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Communications provisoires - Vorläufige Mitteilungen
Comunicazioni preliminari - Preliminary reports

Latin squares of the sixth order

The properties of a square array of n letters, each repeated n times, and such that each letter occurs once in each row and once in each column of the n^2 cells, were first discussed by EULER[1] (1782); since then the enumeration and the investigation of other properties of these *Latin Squares* have interested many mathematicians. Some aspects of the problem assumed practical importance about twenty years ago, when Latin square arrangements began to be used extensively in the design of agricultural and other scientific experiments.

One problem to which EULER gave particular attention was that of finding a Græco-Latin square, or as he termed it *un quarré magique complet*, namely two superposed squares, one in Roman and one in Greek letters, with the additional restriction that each of the n^2 pairs of one Roman and one Greek letter should occur once and once only. On evidence that was scarcely adequate, he concluded that for 6×6 squares no such arrangement existed; his conclusion was finally confirmed by FISHER and YATES[2] (1934) after a systematic enumeration of Latin squares of this order.

A Græco-Latin square of order n may be looked upon as a (1^n) partition of an $n \times n$ Latin square, since it entails the subdivision of the n^2 cells into n sets such that each contains one cell from each row, one from each column, and one of each letter; to each of these sets of n cells, usually termed *directrices* and possessing the property of being orthogonal with rows, columns, and Roman letters, a different Greek letter is then assigned. Certain agricultural problems recently caused the writer to investigate the existence of less complete partitions of a 6×6 Latin square, and in particular of (3^2) and (2^3) partitions, these requiring the subdivision of the 36 cells into either two sets of eighteen or three sets of twelve such that each set contains three or two from each row, column, and letter. He demonstrated the existence of (2^3) partitions for every 6×6 square and of (3^2) partitions for most squares (FINNEY[3], 1945).

[1] L. EULER, "Recherches sur une nouvelle espèce de quarrés magiques", Verhandelingen uitgegeven door het Zeeuwsch Genootschap der Wetenschappen te Vlissingen *9*, 85–239 (1782).

[2] R. A. FISHER and F. YATES, "The 6×6 Latin squares", Proc. Cambridge Philos. Soc. *30*, 492–507 (1934).

[3] D. J. FINNEY, "Some orthogonal properties of the 4×4 and 6×6 Latin squares", Ann. Eugenics *12*, 213–219 (1945).

This study suggested the further problem of discovering other orthogonal partitions of the 6×6 squares and of enumerating them. FISHER and YATES have classified the squares into twelve adjugate sets, such that any orthogonal property of the kind under discussion is common to all squares of the same set; consequently only a detailed examination of one square from each set was necessary. The procedure followed was essentially the same as that used by EULER in his search for Græco-Latin squares, namely the exhaustive ascertainment of directrices followed by the listing of sets of directrices having no cells in common. EULER found one square to have a set of four directrices giving a $(1^4, 2)$ partition, and from this can be formed, by combination of parts, every other type of partition except the (1^6); the existence of $(1^4, 2)$ partitions has been demonstrated for four of the twelve adjugate sets.

As an illustration of the results obtained, the properties of one square will be discussed in some detail. The square chosen is:

A	B	C	D	E	F
B	A	F	E	D	C
C	D	A	B	F	E
D	F	E	A	C	B
E	C	B	F	A	D
F	E	D	C	B	A

which is a representative of an adjugate set (FISHER and YATES' XV, XVI) having a remarkably high degree of symmetry in its orthogonal partitions. There are 24 directrices, and each cell of the square lies on four of these; for example, the first cell of the first row has passing through it the directrices AFBCDE, AEFBCD, ADEFBC, ACDEFB, the six letters being taken from the six rows of the square in the order specified. Sets of four directrices leading to $(1^4, 2)$ partitions can be chosen in thirty different ways, and these use every directrix five times. A typical one of these partitions, the nearest approach possible to a 6×6 Græco-Latin square, is:

Aα	Bβ	Cγ	Dδ	Eε	Fε
Bε	Aε	Fα	Eγ	Dβ	Cδ
Cβ	Dγ	Aδ	Bα	Fε	Eε
Dε	Fδ	Eβ	Aε	Cα	Bγ
Eδ	Cε	Bε	Fβ	Aγ	Dα
Fγ	Eα	Dε	Cε	Bδ	Aβ

where α, β, γ, δ mark the four directrices and ε the residual *duplex*, or set of two cells from each row, column, and letter. In the thirty partitions, each of fifteen duplexes occurs twice. By combination of a directrix with a duplex, 120 different $(1^3, 3)$ partitions can be formed, and a further forty exist which cannot be derived in this way; in the total of 160, every directrix occurs twenty times. The $(1^2, 2^2)$ partitions have not been enumerated systematically, but the existence of at least 180 has been established and there are indications that this is the full total. Other properties of the directrices are that each has two cells in common with five of the others, one cell in common with eight of the others, and no cell in common with the remaining ten.

The full enumerations that have been made are summarized in the following table; the figure in the column (1, 5) is, of course, the number of directrices. The adjugate sets are numbered according to FISHER and YATES' classification of seventeen type squares, five of the sets having two type numbers.

Square type	Type of partition				
	(1, 5)	$(1^2, 4)$	$(1^3, 3)$	$(1^4, 2)$	$(1^2, 2^2)$
I, II	8	14	0	0	24
III	8	4	0	0	4
IV	8	16	8	2	20
V, VI	8	12	8	2	24
X	32	204	256	56	336 [1]
XV, XVI	24	120	160	30	180(?)

