detailed drawing procedure to be omitted. The computer then calculates the movement of the cutting tool to machine the component and records the information on magnetic tape. A control unit associated with the machine tool into the reader of which this tape is placed controls servo-mechanisms, which move the slides in accordance with the instructions on the tape. Dr. Williamson said that the possible uses of a control system of this type go far beyond the limited field of machine tools, and the principle is applicable to all industrial processes.

The next paper, presented by Dr. Denis Taylor, of the Atomic Energy Research Establishment, Harwell, was entitled "Atomic Energy and Automation". Dr. Taylor said that automation has a large part to play in the development of atomic energy for two reasons. First, there are those processes which arise in any industry which, although they can be carried out manually, can be carried out on a large scale more satisfactorily by automatic machinery; and secondly, there are processes peculiar to atomic energy which, because of the radiation hazards, are difficult or impossible to carry out manually. Dr. Taylor described various automatic equipments used in the laboratories for reducing the amount of assistant labour that would otherwise be required for carrying out routine measurements. Such machines are capable of working night and day with very little attention and quickly pay for themselves. Automation also finds application in the atomic-energy field in the processing of experimental data, such as in the study of cosmic-ray showers. A common experiment is the observation of the coincidence-rate of two counters as a function of their separation, and this may be extended to include the coincidence-rate of three or more counters as a function of the size of the geometrical configuration, triangle or square, etc. An enormous amount of data will be obtained in quite a short time, and some form of automatic processing of the data becomes essential. In the atomic-energy field, as in the chemical industry, there has been a change-over from batch processing to continuous flow techniques, and automatic control for plants processing radioactive materials is particularly attractive because of the health hazard. Another problem which arises is that of handling the reactor fuel elements. After a nuclear reactor has been in operation for some time, re-cycling of active fuel elements may be required in order to re-use the elements. These elements will be highly radioactive and could not be handled directly. Here, therefore, there is an important problem in the field of automation.

The next and last paper, "Conscious Machines", was presented by Mr. J. Sargrove, who, as early as 1948, set up an automatic line in Britain for making radio receivers. Mr. Sargrove spoke mainly of automatic machines for inspecting and controlling the production of a number of small and common commodities. He showed a film to illustrate different types of electronic problems which occur in industry, starting with a very simple application and leading up to more complex ones, as follows: (1) automatic electronic stock-keeping; (2) automatic printing of calendars; (3) automatic production of continuous stationery; (4) automatic processing of knitted 'Nylon'; (5) automatic extrusion of plastic rods, such as knitting needles; (6) high-speed weighing of pieces of dough, and automatic control of a dough divider in a bakery; (7) high-speed counting, batching and packaging of tablets in the pharmaceutical industry.

Having given these examples, Mr. Sargrove went on to say that if we are genuinely to increase our standard of living with full employment, this can only happen by an increase in the total production of goods and commodities. If all human beings are fully employed, this extra output, which we all desire, can only come from the more intensive use of automation. In his experience, no employee has ever been discharged from a firm due directly to the introduction of automatic machines.

THE CHROMOSOMES OF MAN

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ACCURATE knowledge of the number of chromosomes and of their behaviour in mitosis and meiosis has illuminated the genetic analysis of many species. The outstanding example, of course, is *Drosophila melanogaster*[1]. *Zea mais*[2] and *Oenothera lamarckiana*[3] are notable examples from the plant kingdom. Chromosome observations have been of some value even in the fungus *Neurospora crassa*[4], and recent work[5] has given promise that the genetics of the house mouse may benefit in the same way. There is therefore good reason for supposing that the genetic study of man himself may be advanced by reliable information about his chromosomes. The unique features of the human genetic milieu—the alterati ns in breeding structure[6], the changing selection pressures[7], and the possible influence upon mutation-rates of the environmental changes of the past two or three centuries—are all in great need of study and measurement in order to be able to estimate their effect upon the genetic structure of future human populations, and it is possible that a thorough examination of the chromosomes in a range of human groups would make a useful contribution. The rapid and economical technical methods now available would enable relatively large numbers of individuals to be examined and should make a new approach to human cytogenetics both possible and rewarding. Nor is this the only field in which chromosome observations may be of value to human biology. The rapid pace at which knowledge of the chromosomes in tumours of experimental animals[8] is advancing suggests that the chromosomes may have an increased part to play in the investigation of human neoplastic conditions; and they may also be able to assist in the causal analysis of infertility, at least in the male[9].

