copies of Table I. printed on heavy cardboard to be used in breeding houses and pens, in the field and at the desk.

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THE CHEMICAL COMPOSITION OF BORNITE

Since the analyses of crystallized material from Cornwall by Plattner,[1] bornite has generally been considered to be a cuprous sulfoferrite, $Cu_3FeS_3(3Cu_2S \cdot Fe_2S_3)$. In 1903 Harrington[2] made a critical study of the published analyses, added several new analyses, and concluded that the chemical formula of bornite is $Cu_5FeS_4(5Cu_2S \cdot Fe_2S_3)$. Recently Kraus and Goldsberry[3] made an analysis of crystallized bornite from Bristol, Conn., which gave the formula $Cu_{12}Fe_2S_9(6Cu_2S \cdot Fe_2S_3)$, and also confirmed Harrington's formula Cu_5FeS_4, of crystallized bornite from the same locality. They conclude that bornite is of variable chemical composition, and in order to explain the facts they assume a morphotropic series of minerals ranging from chalcopyrite, $CuFeS_2$, through barnhardtite, $Cu_4Fe_2S_5$, and various bornites $Cu_6Fe_2S_6$, $Cu_8Fe_2S_7$, $Cu_{10}Fe_2S_8$, $Cu_{12}Fe_2S_9$, up to $Cu_{76}Fe_2S_{41}$, finally ending with chalcocite Cu_2S, each member of the series differing from the one below it by the addition of one molecule of Cu_2S.

As a metallographic examination of the two analyzed bornites showed no foreign admixture, the work of Kraus and Goldsberry furnishes, for the first time, proof that bornite is variable in composition. It is believed, however, that there is a more rational explanation of the variability in composition of bornite than the one advanced by Kraus and Goldsberry.

The recorded analyses of bornite show a copper content varying from 77 to 55 per cent., and an iron content varying from 18 to 6 per cent. In Fig. 1 I have plotted on the triangular coordinate diagram of J. Willard Gibbs the available bornite analyses (59 in number) given in Hintze's "Handbuch" and in the

1 *Pogg. Ann.*, 47, 351, 1839.

2 *Amer. Jour. Sci.*, 16, 151, 1903.

3 *Amer. Jour. Sci.*, 37, 539, 1914.