The remaining six sets, types VII; VIII, IX; XI, XII; XIII; XIV; XVII, have no directrices, and therefore cannot have partitions of the types listed.

The remaining types of partition of the number six, namely (1, 2, 3), (2^3), (2, 4) and (3^2), have not yet been completely enumerated, though the total numbers that can be derived by combination of parts in $(1^4, 2)$ or $(1^3, 3)$ partitions have been counted. Even these are sometimes very numerous, especially for squares of type X, for which the figures are 976, 168, 238, and 224 respectively. Squares of types XI–XIV and XVII have no (3^2) partitions, and squares without directrices clearly have no (1, 2, 3) partitions, but otherwise partitions of these types can be found for all squares.

The square already discussed, in common with others of type XV, XVI, has twenty pairs of mutually orthogonal $(1^3, 3)$ partitions, of which the following is an example:

Aα1	Bβ2	Cγ3	Dδ4	Eδ4	Fδ4
Bδ4	Aδ4	Fα2	Eγ4	Dδ3	Cβ1
Cδ4	Dγ1	Aδ4	Bα3	Fβ4	Eδ2
Dδ2	Fδ3	Eδ1	Aβ4	Cα4	Bγ4
Eβ3	Cδ4	Bδ4	Fδ1	Aγ2	Dα4
Fγ4	Eα4	Dβ4	Cδ2	Bδ1	Aδ3

Here both the Greek letters and the numbers mark $(1^3, 3)$ partitions of the original Latin square, and also each of 1, 2, 3 occurs once in the same cell as each of α, β, γ, three times in the same cell as δ, while 4 occurs three times with each of α, β, γ, nine times with δ. This appears to be the most complex type of orthogonal partitioning possible for 6×6 Latin squares; twelve such pairs of partitions may be found for squares of type X, but the remaining types have none.

In this brief note, it has been possible to give only an indication of the properties of these orthogonal partitions; a full account of the results so far attained will shortly be published in the Annals of Eugenics (1947)[1]. Much still remains to be done, especially in respect of those partitions which have yet to be enumerated. In arrays of letters which at first inspection seemed remarkable only for their complete lack of symmetry, many interesting and complex patterns have come to light, and there now seems little doubt that the numbers and interrelationships of the remaining partitions will also show symmetric structures.

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University of Oxford, August 29, 1946.

Zusammenfassung

EULER hatte in seiner Originalabhandlung über die lateinischen Quadrate vermutet, daß kein Paar wechselseitig orthogonaler 6×6 Quadrate existiert, was einige Jahre später bewiesen wurde. Man fand dann aber, daß diese 6×6 lateinischen Quadrate einige interessante orthogonale Verteilungen in einem schwächeren als dem EULERschen Sinne besitzen, die zum Teil klassifiziert und aufgezählt werden konnten. Die vorliegende Note charakterisiert die erhaltenen Resultate und gibt einige interessante Symmetrieeigenschaften dieser Verteilungen an.

[1] Not completely enumerated.

[1] D. J. FINNEY, "Orthogonal partitions of the 6×6 Latin squares", Ann. Eugenics *13* (in the press) (1947).

Hemmungswirkung verschiedener Chinone auf die Eiweißspaltung durch Papain[1]

K. WALLENFELS[2] gibt in einer vor kurzem erschienenen Arbeit der Vermutung Ausdruck, daß die durch die Einwirkung von Chinonen auf Bakterienkulturen erzielte Wachstumshemmung auf der Beeinflussung eines chinonempfindlichen Fermentsystems beruht. Diese Annahme erscheint uns als eine brauchbare Arbeitshypothese, hingegen können wir uns nach Vergleich der von WALLENFELS zitierten Versuche von KUHN und BEINERT über die Carboxylasehemmung durch Chinone mit den von A. E. OXFORD[3] sowie E. F. MOELLER[4] gemessenen Wachstumshemmungen bei *Staphylococcus aureus* nicht der Meinung anschließen, daß die Carboxylase bei der antibakteriellen Wirkung eine entscheidende Rolle spielt. Dazu sind die Übereinstimmungen der Hemmungsreihen doch nicht überzeugend genug; außerdem sind eine Anzahl weiterer bei Bakterien nachgewiesener Fermente bekannt, die sich durch Chinone hemmen lassen und daher für die antibiotische Wirkung durch ihre Hemmbarkeit auch verantwortlich sein können.

Um zur Klärung dieser Fragen beizutragen, haben wir kürzlich die Hemmung der Aktivität von Urease und Katalase durch eine Anzahl verschiedener Chinone untersucht und darüber an anderer Stelle berichtet[5]. Die erhaltenen Ergebnisse lassen einen ursächlichen Zusammenhang zwischen diesen beiden Fermenten und der antibiotischen Wirksamkeit der Chinone unwahrscheinlich erscheinen.

[1] Ausführliche Veröffentlichung mit weiteren Belegen folgt in den Monatsheften für Chemie (Wien).

[2] K. WALLENFELS, Chemie *58*, 1 (1945).

[3] A. E. OXFORD, Chem. Ind. *61*, 189 (1942).

[4] Zitiert bei WALLENFELS, Anm. 2.

[5] O. HOFFMANN-OSTENHOF und W. H. LEE, Mh. Chem. *76*, 180 (1946); O. HOFFMANN-OSTENHOF und E. BIACH, Mh. Chem. (im Druck).