The first attempt to determine the number of chromosomes in human cells would appear to have

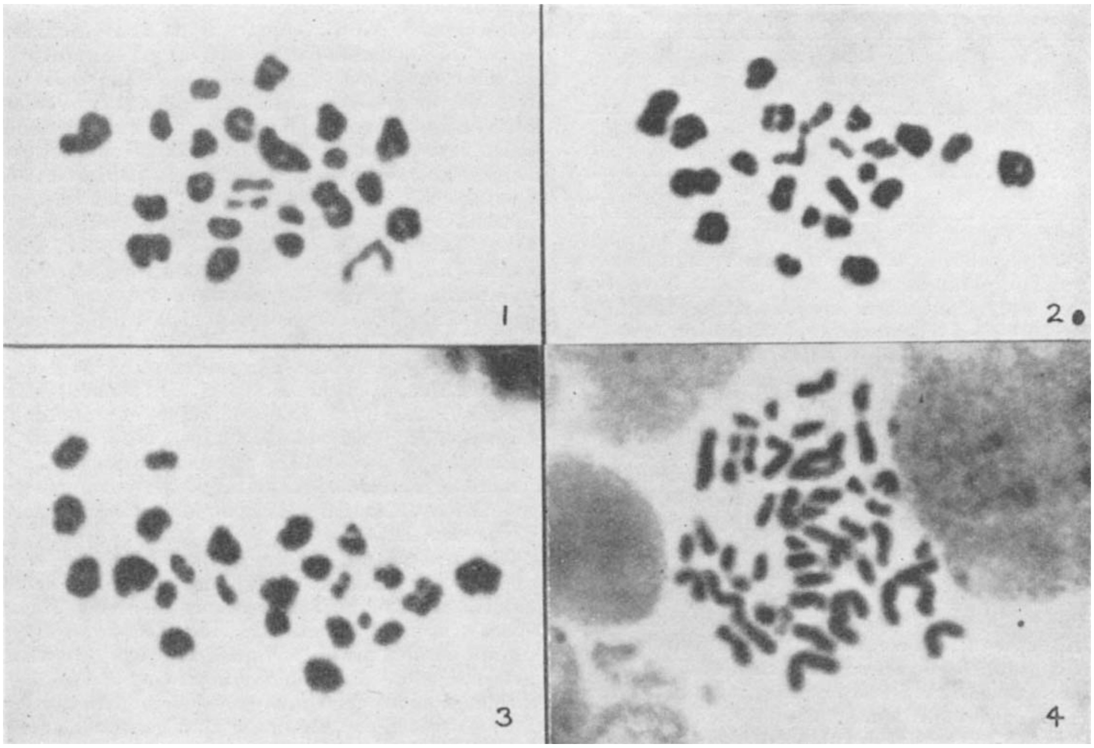

Fig. 1. First spermatocyte of patient 1 at diakinesis, 23 bivalents
Fig. 2. First spermatocyte of patient 3 at diakinesis, 23 bivalents
Fig. 3. First spermatocyte of patient 2, 22 bivalents plus univalent *X*- and *Y*-chromosomes
Fig. 4. Spermatogonial metaphase of patient 1, 46 chromosomes
All × 2,800

been made by Hansemann, who in 1891 reported three cells from 'normal human tissues' with 18, 24, and more than 40 chromosomes, respectively[10]. From then until the appearance of de Winiwarter's classical paper[11] in 1912, diploid numbers ranging from 16 to 36 were reported, the balance of opinion being in favour of 24. De Winiwarter claimed that there were 47 chromosomes at metaphase in spermatogonia, and 23 autosomal bivalents plus an unpaired *X* in primary spermatocytes. Painter[12] in 1921 reported the presence of a small *Y* chromosome in males and was the first to assert that the correct diploid number was 48 in both sexes[13]. In the following two decades most authors[14] supported Painter's position; but de Winiwarter and his associates[15] adhered to the opinion that there was only a single sex-chromosome at meiosis in the male and 47 chromosomes in spermatogonia. Koller's account[16] of the behaviour of the sex-chromosomes in spermatocyte meiosis brought this period to an end just before the outbreak of the Second World War. From then on, the value of $2n = 48$ in both male and female remained unchallenged for nearly twenty years, and it seemed that the chromosome number of man had finally been established. However, in a very recent paper[17], Tjio and Levan report consistent counts of $2n = 46$ in cultures of lung tissue taken from four aborted embryos, and refer to further counts of $2n = 46$ obtained by Hansen-Melander, Melander and Kullander in preparations of liver, also from aborted embryos. The regular loss of two chromosomes during development of the organs or growth of the cultures would seem to be most unlikely, and the implication was clear that the generally accepted figure of $2n = 48$ might, after all, have been in error.

A re-examination of spermatocyte and spermatogonial chromosomes was obviously desirable, and we have been fortunate in securing testis tissue from three males, aged forty-seven, fifty-three, and sixty-three years respectively. The material was obtained at the Churchill Hospital, Oxford, from fresh operative specimens at the moment of removal from the body. The tubules were teased out in hypotonic fluid, allowed to remain in the fluid for 30 min. at room temperature, fixed in acetic alcohol and stained by the Feulgen procedure. Squash preparations were made in the usual way. Many of them contained one or more small clusters of spermatocytes in the most suitable stages for counting, namely, diakinesis and first metaphase. Obviously broken cells with scattered chromosomes, and cells in which the chromosomes were clumped or badly fixed, were rejected. Counts were made on all the remainder and are summarized in Table 1. It will be seen that the great majority contained 23 bivalents, and that our results therefore complement those of Tjio and Levan. Examples of these cells are shown in Figs. 1 and 2. In a few cells at late diakinesis and first metaphase, the *X*- and *Y*-chromosomes were unpaired and usually well separated from each other, so that 24 bodies were counted (Fig. 3). Precocious disjunction (already reported by Koller[16] in sectioned material) would seem to be the most likely explanation of the non-association of *X* and *Y* in these exceptional cells, although some cases may have been due to the rupture of the terminal connexion between them during the making of the preparations. The

Table 1. COUNTS OF NUMBERS OF BODIES PRESENT IN FIRST SPERMATOCYTES AT STAGES FROM LATE DIPLOTENE TO METAPHASE

Patient	Age	First spermatocytes containing: 22 bivalents or fewer	23 bivalents	22 bivalents + X + Y
1	63	9	81	11
2	53	3	39	11
3	47	2	29	3
Total		14	149	25

few cells recorded as containing fewer than 23 bivalents, although apparently intact, may have been damaged and we attach no significance to them.

Relatively few spermatogonia were observed in mitosis and, in contrast to the spermatocytes, most of them were broken and their chromosomes scattered. We have noticed similar fragility of spermatogonia in several other species of mammals. Nevertheless, a few clear counts of 46 chromosomes were obtained in apparently intact cells, one of which is shown in Fig. 4. It is noteworthy that the centric constrictions are sometimes greatly elongated in from one to four chromosomes.

In the great majority of first spermatocytes examined, the sex chromosomes were associated terminally, the attachment varying from a relatively long thin thread to a condition in which only a slight narrowing indicated where X ended and Y began. All these associations could be interpreted as terminal chiasmata, although Sachs[18] denies that true chiasmata occur in the sex-bivalent of man. The few cells in which the sex-chromosomes were present as univalents have been mentioned. In one cell only the X- and Y-chromosomes appeared to be associated in a different manner. The structure of this bivalent was not resolved with certainty; but its appearance strongly suggested the presence of a sub-terminal chiasma, or possibly that it was a 'symmetrical' sex-bivalent as described by Koller[16]. This single observation can scarcely be construed as support for the possibility of crossing over between X and Y: on the other hand, the observations as a whole are certainly not inconsistent with the occurrence of partial sex-linkage[19].

Koller[16] figured diplotene bivalents with many chiasmata. This observation we confirm. The largest autosomal bivalent frequently has five chiasmata; and some of the others may have four. In well-fixed cells the successive loops can be clearly seen in planes at right angles to each other, as in the classical plant and orthopteran species. In cells where the bivalents are rather crowded, it would not be difficult to mistake a terminal loop for an additional small bivalent. The numbers of chiasmata were counted in some of the clearest cells at stages from late diplotene to mid-diakinesis, and the results are given in Table 2.

Since the hypothesis that each cytological chiasma represents a single genetic cross-over was first put forward, evidence in its favour has been steadily accumulated, although its general validity has been questioned[20]. Assuming it to be true in man, the counts of chiasmata can be used for making an estimate of the total genetic length of the human chromosome set, on the basis that one chiasma is equivalent to 50 centimorgans. The over-all mean number of chiasmata per cell is 55·9 and the estimate of genetic length is, therefore, 27·9 morgans. However, should there have been any reduction of chiasmata by terminalization, the observed frequencies will have been somewhat less than the original frequencies, with the result that the estimate of genetic length will be a minimum one. So far as we are aware, the only other mammalian species in which estimates of total genetic length of chromosomes have been obtained is the house mouse, and it is satisfactory to note that the estimates obtained from Slizynski's chiasma counts[21] and by Carter's linkage-data method are in reasonable agreement. The two methods yield values of 19·2 and 16·2 morgans respectively[22]. It would appear that, genetically, the chromosomes of man are at least half as long again as the chromosomes of the mouse.

Table 2. COUNTS OF CHIASMATA AT STAGES FROM LATE DIPLOTENE TO MID-DIAKINESIS

Patient	Age	Cells counted	Chiasmata per cell: Range	Mean
1	63	11	50–62	54·4
2	53	6	52–62	57·1
3	47	6	50–63	57·1
Total		23	50–63	55·9

The reservation should be made that the estimate of 27·9 morgans strictly applies to middle-aged and elderly males only. However, in the mammalian species studied genetically, recombination fractions do not in general differ much with age or sex. As a rule the values are slightly higher in the female sex, although there are some exceptions. There is therefore no reason for supposing that genetic lengths will be greatly different in the two human sexes, and until direct estimates have been obtained at oogenesis the value of 27·9 morgans derived from chiasma counts at male meiosis may be regarded as an approximate minimum estimate for the female also.

Two comments in connexion with the high frequency of occurrence of chiasmata are relevant: it reflects the rarity with which autosomal linkages have been detected in man; and it implies a genetic system in which there is a rapid re-assortment of the genotypic variability, which, according to Darlington[23], is the mark of a plastic species able to adapt itself readily to diverse environmental circumstances.

Returning to the question of the chromosome number of man, how should the discrepancy between the recent counts and the older ones be explained? Although the occurrence of numerical chromosomal polymorphism has now been established within populations of one mammalian species[24] and may exist in a second[25], it is most unlikely that the occurrence of a similar situation in the human species could provide the whole answer—the probability of drawing by chance from such a polymorphic population seven successive individuals (four of Tjio and Levan, three recorded here) with 46 somatic chromosomes after an even larger series all with 47 or 48 would be altogether too low. Nevertheless, the rare occurrence of individuals with the latter numbers is not excluded. The alternative is to assume a persistent error, and this we consider to be the more likely explanation. (It is of interest to note that in his preliminary communication on the subject, Painter was uncertain whether the diploid number was 46 or 48.) Three features of the behaviour of human chromosomes which have already been mentioned may have contributed to erroneous counting. In somatic cells and spermatogonia, one or more of the exceptionally long centric constrictions seen in some chromosomes may have been overlooked, with the result that each arm was counted as a separate chromosome; and in spermatocytes, counts of 24 bodies could have arisen as a consequence of precocious disjunction of X- and Y-chromosomes, or from mistaking an end loop of one of the larger elements for a separate bivalent. In view of the much closer packing of the chromosomes in the cells, these difficulties would have been much more serious with the older sectioning technique. Undoubtedly the adoption of the squash method[26] and ancillary treatments for dispersing the chromosomes within the cells[27] is bringing about a great change in mammalian chromosomal cytology, and it is to this technical improvement that the rectification of the error—if such it be—must primarily be attributed. The crux lies no longer in the microscopy but in the preparative technique. The weary hours of toil which the pioneers must have spent at the microscope is reflected in de Winiwarter's *cri de coeur*, "J'ai perdu un temps énorme à répéter des numérations fatigantes et j'avoue aussi, très fastidieuses". The wonder is that there is so little to alter.

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PROPERTIES OF MAGNETIC MATERIALS

THE final session of Section A (Physics) of the British Association was held on September 5, and appropriately for a Sheffield meeting was devoted to three papers dealing with various aspects of magnetism.

Prof. W. Sucksmith, of the Department of Physics, University of Sheffield, gave an outline of the developments leading to present-day production of magnetically hard materials for permanent magnets and magnetically soft materials for use in dynamos, transformers and other electromagnetic devices. The desirable characteristics of the two types of material are respectively high coercivity and high permeability. Until the early years of the twentieth century, tool steel was used in the manufacture of permanent magnets and no special materials were produced for the purpose. Subsequent empirical development culminated in the production of oxide magnets (cobalt ferrite, $CoO.Fe_2O_3$) by Kato and the iron–aluminium–nickel magnet steel, the parent of many present-day magnet steels, by Mishima.

A number of interesting problems of fundamental importance have arisen from considerations of the magnetization processes responsible for the high coercivity of permanent-magnet materials. Modern theories of magnetization processes are based on refinements of the theory of magnetic domains originally proposed by Weiss. In general, it is supposed that ferromagnetics are subdivided into domains in each of which the elementary magnetization vectors lie along one of two or more preferred directions; domains characterized by different preferred directions are separated by domain boundary walls. In the demagnetized state the domain arrangement is such as to produce zero external magnetization. However, when a magnetic field is applied the domain walls move, domain magnetization vectors rotate from the preferred directions and the specimen becomes magnetized. Materials in which domain boundary movements are greatly impeded by structural and other imperfections are magnetically hard and have applications as permanent magnets. Néel, in his theory of 'disperse fields', has considered these aspects in detail. High coercivities may also be obtained in materials in which magnetization cannot occur by boundary movement but by rotation of domain magnetization vectors from one preferred axis to another. Thus if the dimensions of an isolated ferromagnetic particle are sufficiently small ($\sim$ 300 A.), it is energetically unfavourable for boundary walls to be created and the particle is a single magnetic domain. No boundary movements are involved in the magnetization of an assembly of single-domain particles; only rotations of the magnetization vectors may occur against anisotropy forces arising from the shape of the particles, crystalline anisotropy or strain anisotropy. It follows, as Néel in France and Stoner in Britain have shown, that prolate ellipsoidal particles departing by relatively small amounts from a spherical form will possess high coercivity. This work has stimulated the production of compacts of oriented single-domain particles of acicular shape for use as permanent magnets and also for magnetic recording tape.

In this connexion work on single-domain assemblies which is being carried out at Sheffield was also